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Impact of Switching To The ICRP-74 Neutron Flux-To-Dose Equivalent Rate Conversion Factors At The Sandia National Laboratory Building 818 Neutron Source Range

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Abstract

Sandia National Laboratories (SNL) maintains a neutron calibration facility which supports the calibration, maintenance, and repair of Radiation Protection Instruments. The SNL neutron reference fields are calibrated using the following methodology: Fluence rate is initially established by calculation using the NIST traceable source emission rate (decay corrected). Correction factors for the effects of room return or scatter, and source anisotropy are then developed by using a suitable radiation transport code to model the geometry of the facility. The conventionally true neutron dose rates are then determined using the appropriate fluence-to-dose equivalent conversion coefficients at several reference positions. This report describes the impact on calculated neutron dose rates of switching from NCRP-38 to ICRP-74 neutron flux-to-dose equivalent rate conversion factors. This switch is driven by recent changes to dosimetry requirements addressed in 10 CFR 835 (*Occupational Radiation Protection*).

Acknowledgement

The author wishes to thank David Sinton (SNL Safety and Health Instrumentation and Standards Project Leader) and David T. Seagraves (Los Alamos National Laboratories) for their support and guidance regarding this work.

Acronyms and Abbreviations

EFCOG	Energy Facility Contractors Group
hr	hour
ICRP	International Commission on Radiation Protection
ICRU	International Commission on Radiological Units
MeV	Million electron-volts
mrem	millirem
NCRP	National Council on Radiation Protection and Measurements
NIST	National Institute of Standards and Technology
s	second
SNL	Sandia National Laboratories

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INTRODUCTION

A Purpose

The reference fields in the Sandia National Laboratories Building 818 Neutron Calibration Facility are currently established using NCRP-38 neutron flux-to-dose rate conversion factors. The June 8, 2007 publication of 10 CFR 835 (*Occupational Radiation Protection*) requires that an updated set of neutron radiation weighting factors based on recommendations in ICRP-60 be used. The Neutron Task Team of the Energy Facility Contractors Group (EFCOG) in assisting DOE HQ for a better implementation of neutron dosimetry associated with the amended 10 CFR 835, further recommended that ICRP-74 fluence-to-dose equivalent conversion factors (or flux-to-dose equivalent rate conversion factors) are appropriate for neutron exposure determination. This report assesses the impact on reference field values of adopting the ICRP-74 factors.

B Background Information

A. On June 8, 2007, the Department of Energy (DOE) published an amended Federal rule for Occupational Radiation Protection, 10 CFR 835. The amended rule became effective July 9, 2007, with full compliance required by July 9, 2010.

The changes published in the amended 10 CFR 835 included both minor text revisions and significant rule changes. Significant changes included:

> Updating the dosimetric models and dose terms used by DOE facilities to be consistent with newer recommendations from the ICRP-60.

B. During the two week period January 29 – February 5, 2004, Michael Mallett, Tom McLean, David Seagraves, and Milan Gadd of the Health Physics Measurements Group, HSR-4, Los Alamos National Laboratory (LANL), performed a variety of measurements at Sandia National Laboratory's (SNL) Building 818 Neutron Source Range (NSR), with the goal of characterizing the facility's neutron reference fields. In addition, extensive Monte Carlo simulations were performed by David Seagraves to determine dose rates, room return, source anisotropy, and fluence-to-dose equivalent conversion factors. This work was documented in LA-UR-05-1877 (*Characterization of the Sandia National Laboratory Building 818 Neutron Source Range*). This report presents an overview of the measurements and analysis performed to characterize the SNL neutron reference fields, summarizes the results, and recommends a protocol for determining conventionally true neutron dose rates.

C Scope

The impact of adopting the ICRP-74 flux-to-dose equivalent rate conversion factors was assessed by updating the Monte Carlo simulations used to determine Fluence-to-Dose Conversion Coefficients, Anisotropy Factors and Dose Rate/Room Return for bare ^{252}Cf and PuBe sources. The original code was developed to run on MCNP4. Minor edits in format were made to allow the use of the newer MCNP5 version 1.40. Additional F5 tallies were added to include the newer ICRP-74 values. Tallies associated with the original NCRP-38 values were retained so that code output could be checked against the values in LA-UR-05-1877. This was done as a quality assurance step to ensure that no errors were introduced during modification of the input files. Because there have been no significant changes to Building 818 since the original input files were used, the input geometry data was not modified.

Simulations were run for two different types of neutron sources; PuBe and bare ^{252}Cf. The updated input files are included in Appendices A through F.

No measurements of neutron spectra or dose rates were conducted.

RATIONAL AND MONTE CARLO MODELING METHODOLOGY

This work is an update to some of the information presented in LA-UR-05-1788. A detailed discussion of the methodology and calculational process used to determine the conventionally true dose equivalent rate for the SNL neutron reference field is contained in section F of LA-UR-05-1788, and is only summarized in this document.

Equation 1 describes the calculational process:

$$DE(mrem/hr) = \frac{Q*F}{4\pi r^2} A*S*D, \qquad \text{Eqn 1}$$

Where:

DE	=	Dose Equivalent Rate (mrem/hr),
Q	=	Decay-Corrected Source Emission Rate (n/s),
F	=	Flux-to-Dose Equivalent Rate Conversion Coefficient (mrem/h per n/cm^2 sec),
r	=	Source-to-Detector Distance (cm),
A	=	Anisotropy Correction Factor,
S	=	Scatter Correction Factor, and
D	=	Geometry Correction Factor, 1.0 for source-to-detector distance equal to or greater than 50 cm.

In this work, new values were developed for the following factors: F, A, and S.

The NCRP-38 and ICRP-74 Flux-to-Dose Equivalent Rate Conversion Factors used in this work are listed in Appendix G and are shown graphically in Figure 1.

Starting with the basic spectral information for a source (^{238}PuBe or bare ^{252}Cf) and folding in the newer ICRP conversion factor values yields the ambient dose equivalent rate, H*(10). This is an operational quantity for area monitoring. It is defined as the dose equivalent (H_T) that would be produced by a given neutron field in the International Commission on Radiation Units and Measurements (ICRU) sphere at a depth of 10 mm. This sphere approximates the human body. The neutron field is considered uniform. For the case of uniform external irradiation of the whole body, a tissue weighting factor (W_T) equal to 1 may be used in determination of the effective dose. The ambient dose gives a conservative estimation of the effective dose ($E = H_T * W_T$) that a person would receive if they were to stand in the same location as the monitoring instrument.

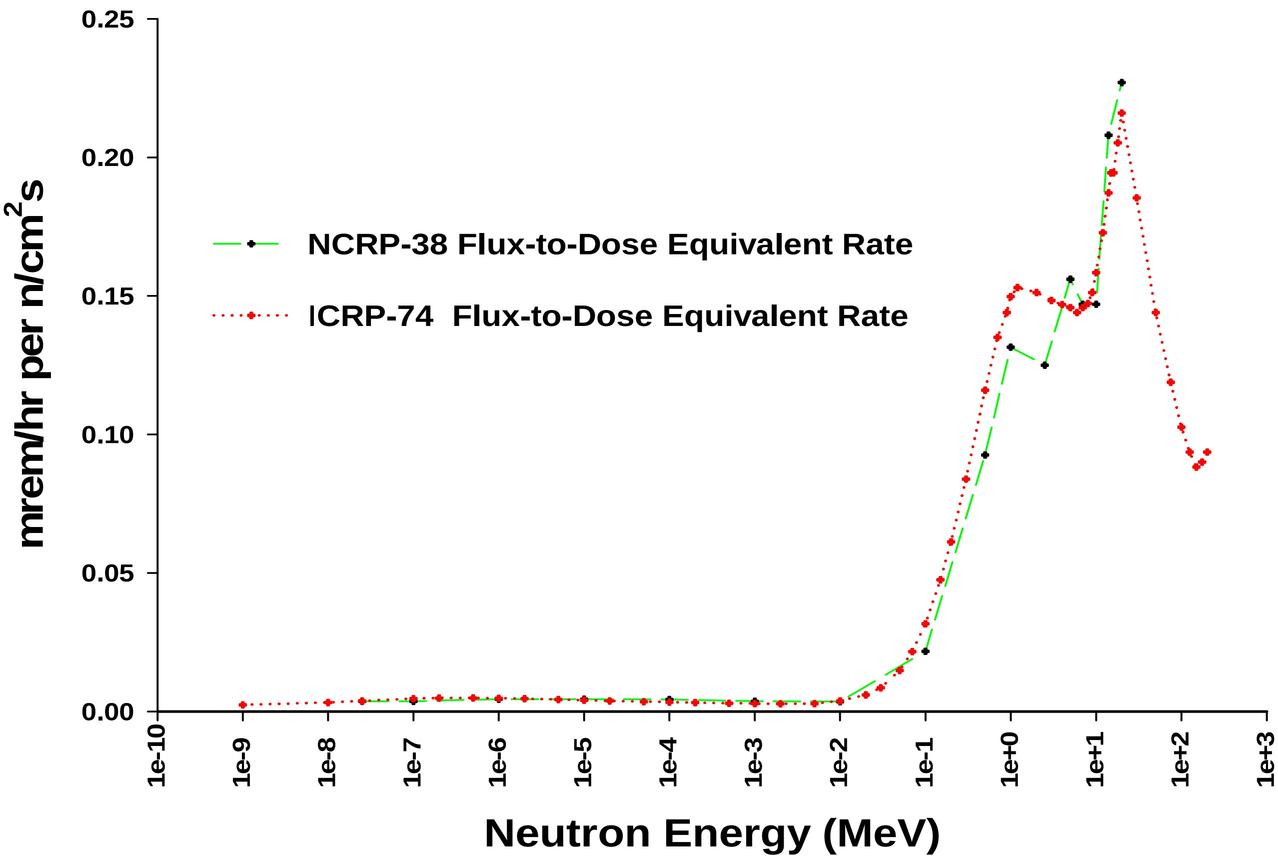

Figure 1: NCRP-38 and ICRP-74 Neutron Flux-to-Dose Equivalent Rate Conversion Factors**.**

The original MCNP4 input files contained detailed modeling of the Calibration Bar (Figure 2), the building structure (Figure 3) and the sources (Appendix H, Figures H-1 and H-2). As none of these items have changed, there was no need to modify any input geometry. The relevant MCNP input files are presented in Appendices A through F for reference.

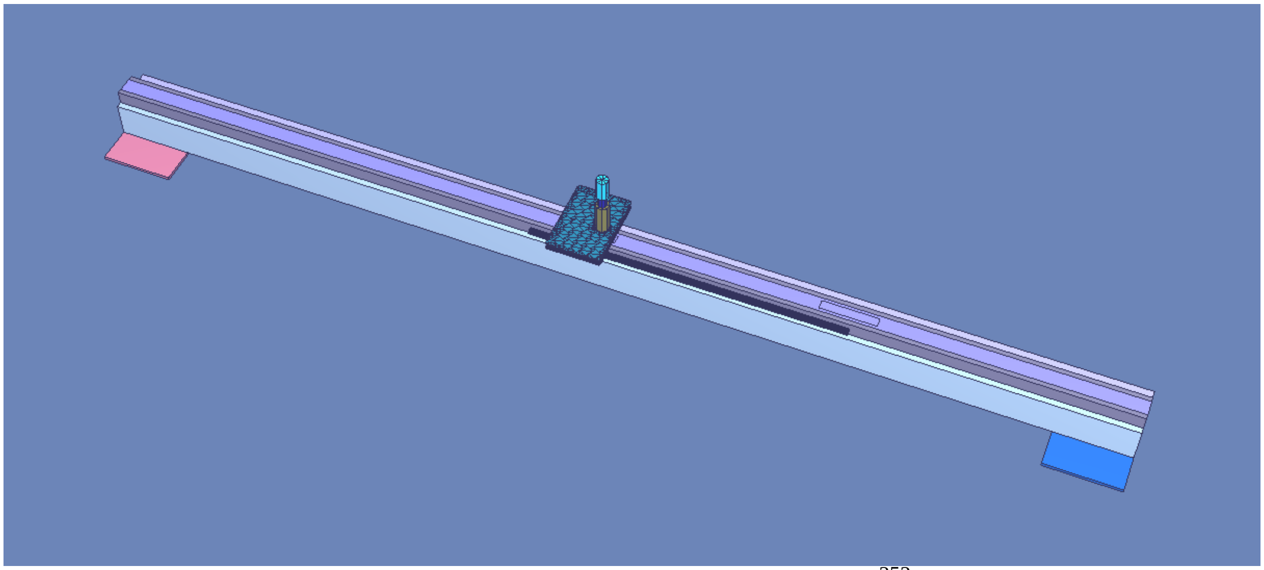

Figure 2: 3-D view of the Calibration Bar. In this picture, the bare ^{252}Cf source is displayed.

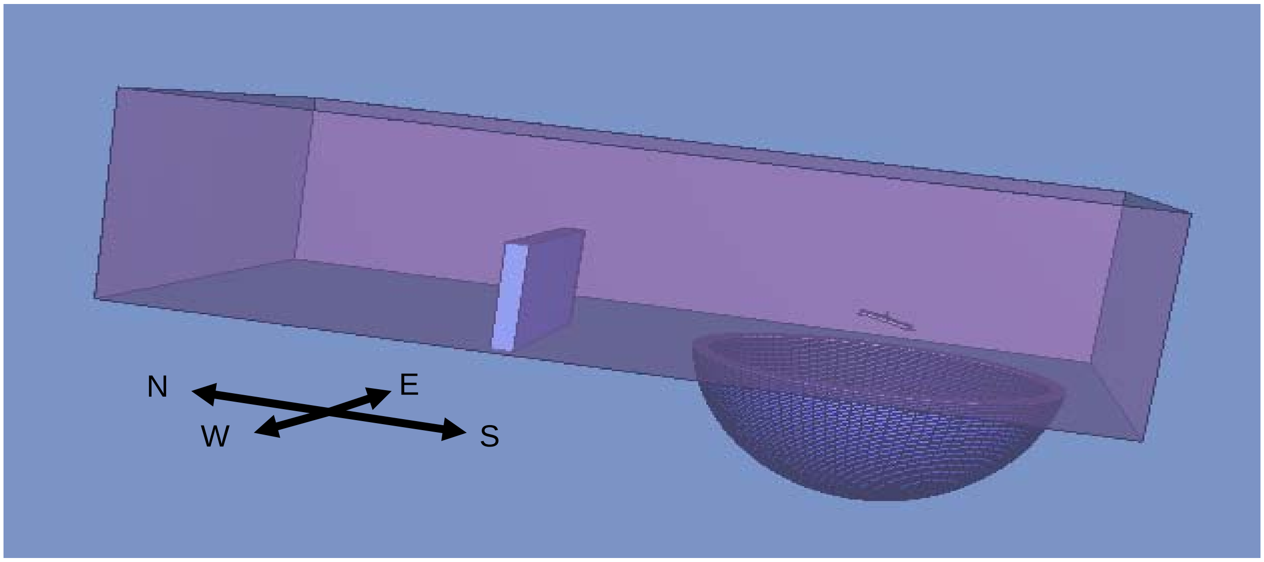

Figure 3: 3-D transparent view of Building 818.

Bldg. 818 contains a boron-frit-lined hemispherical pit. This pit is designed to minimize the floor component of Room Return. All neutron calibration activities take place over the pit. A thin aluminum superstructure over the pit (not shown in this figure, but accounted for in the MCNP geometry code) acts as a floor so that personnel can position neutron sources and equipment. A cement block wall separates the neutron calibration range from a gamma calibration range. Components of the gamma range were not relevant to this work and were not included in the input geometry.

A generic explanation of how the Flux-to-Dose Equivalent Rate Conversion Coefficient, F, Anisotropy Correction Factor, A, and the Scatter Correction Factor, S, were calculated is presented in Appendix H.

RESULTS

A Flux-to-Dose Equivalent Rate Conversion Coefficients, F

Table 1: Flux-to-Dose Equivalent Rate Conversion Coefficients (mrem/h per n/cm^2 sec)

Neutron field	Reference for Source Spectrum	F NCPR 38 value published in LA-UR-05-1788	F NCPR 38 value generated using updated input file	F ICRP-74 value generated using updated input file
Bare ^{252}Cf	ISO 8529: Maxwellian w/ Temp. Parameter of 1.42 MeV	0.120	0.120	0.138
Bare ^{238}PuBe	ISO 8529: ^{241}AmBe	0.134	0.134	0.141

B Anisotropy Correction Factors, A

Table 2: Anisotropy Correction Factor for SNL Neutron Sources

Source Type	Source ID	A NCPR 38 value published in LA-UR-05-1788)	A NCPR 38 value generated using updated input file	A ICRP-74 value generated using updated input file
Bare ^{252}Cf	Frontier Technology Corp., Model 10 FTC-CF-329	1.020	1.020	1.023
Bare ^{238}PuBe	Monsanto Research Corp., Model 2725 MRC-Pu-8-Be-446	1.039	1.039	1.051

C Scatter Correction Factors, S

Table 3: Scatter Correction Factor for SNL Neutron Reference Fields in Bldg. 818

Source Type	Source-to-Detector Distance	S NCPR 38 value published in LA-UR-05-1788)	S NCPR 38 value generated using updated input file	S ICRP-74 value generated using updated input file
Bare ^{252}Cf	100 cm	1.088	1.088	1.092
Bare ^{238}PuBe	100 cm	1.071	1.072	1.078

DISCUSSION

A Combined Effect of New Values

Equation 1 shows that all factors used in the determination of the conventionally true dose equivalent rate are multiplicative. The percent change in the conventionally true dose equivalent rate, for a particular type of source, due to switching from NCRP-38 to ICRP-74 flux-to-dose equivalent rate values is determined as shown in equation 2:

$$\%Change = 100\% * (\frac{F * A * S(ICRP-74)}{F * A * S(NCRP-38)} - 1) \qquad \text{Eqn. 2}$$

For bare ^{252}Cf: $\% \text{ Change} = 100\% * (\frac{0.138 * 1.023 * 1.092}{0.120 * 1.020 * 1.088} - 1) = 15.8\ \%$

For bare ^{238}PuBe: $\% \text{ Change} = 100\% * (\frac{0.141 * 1.051 * 1.078}{0.134 * 1.039 * 1.071} - 1) = 7.1\ \%$

B Uncertainty

The estimated uncertainty in this calibration method remains unchanged from the values listed in LA-UR-05-1788, which are shown below. All calculational results presented in Tables 1 – 3 had relative errors of < 1%.

Table 4: Estimated Uncertainties for Neutron Reference Radiation Fields at SNL Bldg. 818 Neutron Source Range

Field (Neutron Dose Equivalent Rate)	95% Confidence Level (1.96 σ)
Free-In-Air: Bare ^{252}Cf	± 5.4%
Free-In-Air: Bare ^{238}PuBe [^{241}AmBe]	± 9.0%

CONCLUSIONS

The transition from NCRP-38 to the use of ICRP-74 neutron conversion coefficients will require the use of new Flux-to-Dose Equivalent Rate Conversion Factors, Anisotropy Correction Factors and Scatter Factors as shown in Tables 1, 2, and 3 above.

The use of ICRP-74 conversion coefficients will increase the stated values of the SNL reference neutron field for bare ^{252}Cf by 15.8%.

The use of ICRP-74 conversion coefficients will increase the stated values of the SNL reference neutron field for bare ^{238}PuBe by 7.1%.

REFERENCES

Characterization of the Sandia National Laboratory Building 818 Neutron Source Range, Los Alamos National Laboratories, LA-UR-05-1788, March 11, 2005

10 CFR 835, Occupational Radiation Protection

ICRP (International Committee on Radiological Protection), *1997 Conversion Coefficients for use in Radiological Protection against External Radiation*, Report 74, Annals of the ICRP, volume26, number 3, Pergamon Press, Oxford, England.

NCRP (National Council on Radiation Protection and Measurements), 1973 *Protection Against Neutron Radiation*, Report 38, NCRP Publications, Washington D.C.

APPENDIX A: NCRP-38 AND ICRP-74 FLUX-TO-DOSE EQUIVALENT RATE CONVERSION COEFFICIENT FOR BARE ^{252}CF

MCNP5 Version 1.40 Input file: CFFD.i

```
Bare Cf-252 NCRP-38 and ICRP-74 Fluence to Dose Conversion Coefficient
c    Modified: David T. Seagraves 5/2/03
c    Modified: Dann Ward  9 26 2008
1    0 -1 imp:n=1
2    0 1 imp:n=0

c    SURFACE FOR UNIVERSE
c
1    so 100

mode n
c
c    xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
f5:n 50 0 0 0.0
fc5  mrem/hr per n/s
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de5  2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df5  3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
c
c    xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
f205:n 50 0 0 0.0
fc205     mrem/hr per n/s
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de205   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df205   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
c
sdef par=1 erg=d1 pos=0 0 0
sp1  -2 1.42
c
c xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
prdmp 1j -180 0 2
ctme 10
```

APPENDIX B: NCRP-38 AND ICRP-74 FLUX-TO-DOSE EQUIVALENT RATE CONVERSION COEFFICIENT FOR BARE PUBE

MCNP5 Version 1.40 Input file: PBFD.i

```
Pu-238/Be (AmBe) NCRP-38 and ICRP 74 Fluence to Dose Conversion Coefficient
c    Modified: David T. Seagraves 5/2/03
c    Modified: Dann Ward  9 26 2008
1    0 -1 imp:n=1
2    0 1 imp:n=0
c    UNIVERSE
c

1    so 100

mode n
c
c    xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
f5:n 50 0 0 0
fc5  mrem/hr per n/s
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de5  2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df5  3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
c
c    xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
f205:n  50 0 0 0.0
fc205   mrem/hr per n/s
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de205   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df205   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
c    xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
sdef par=1 erg=d1 pos=0 0 0
c    ISO 8529:1989 Am-241/Be source fluence per unit linear energy bin
si1  h 4.14e-7 0.11 0.33 0.54 0.75 0.97 1.18 1.4 1.61 1.82 2.04 2.25
      2.47 2.68 2.9 3.11 3.32 3.54 3.75 3.97 4.18 4.39 4.61 4.82 5.04
      5.25 5.47 5.68 5.89 6.11 6.32 6.54 6.75 6.96 7.18 7.39 7.61 7.82
      8.03 8.25 8.46 8.68 8.89 9.11 9.32 9.53 9.75 9.96 10.18 10.39 10.6
      10.82 11.03 11.09
sp1  d 0 1.436e-2 3.340e-2 3.127e-2 2.812e-2 2.5e-2 2.136e-2 1.983e-2
      1.747e-2 1.925e-2 2.225e-2 2.146e-2 2.248e-2 2.277e-2 2.951e-2
      3.559e-2 3.685e-2 3.458e-2 3.066e-2 2.999e-2 2.691e-2 2.863e-2
      3.178e-2 3.074e-2 3.334e-2 3.041e-2 2.738e-2 2.332e-2 2.059e-2
      1.815e-2 1.767e-2 2.039e-2 1.83e-2 1.63e-2 1.677e-2 1.681e-2
      1.883e-2 1.837e-2 1.688e-2 1.435e-2 9.677e-3 6.521e-3 4.255e-3
      3.667e-3 3.806e-3 5.058e-3 6.253e-3 5.519e-3 4.675e-3 3.696e-3
      2.781e-3 1.514e-3 3.633e-4 0
c
c     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

```
c
prdmp 1j -180 0 2
ctme 10
```

APPENDIX C: ANISOTROPY CORRECTION FACTOR FOR BARE ^{252}CF

MCNP5 Version 1.40 Input file: 74Cf

```
Bare Cf-252 Anisotropy @ SNL Low Scatter Facility
c Cf-252: Frontier Technology Corp. Model 10
c Modified: David T. Seagraves 2/4/04, Dann C. Ward 10/24/08
c
1    5 -12.0 -19 21 -20 imp:n=1 $ Cf oxide/Pd alloy
2    6 -0.444 -22 -24 23 #1 imp:n=1 $ Zircalloy-2 fill
3    3 -7.92 (-25 -27 26) (22:-23:24) imp:n=1 $ inner capsule
4    0 (-28 -29 26) (25:27) imp:n=1 $ void space between inner/outer cap.
5    3 -7.92 ((-30 -32 31):(-33 34 -31)) (28:-26:29) imp:n=1 $ outer capsule
c
6    9 -8.3656 -35 (33:-34) imp:n=1 $ brass rod below source
c
7    0 -1000 35 (30:32:-31) imp:n=1 $ inside universe/outside source
8    0 1000 imp:n=0 $ outside universe

c SURFACES FOR CF SOURCE CAPSULE
c
19   cz 0.06735
20   pz 0.0254
21   pz -0.0254
22   cz 0.19558
23   pz -1.8546
24   pz 0.0504
25   cz 0.27682
26   pz -2.2483
27   pz 0.2409
28   cz 0.29718
29   pz 0.3425
30   cz 0.47117
31   pz -2.4515
32   pz 0.7997
33   cz 0.2413
34   pz -2.9595
c
35 rcc 0 0 -10.0715 0 0 7.62 0.47625 $ SURFACES FOR BRASS SOURCE SUPPORT ROD
c
c SURFACES FOR UNIVERSE
c
1000 so 120

mode n
c
c xxxxxxxxxxxxxxxx SOURCE DEFINITION xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
sdef par=1 erg=d1 pos=0 0 0 rad=d2 axs=0 0 1 ext=d3
sp1  -2 1.42
si2  h 0 0.06735
sp2  -21 1
si3  h -0.0254 0.0254
sp3  -21 0
c
c xxxxxxxxxxxxxxxx TALLY CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

```
c
f5:n 0 -100 0 0 $ tally is centered on the rabbit
fc5 mrem/hr per n/s
c   NCRP-38 neutron flux-to-dose rate conversion factor
c   units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de5  2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df5  3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
c
c
f205:n 0 -100 0 0.0
fc205     mrem/hr per n/s
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de205   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df205   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c xxxxxxxxxxxxxxxx MATERIAL CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
c 304 Stainless Steel @ den-7.92
m3   26000.55c -0.695 24000.50c -0.190 28000.50c -0.095 25055.60c -0.020
c
m5   98252.60c -0.018261 8016.60c -0.001739 46108.50c -0.98
c Zircalloy-2 @ 0.444 g/cm3
c Modified ZAID for Tin from 50000.35c to 50000.40c Dann 8 31 08
m6   40000.60c -0.98307 50000.40c -0.015 26000.55c -0.0012
     24000.50c -0.0009 28000.50c -0.0005
m9   29000.50c -0.97 82000.50c -0.03 $ 360 brass @ 8.3656 g/cm3
prdmp 1j -180 0 2
ctme 30
```

APPENDIX D: ANISOTROPHY CORRECTION FACTOR FOR BARE PUBE

MCNP5 Version 1.40 Input file: 74Pb

```
Pu-238/Be (AmBe) Anisotropy @ SNL Low Scatter Facility
c Monsanto Research Corp. Model 2725 - B.T.
c Modified: David T. Seagraves 2/04/04, Dann C. Ward 10/23/08
c
c
4    3 -7.92 -33 34 imp:n=1 $ source capsule
5    11 -0.9 -34 imp:n=1 $ inside source / Be
6    9 -8.3656 -35 imp:n=1 $ brass rod below source
c
7    0 33 35 -1000 imp:n=1 $ inside universe/outside source
8    0 1000 imp:n=0 $ outside universe

c SURFACES FOR CF SOURCE CAPSULE
c
33   rcc 0 0 -2.4515 0 0 4.445 1.27 $ OUTER SOURCE CAPSULE
34   rcc 0 0 -1.0795 0 0 2.48158 1.03124 $ INSIDE SOURCE CAPSULE
c
35   rcc 0 0 -10.0715 0 0 7.62 0.47625 $ SURFACES FOR BRASS SOURCE SUPPORT
ROD
c
c SURFACES FOR GROUND AND AIR SPACE OUTSIDE BUILDING
c
1000 so 120

mode n
c
c xxxxxxxxxxxxxxxx SOURCE DEFINITION xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
sdef par=1 erg=d3 pos 0 0 0 rad=d1 axs=0 0 1 ext=d2
si1  h 0 1.03124
sp1  -21 1
si2  h -1.0795 1.40208
sp2  -21 0
c ISO 8529:1989 Am-241/Be source fluence per unit linear energy bin
si3  h 4.14e-7 0.11 0.33 0.54 0.75 0.97 1.18 1.4 1.61 1.82 2.04 2.25
     2.47 2.68 2.9 3.11 3.32 3.54 3.75 3.97 4.18 4.39 4.61 4.82 5.04
     5.25 5.47 5.68 5.89 6.11 6.32 6.54 6.75 6.96 7.18 7.39 7.61 7.82
     8.03 8.25 8.46 8.68 8.89 9.11 9.32 9.53 9.75 9.96 10.18 10.39 10.6
     10.82 11.03 11.09
sp3  d 0 1.436e-2 3.340e-2 3.127e-2 2.812e-2 2.5e-2 2.136e-2 1.983e-2
     1.747e-2 1.925e-2 2.225e-2 2.146e-2 2.248e-2 2.277e-2 2.951e-2
     3.559e-2 3.685e-2 3.458e-2 3.066e-2 2.999e-2 2.691e-2 2.863e-2
     3.178e-2 3.074e-2 3.334e-2 3.041e-2 2.738e-2 2.332e-2 2.059e-2
     1.815e-2 1.767e-2 2.039e-2 1.83e-2 1.63e-2 1.677e-2 1.681e-2
     1.883e-2 1.837e-2 1.688e-2 1.435e-2 9.677e-3 6.521e-3 4.255e-3
     3.667e-3 3.806e-3 5.058e-3 6.253e-3 5.519e-3 4.675e-3 3.696e-3
     2.781e-3 1.514e-3 3.633e-4 0
c
c xxxxxxxxxxxxxxxx TALLY CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

```
c
f5:n 0 -100 0 20.0 $ tally is centered on the rabbit
fc5 mrem/hr per n/s @ 0-deg off y-axis
c   NCRP-38 neutron flux-to-dose rate conversion factor
c   units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de5  2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df5  3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
c
c
c
f205:n  0 -100 0 20.0
fc205   mrem/hr per n/s
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de205   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df205   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
c
c xxxxxxxxxxxxxxxx MATERIAL CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
c 304 Stainless Steel @ den-7.92
m3   26000.55c -0.695 24000.50c -0.190 28000.50c -0.095 25055.60c -0.020
c
m9   29000.50c -0.97 82000.50c -0.03 $ 360 brass @ 8.3656 g/cm3
c
m11  4009.50c 1 $ Be at an effective density of 0.9 g/cc
prdmp 1j -180 0 2
ctme 30
```

APPENDIX E: SCATTER CORRECTION FACTOR FOR BARE ^{252}CF

MCNP5 Version 1.40 Input file: XRCf

```
Bare Cf-252 Spectrum @ SNL Low Scatter Facility
c Cf-252: Frontier Technology Corp. Model 10
c Modified: David T. Seagraves 11/03/03
c Modified:  Dann C. Ward 9/03/08
1    5  -12.0 -19 21 -20 imp:n=1 $ Cf oxide/Pd alloy
2    6  -0.444 -22 -24 23 #1 imp:n=1 $ Zircalloy-2 fill
3    3  -7.92 (-25 -27 26) (22:-23:24) imp:n=1 $ inner capsule
4    1  -1.0e-3 (-28 -29 26) (25:27) imp:n=1 $ void space between inner/outer
c         cap.
5    3  -7.92 ((-30 -32 31):(-33 34 -31)) (28:-26:29) imp:n=1 $ outer capsule
c
6    9  -8.3656 -35 (33:-34) imp:n=1 $ brass rod below source
7    3  -7.92 -36 35 imp:n=1 $ support for brass rod
8    3  -7.92 -37 36 38 imp:n=1 $ support
9    1  -1.0e-3 -38 imp:n=1 $ air space below support
10   4 -2.7 -39 37 imp:n=1 $ source platform
11   3 -7.92 (-40 : -41) 55 59 imp:n=1 $ steel rails
12   4 -2.7 -42 43 imp:n=1 $ al rail assembly
13   1 -1.0e-3 -43 55 59 imp:n=1 $ air space in rail assembly
14   4 -2.7 -44 40 imp:n=1
15   4 -2.7 -45 41 imp:n=1
16   4 -2.7 -46 47 imp:n=1 $ al support
17   1 -1.0e-3 -47 imp:n=1 $ air space in al support
18   4 -2.7 -48 imp:n=1 $ end support
19   4 -2.7 -62 imp:n=1 $ end support
20   4 -2.7 -49 50 imp:n=1 $ mini scale support
21   1 -1.0e-3 -50 imp:n=1 $ air space next to mini scale
22   4 -2.7 -51 imp:n=1 $ reading head mount
23   4 -2.7 -52 53 imp:n=1 $ inst platform
24   1 -1.0e-3 -53 imp:n=1 $ air space in inst plat
25   4 -2.7 (-54 : -55 : -56 : -57) #11 imp:n=1
26   4 -2.7 (-58 : -59 : -60 : -61) #11 imp:n=1
c
99   4 -0.083 115 -105 -108 imp:n=1 $ simulation of honeycomb
100  0 (1000:1001:-1002) 1003 imp:n=0 $ outside
101  2 -2.3 100 -101 102 -103 104 -105 109 imp:n=1 $ concrete floor
102  1 -1e-3 -107 162 35 36 37 39 (30:32:-34) #11
     42 43 #14 #15 46 48 62 49 51 52 #25 #26 imp:n=1 $ air space in room
103  7 -8.0 -106 107 imp:n=1 $ steel walls and ceiling
104  10 -2.3569 108 -109 -105 imp:n=1 $ borated concrete pit shell
105  1 -1e-3 -108 -105 #106 #107 #108 #109 #110 #111 #112 #113 #114
     #115 #116 #117 #118 #119 #120 #121 #122 142 144 146 148 150 152
     154 156 158 160 #99 imp:n=1 $ air space in pit
106  4 -2.7 (114 -117 110 -111 -108):(116 -115 110 -111 -108):
     (117 -116 112 -113 -108) imp:n=1 $ center i-beam in pit (N-S)
107  4 -2.7 (114 -117 118 -119 -108):(116 -115 118 -119 -108):
     (117 -116 120 -121 -108) imp:n=1
108  4 -2.7 (114 -117 122 -123 -108):(116 -115 122 -123 -108):
     (117 -116 124 -125 -108) imp:n=1
109  4 -2.7 (114 -117 126 -127 -108):(116 -115 126 -127 -108):
     (117 -116 128 -129 -108) imp:n=1
110  4 -2.7 (114 -117 130 -131 -108):(116 -115 130 -131 -108):
```

```
     (117 -116 132 -133 -108) imp:n=1
111  4 -2.7 (135 -134 114 -117 119 -110):(135 -134 116 -115 119 -110):
     (137 -136 117 -116 119 -110) imp:n=1
112  like 111 but trcl=(0 -121.92 0) imp:n=1
113  like 111 but trcl=(243.84 0 0) imp:n=1
114  like 111 but trcl=(243.84 -121.92 0) imp:n=1
115  like 111 but trcl=(0 121.92 0) imp:n=1
116  like 111 but trcl=(0 243.84 0) imp:n=1
117  like 111 but trcl=(243.84 121.92 0) imp:n=1
118  like 111 but trcl=(243.84 243.84 0) imp:n=1
119  4 -2.7 (135 -134 114 -117 -122 -108):(135 -134 116 -115 -122 -108):
     (137 -136 117 -116 -122 -108) imp:n=1
120  4 -2.7 (135 -134 114 -117 131 -108):(135 -134 116 -115 131 -108):
     (137 -136 117 -116 131 -108) imp:n=1
121  4 -2.7 (139 -138 114 -117 -122 -108):(139 -138 116 -115 -122 -108):
     (141 -140 117 -116 -122 -108) imp:n=1
122  4 -2.7 (139 -138 114 -117 131 -108):(139 -138 116 -115 131 -108):
     (141 -140 117 -116 131 -108) imp:n=1
123  4 -2.7 143 -142 -108 imp:n=1 $ support beam
124  1 -1e-3 -143 -108 imp:n=1 $ air inside support beam
125  4 -2.7 145 -144 -108 imp:n=1
126  1 -1e-3 -145 -108 imp:n=1
127  4 -2.7 147 -146 -108 imp:n=1
128  1 -1e-3 -147 -108 imp:n=1
129  4 -2.7 149 -148 -108 imp:n=1
130  1 -1e-3 -149 -108 imp:n=1
131  4 -2.7 151 -150 -108 imp:n=1
132  1 -1e-3 -151 -108 imp:n=1
133  4 -2.7 153 -152 -108 imp:n=1
134  1 -1e-3 -153 -108 imp:n=1
135  4 -2.7 155 -154 -108 imp:n=1
136  1 -1e-3 -155 -108 imp:n=1
137  4 -2.7 157 -156 -108 imp:n=1
138  1 -1e-3 -157 -108 imp:n=1
139  4 -2.7 159 -158 -108 imp:n=1
140  1 -1e-3 -159 -108 imp:n=1
141  4 -2.7 161 -160 -108 imp:n=1
142  1 -1e-3 -161 -108 imp:n=1
c
143  2 -2.3 -162 imp:n=1 $ concrete shield wall next to gamma well
c
1000 1 -1e-3 -1000 105 -1001 106 imp:n=1 $ air space around building
1001 8 -1.7 ((-1000 1002 -105 1003):(109 -1003 -104)) #101 imp:n=1 $ ground
c     around building

c SURFACES FOR CF SOURCE CAPSULE
c
19   cz 0.06735
20   pz 0.0254
21   pz -0.0254
22   cz 0.19558
23   pz -1.8546
24   pz 0.0504
25   cz 0.27682
26   pz -2.2483
27   pz 0.2409
28   cz 0.29718
```

```
29   pz 0.3425
30   cz 0.47117
31   pz -2.4515
32   pz 0.7997
33   cz 0.2413
34   pz -2.9595
c
35   rcc 0 0 -10.0715 0 0 7.62 0.47625 $ SURFACES FOR BRASS SOURCE SUPPORT
ROD
36   rcc 0 0 -2.4515 0 0 -7.62 0.9525 $ BRASS/SOURCE SUPPORT
37   rcc 0 0 -4.9915 0 0 -7.62 1.42875 $ SUPPORT
38   rcc 0 0 -10.0715 0 0 -2.54 0.9525 $ AIR SPACE BELOW SUPPORT
c
39   1 rpp -8.509 2.921 -8.255 8.255 -12.6115 -11.3415 $ SOURCE PLATFORM
c
40   1 rcc 106.68 -3.81 -14.5165 -213.36 0 0 0.635 $ steel rail - left side
41   1 rcc 106.68 3.81 -14.5165 -213.36 0 0 0.635 $ steel rail - right side
42   1 rpp -106.68 106.68 -2.54 2.54 -16.739 -13.8815 $ al rail assembly
43   1 rpp -106.68 106.68 -1.5875 1.5875 -15.469 -13.8815 $ air space in rail
c      assembly
44   1 rpp -106.68 106.68 -3.81 -2.54 -14.834 -14.199
45   1 rpp -106.68 106.68 2.54 3.81 -14.834 -14.199
46   1 rpp -106.68 106.68 -3.81 3.81 -24.359 -16.739 $ 3"x3" al support
47   1 rpp -106.68 106.68 -3.4925 3.4925 -24.0415 -17.0565 $ air space in al
c      support
48   1 rpp -106.68 -91.44 -11.43 11.43 -24.994 -24.359 $ al end plate
62   1 rpp 91.44 106.68 -11.43 11.43 -24.994 -24.359 $ al end plate
49   1 rpp -106.68 106.68 3.81 6.35 -20.549 -16.739 $ mini scale support
50   1 rpp -106.68 106.68 4.445 6.35 -20.549 -17.347
51   1 rpp -1.524 2.921 6.35 7.3025 -22.7715 -12.6115 $ reading head mount
52   1 rpp 42.38 57.62 -8.89 8.89 -12.6115 -11.3415 $ inst platform
53   1 rpp 43.3325 56.6675 -7.9375 7.9375 -11.9765 -11.3415 $ air space in
c      inst plat
c
c SURFACES FOR LPS GUIDE ON SOURCE PLATFORM
c
54   1 rpp -8.509 2.921 -5.715 5.715 -13.8815 -12.6115
55   1 rpp -8.509 2.921 -0.9525 0.9525 -15.1515 -13.8815
56   1 rpp -8.509 2.921 -5.715 -3.4925 -15.7865 -12.6115
57   1 rpp -8.509 2.921 3.4925 5.715 -15.7865 -12.6115
c
c SURFACES FOR LPS GUIDE ON SOURCE PLATFORM
c
58   1 rpp 44.285 55.715 -5.715 5.715 -13.8815 -12.6115
59   1 rpp 44.285 55.715 -0.9525 0.9525 -15.1515 -13.8815
60   1 rpp 44.285 55.715 -5.715 -3.4925 -15.7865 -12.6115
61   1 rpp 44.285 55.715 3.4925 5.715 -15.7865 -12.6115
C
c SURFACES FOR CONCRETE FLOOR
c
100   px -1493.52
101   px 487.68
102   py -533.4
103   py 533.4
104   pz -157.48
105   pz -137.16
c
```

```
c SURFACES FOR AIR SPACE IN ROOM AND STEEL WALLS
c
106   rpp -1493.52 487.68 -533.4 533.4 -137.16 350.52
107   rpp -1493.42 487.58 -533.3 533.3 -137.16 350.42
c
c SURFACES FOR PIT
c
108   sz -76.2 365.76
109   sz -76.2 396.24
c
c SURFACES FOR PIT I-BEAMS AND SUPPORTS
c
110   py -3.81
111   py 3.81
112   py -0.3175
113   py 0.3175
114   pz -152.4
115   pz -142.24
116   pz -142.875
117   pz -151.765
c
118   py -125.73
119   py -118.11
120   py -122.2375
121   py -121.6025
c
122   py -247.65
123   py -240.03
124   py -244.1575
125   py -243.5225
c
126   py 118.11
127   py 125.73
128   py 121.6025
129   py 122.2375
c
130   py 240.03
131   py 247.65
132   py 243.5225
133   py 244.1575
c
134   px -116.84
135   px -127.0
136   px -121.6025
137   px -122.2375
c
138   px 127
139   px 116.84
140   px 122.2375
141   px 121.6025
c
142   rpp -125.73 -118.11 -3.81 3.81 -500 -152.4
143   rpp -125.4125 -118.4275 -3.4925 3.4925 -500 -152.4
144   rpp 118.11 125.73 -3.81 3.81 -500 -152.4
145   rpp 118.4275 125.4125 -3.4925 3.4925 -500 -152.4
146   rpp -125.73 -118.11 -125.73 -118.11 -500 -152.4
147   rpp -125.4125 -118.4275 -125.4125 -118.4275 -500 -152.4
```

```
148   rpp -125.73 -118.11 -247.65 -240.03 -500 -152.4
149   rpp -125.4125 -118.4275 -247.3325 -240.3475 -500 -152.4
150   rpp -125.73 -118.11 118.11 125.73 -500 -152.4
151   rpp -125.4125 -118.4275 118.4275 125.4125 -500 -152.4
152   rpp -125.73 -118.11 240.03 247.65 -500 -152.4
153   rpp -125.4125 -118.4275 240.3475 247.3325 -500 -152.4
c
154   rpp 118.11 125.73 -125.73 -118.11 -500 -152.4
155   rpp 118.4275 125.4125 -125.4125 -118.4275 -500 -152.4
156   rpp 118.11 125.73 -247.65 -240.03 -500 -152.4
157   rpp 118.4275 125.4125 -247.3325 -240.3475 -500 -152.4
158   rpp 118.11 125.73 118.11 125.73 -500 -152.4
159   rpp 118.4275 125.4125 118.4275 125.4125 -500 -152.4
160   rpp 118.11 125.73 240.03 247.65 -500 -152.4
161   rpp 118.4275 125.4125 240.3475 247.3325 -500 -152.4
c
c
c SURFACE FOR CONCRETE SHIELD WALL NEXT TO GAMMA WELLS
c
162   rpp -716.28 -670.56 -487.68 35.56 -137.16 106.68
c
c SURFACES FOR GROUND AND AIR SPACE OUTSIDE BUILDING
c
1000 cz 1600
1001 pz 1600
1002 pz -187.96
1003 sz -76.2 426.72

mode n
c
*tr1 0 0 0 60 150 90 30 60 90 90 90 0
c
c
c xxxxxxxxxxxxxxxx SOURCE DEFINITION xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
sdef par=1 erg=d1 pos=0 0 0 rad=d2 axs=0 0 1 ext=d3
sp1  -2 1.42
si2  h 0 0.06735
sp2  -21 1
si3  h -0.0254 0.0254
sp3  -21 0
c
c xxxxxxxxxxxxxxxx TALLY CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
f5:n 0 -100 0 20.0 $ tally is centered on the rabbit
fc5 mrem/hr per n/s @ 0-deg off y-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de5  2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df5  3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f15:n 0 -100 0 20.0
fc15 ROSPEC Energy Bin Structure @ 0-deg off y-axis
e15  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
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     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
f205:n  0 -100 0 20.0 $ tally is centered on the rabbit
fc205     mrem/hr per n/s @ 0 deg off y-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de205   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df205   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
f25:n -25.8819 -96.5926 0 20.0 $ tally is centered on the rabbit
fc25 mrem/hr per n/s @ 15-deg off y-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de25 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df25 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f35:n -25.8819 -96.5926 0 20.0
fc35 ROSPEC Energy Bin Structure @ 15-deg off y-axis
e35  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
f225:n  -25.8819 -96.5926 0 20 $ tally is centered on the rabbit
fc225     mrem/hr per n/s @ 15 deg off y-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
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de225   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df225   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
f45:n -50 -86.6025 0 20.0 $ tally is centered on the rabbit
fc45 mrem/hr per n/s @ 30-deg off y-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de45 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df45 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f55:n -50 -86.6025 0 20.0
fc55 ROSPEC Energy Bin Structure @ 30-deg off y-axis
e55  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
f245:n  -50 -86.6025 0 20 $ tally is centered on the rabbit
fc245     mrem/hr per n/s @ 30 deg off y-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de245   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df245   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
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        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
f65:n -96.5926 -25.8819 0 20.0 $ tally is centered on the rabbit
fc65 mrem/hr per n/s @ -15-deg off x-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de65 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df65 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f75:n -96.5926 -25.8819 0 20.0
fc75 ROSPEC Energy Bin Structure @ -15-deg off x-axis
e75  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
f265:n  -96.5926 -25.8819 0 20 $ tally is centered on the rabbit
fc265     mrem/hr per n/s @ -15 deg offx-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de265   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df265   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
f85:n -100 0 0 20.0 $ tally is centered on the rabbit
fc85 mrem/hr per n/s @ 0-deg off x-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
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de85 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df85 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f95:n -100 0 0 20.0
fc95 ROSPEC Energy Bin Structure @ 0-deg off x-axis
e95  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
f285:n  -100 0 0 20 $ tally is centered on the rabbit
fc285     mrem/hr per n/s @ 0 deg off x-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de285   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df285   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
f105:n -96.5926 25.8819 0 20.0 $ tally is centered on the rabbit
fc105 mrem/hr per n/s @ 15-deg off x-axis
c     NCRP-38 neutron flux-to-dose rate conversion factor
c     units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de105 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df105 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
      9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f115:n -96.5926 -25.8819 0 20.0
fc115 ROSPEC Energy Bin Structure @ 15-deg off x-axis
e115 .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
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     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
f305:n  -96.5926 25.8819 0 20 $ tally is centered on the rabbit
fc305   mrem/hr per n/s @ 15 deg off x-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de305   1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
        5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-
03
        0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1
1.2
        2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df305   2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
        4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
        3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
        3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
        4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
        1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
        1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
        1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
        1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
        9.3600E-02
c
c
c xxxxxxxxxxxxxxxx MATERIAL CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
c Air with 15 g/m3 water vapor
m1   1001.60c -0.0056 7014.60c -0.7447 8016.60c -0.24096 18000.35c -0.012823
c
c ANSI/ANS 6.6.1-1987 Concrete Composition den-2.3
m2   1001.60c 7.86e+21 8016.60c 4.38e+22 11023.60c 1.05e+21
     12000.60c 1.40e+20 13027.60c 2.39e+21 14000.60c 1.58e+22
     19000.60c 6.90e+20 20000.60c 2.92e+21 26000.55c 3.10e+20
c
c 304 Stainless Steel @ den-7.92
m3   26000.55c -0.695 24000.50c -0.190 28000.50c -0.095 25055.60c -0.020
c
m4   13027.60c 1 $ aluminum den 2.7 g/cm3
c
m5   98252.60c -0.018261 8016.60c -0.001739 46108.50c -0.98
c Zircalloy-2 @ 0.444 g/cm3
c    ZAID for Tin changed from 50000.35c to 50000.40c by Dann 8 31 08
m6   40000.60c -0.98307 50000.40c -0.015 26000.55c -0.0012
     24000.50c -0.0009 28000.50c -0.0005
m7   26000.55c 1 $ iron - 8.0 g/cm^3
m8   1001.60c 9.77e+21 8016.60c 3.48e+22 13027.60c 4.88e+21
     14000.60c 1.16e+22 $ ground @ 1.7 g/cm3
m9   29000.50c -0.97 82000.50c -0.03 $ 360 brass @ 8.3656 g/cm3
c Modified ANSI/ANS 6.6.1-1987 Concrete Composition - den-2.3569 g/cc
c 0.75% by wt Boron additive
m10  1001.60c -0.0056 5010.60c -1.4925E-3 5011.60c -6.0075E-3
     8016.60c -0.4973 11023.60c -0.0171 12000.60c -0.0024
```

```
     13027.60c -0.0458 14000.60c -0.315 19000.60c -0.0191
     20000.60c -0.0831 26000.50c -0.0123
prdmp 1j -180 0 2
ctme 900
```

APPENDIX F: SCATTER CORRECTION FACTOR FOR BARE PUBE

MCNP5 Version 1.40 Input file: DRPb

```
Pu-238/Be (AmBe) Spectrum @ SNL Low Scatter Facility
c Monsanto Research Corp. Model 2725 - B.T.
c Modified: David T. Seagraves 2/03/04
c Modified:  Dann C. Ward 09/08/08
c
4    3 -7.92 -33 34 imp:n=1 $ source capsule
5    11 -0.9 -34 imp:n=1 $ inside source / Be
6    9 -8.3656 -35 imp:n=1 $ brass rod below source
7    3 -7.92 -36 35 imp:n=1 $ support for brass rod
8    3 -7.92 -37 36 38 imp:n=1 $ support
9    1 -1.0e-3 -38 imp:n=1 $ air space below support
10   4 -2.7 -39 37 imp:n=1 $ source platform
11   3 -7.92 (-40 : -41) 55 59 imp:n=1 $ steel rails
12   4 -2.7 -42 43 imp:n=1 $ al rail assembly
13   1 -1.0e-3 -43 55 59 imp:n=1 $ air space in rail assembly
14   4 -2.7 -44 40 imp:n=1
15   4 -2.7 -45 41 imp:n=1
16   4 -2.7 -46 47 imp:n=1 $ al support
17   1 -1.0e-3 -47 imp:n=1 $ air space in al support
18   4 -2.7 -48 imp:n=1 $ end support
19   4 -2.7 -62 imp:n=1 $ end support
20   4 -2.7 -49 50 imp:n=1 $ mini scale support
21   1 -1.0e-3 -50 imp:n=1 $ air space next to mini scale
22   4 -2.7 -51 imp:n=1 $ reading head mount
23   4 -2.7 -52 53 imp:n=1 $ inst platform
24   1 -1.0e-3 -53 imp:n=1 $ air space in inst plat
25   4 -2.7 (-54 : -55 : -56 : -57) #11 imp:n=1
26   4 -2.7 (-58 : -59 : -60 : -61) #11 imp:n=1
c
99   4 -0.083 115 -105 -108 imp:n=1 $ simulation of honeycomb
100  0 (1000:1001:-1002) 1003 imp:n=0 $ outside
101  2 -2.3 100 -101 102 -103 104 -105 109 imp:n=1 $ concrete floor
102  1 -1e-3 -107 162 35 36 37 39 #11 33
     42 43 #14 #15 46 48 62 49 51 52 #25 #26 imp:n=1 $ air space in room
103  7 -8.0 -106 107 imp:n=1 $ steel walls and ceilin
104  10 -2.3569 108 -109 -105 imp:n=1 $ borated concrete pit s
105  1 -1e-3 -108 -105 #106 #107 #108 #109 #110 #111 #112 #113 #114
     #115 #116 #117 #118 #119 #120 #121 #122 142 144 146 148 150 152
     154 156 158 160 #99 imp:n=1 $ air space in pit
106  4 -2.7 (114 -117 110 -111 -108):(116 -115 110 -111 -108):
     (117 -116 112 -113 -108) imp:n=1 $ center i-beam in pit (
107  4 -2.7 (114 -117 118 -119 -108):(116 -115 118 -119 -108):
     (117 -116 120 -121 -108) imp:n=1
108  4 -2.7 (114 -117 122 -123 -108):(116 -115 122 -123 -108):
     (117 -116 124 -125 -108) imp:n=1
109  4 -2.7 (114 -117 126 -127 -108):(116 -115 126 -127 -108):
     (117 -116 128 -129 -108) imp:n=1
110  4 -2.7 (114 -117 130 -131 -108):(116 -115 130 -131 -108):
     (117 -116 132 -133 -108) imp:n=1
111  4 -2.7 (135 -134 114 -117 119 -110):(135 -134 116 -115 119 -110):
     (137 -136 117 -116 119 -110) imp:n=1
112  like 111 but trcl=(0 -121.92 0) imp:n=1
```

```
113  like 111 but trcl=(243.84 0 0) imp:n=1
114  like 111 but trcl=(243.84 -121.92 0) imp:n=1
115  like 111 but trcl=(0 121.92 0) imp:n=1
116  like 111 but trcl=(0 243.84 0) imp:n=1
117  like 111 but trcl=(243.84 121.92 0) imp:n=1
118  like 111 but trcl=(243.84 243.84 0) imp:n=1
119  4 -2.7 (135 -134 114 -117 -122 -108):(135 -134 116 -115 -122 -108):
     (137 -136 117 -116 -122 -108) imp:n=1
120  4 -2.7 (135 -134 114 -117 131 -108):(135 -134 116 -115 131 -108):
     (137 -136 117 -116 131 -108) imp:n=1
121  4 -2.7 (139 -138 114 -117 -122 -108):(139 -138 116 -115 -122 -108):
     (141 -140 117 -116 -122 -108) imp:n=1
122  4 -2.7 (139 -138 114 -117 131 -108):(139 -138 116 -115 131 -108):
     (141 -140 117 -116 131 -108) imp:n=1
123  4 -2.7 143 -142 -108 imp:n=1 $ support beam
124  1 -1e-3 -143 -108 imp:n=1 $ air inside support beam
125  4 -2.7 145 -144 -108 imp:n=1
126  1 -1e-3 -145 -108 imp:n=1
127  4 -2.7 147 -146 -108 imp:n=1
128  1 -1e-3 -147 -108 imp:n=1
129  4 -2.7 149 -148 -108 imp:n=1
130  1 -1e-3 -149 -108 imp:n=1
131  4 -2.7 151 -150 -108 imp:n=1
132  1 -1e-3 -151 -108 imp:n=1
133  4 -2.7 153 -152 -108 imp:n=1
134  1 -1e-3 -153 -108 imp:n=1
135  4 -2.7 155 -154 -108 imp:n=1
136  1 -1e-3 -155 -108 imp:n=1
137  4 -2.7 157 -156 -108 imp:n=1
138  1 -1e-3 -157 -108 imp:n=1
139  4 -2.7 159 -158 -108 imp:n=1
140  1 -1e-3 -159 -108 imp:n=1
141  4 -2.7 161 -160 -108 imp:n=1
142  1 -1e-3 -161 -108 imp:n=1
c
143  2 -2.3 -162 imp:n=1 $ concrete shield wall next to gamma well
c
1000 1 -1e-3 -1000 105 -1001 106 imp:n=1 $ air space around building
1001 8 -1.7 ((-1000 1002 -105 1003):(109 -1003 -104)) #101 imp:n=1 $ ground a

c SURFACES FOR CF SOURCE CAPSULE
c
c 31 pz -2.4515
c
33   rcc 0 0 -2.4515 0 0 4.445 1.27 $ OUTER SOURCE CAPSULE
34   rcc 0 0 -1.0795 0 0 2.48158 1.03124 $ INSIDE SOURCE CAPSULE
c
35   rcc 0 0 -10.0715 0 0 7.62 0.47625 $ SURFACES FOR BRASS SOURCE SUPPORT RO
36   rcc 0 0 -2.4515 0 0 -7.62 0.9525 $ BRASS/SOURCE SUPPORT
37   rcc 0 0 -4.9915 0 0 -7.62 1.42875 $ SUPPORT
38   rcc 0 0 -10.0715 0 0 -2.54 0.9525 $ AIR SPACE BELOW SUPPORT
c
39   1 rpp -8.509 2.921 -8.255 8.255 -12.6115 -11.3415 $ SOURCE PLATFORM
c
40   1 rcc 106.68 -3.81 -14.5165 -213.36 0 0 0.635 $ steel rail - left side
41   1 rcc 106.68 3.81 -14.5165 -213.36 0 0 0.635 $ steel rail - right side
42   1 rpp -106.68 106.68 -2.54 2.54 -16.739 -13.8815 $ al rail assembly
```

```
43   1 rpp -106.68 106.68 -1.5875 1.5875 -15.469 -13.8815 $ air space in rail
44   1 rpp -106.68 106.68 -3.81 -2.54 -14.834 -14.199
45   1 rpp -106.68 106.68 2.54 3.81 -14.834 -14.199
46   1 rpp -106.68 106.68 -3.81 3.81 -24.359 -16.739 $ 3"x3" al support
47   1 rpp -106.68 106.68 -3.4925 3.4925 -24.0415 -17.0565 $ air space in al
48   1 rpp -106.68 -91.44 -11.43 11.43 -24.994 -24.359 $ al end plate
62   1 rpp 91.44 106.68 -11.43 11.43 -24.994 -24.359 $ al end plate
49   1 rpp -106.68 106.68 3.81 6.35 -20.549 -16.739 $ mini scale support
50   1 rpp -106.68 106.68 4.445 6.35 -20.549 -17.347
51   1 rpp -1.524 2.921 6.35 7.3025 -22.7715 -12.6115 $ reading head mount
52   1 rpp 42.38 57.62 -8.89 8.89 -12.6115 -11.3415 $ inst platform
53   1 rpp 43.3325 56.6675 -7.9375 7.9375 -11.9765 -11.3415 $ air space in in
c
c SURFACES FOR LPS GUIDE ON SOURCE PLATFORM
c
54   1 rpp -8.509 2.921 -5.715 5.715 -13.8815 -12.6115
55   1 rpp -8.509 2.921 -0.9525 0.9525 -15.1515 -13.8815
56   1 rpp -8.509 2.921 -5.715 -3.4925 -15.7865 -12.6115
57   1 rpp -8.509 2.921 3.4925 5.715 -15.7865 -12.6115
c
c SURFACES FOR LPS GUIDE ON SOURCE PLATFORM
c
58   1 rpp 44.285 55.715 -5.715 5.715 -13.8815 -12.6115
59   1 rpp 44.285 55.715 -0.9525 0.9525 -15.1515 -13.8815
60   1 rpp 44.285 55.715 -5.715 -3.4925 -15.7865 -12.6115
61   1 rpp 44.285 55.715 3.4925 5.715 -15.7865 -12.6115
C
c SURFACES FOR CONCRETE FLOOR
c
100  px -1493.52
101  px 487.68
102  py -533.4
103  py 533.4
104  pz -157.48
105  pz -137.16
c
c SURFACES FOR AIR SPACE IN ROOM AND STEEL WALLS
c
106  rpp -1493.52 487.68 -533.4 533.4 -137.16 350.52
107  rpp -1493.42 487.58 -533.3 533.3 -137.16 350.42
c
c SURFACES FOR PIT
c
108  sz -76.2 365.76
109  sz -76.2 396.24
c
c SURFACES FOR PIT I-BEAMS AND SUPPORTS
c
110  py -3.81
111  py 3.81
112  py -0.3175
113  py 0.3175
114  pz -152.4
115  pz -142.24
116  pz -142.875
117  pz -151.765
c
```

```
118  py -125.73
119  py -118.11
120  py -122.2375
121  py -121.6025
c
122  py -247.65
123  py -240.03
124  py -244.1575
125  py -243.5225
c
126  py 118.11
127  py 125.73
128  py 121.6025
129  py 122.2375
c
130  py 240.03
131  py 247.65
132  py 243.5225
133  py 244.1575
c
134  px -116.84
135  px -127.0
136  px -121.6025
137  px -122.2375
c
138  px 127
139  px 116.84
140  px 122.2375
141  px 121.6025
c
142  rpp -125.73 -118.11 -3.81 3.81 -500 -152.4
143  rpp -125.4125 -118.4275 -3.4925 3.4925 -500 -152.4
144  rpp 118.11 125.73 -3.81 3.81 -500 -152.4
145  rpp 118.4275 125.4125 -3.4925 3.4925 -500 -152.4
146  rpp -125.73 -118.11 -125.73 -118.11 -500 -152.4
147  rpp -125.4125 -118.4275 -125.4125 -118.4275 -500 -152.4
148  rpp -125.73 -118.11 -247.65 -240.03 -500 -152.4
149  rpp -125.4125 -118.4275 -247.3325 -240.3475 -500 -152.4
150  rpp -125.73 -118.11 118.11 125.73 -500 -152.4
151  rpp -125.4125 -118.4275 118.4275 125.4125 -500 -152.4
152  rpp -125.73 -118.11 240.03 247.65 -500 -152.4
153  rpp -125.4125 -118.4275 240.3475 247.3325 -500 -152.4
c
154  rpp 118.11 125.73 -125.73 -118.11 -500 -152.4
155  rpp 118.4275 125.4125 -125.4125 -118.4275 -500 -152.4
156  rpp 118.11 125.73 -247.65 -240.03 -500 -152.4
157  rpp 118.4275 125.4125 -247.3325 -240.3475 -500 -152.4
158  rpp 118.11 125.73 118.11 125.73 -500 -152.4
159  rpp 118.4275 125.4125 118.4275 125.4125 -500 -152.4
160  rpp 118.11 125.73 240.03 247.65 -500 -152.4
161  rpp 118.4275 125.4125 240.3475 247.3325 -500 -152.4
c
c
c SURFACE FOR CONCRETE SHIELD WALL NEXT TO GAMMA WELLS
c
162  rpp -716.28 -670.56 -487.68 35.56 -137.16 106.68
c
```

```
c SURFACES FOR GROUND AND AIR SPACE OUTSIDE BUILDING
c
1000 cz 1600
1001 pz 1600
1002 pz -187.96
1003 sz -76.2 426.72

mode n
c
*tr1 0 0 0 60 150 90 30 60 90 90 90 0
c
c
c xxxxxxxxxxxxxxxx SOURCE DEFINITION xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
sdef par=1 erg=d3 pos 0 0 0 rad=d1 axs=0 0 1 ext=d2
si1  h 0 1.03124
sp1  -21 1
si2  h -1.0795 1.40208
sp2  -21 0
c ISO 8529:1989 Am-241/Be source fluence per unit linear energy bin
si3  h 4.14e-7 0.11 0.33 0.54 0.75 0.97 1.18 1.4 1.61 1.82 2.04 2.25
     2.47 2.68 2.9 3.11 3.32 3.54 3.75 3.97 4.18 4.39 4.61 4.82 5.04
     5.25 5.47 5.68 5.89 6.11 6.32 6.54 6.75 6.96 7.18 7.39 7.61 7.82
     8.03 8.25 8.46 8.68 8.89 9.11 9.32 9.53 9.75 9.96 10.18 10.39 10.6
     10.82 11.03 11.09
sp3  d 0 1.436e-2 3.340e-2 3.127e-2 2.812e-2 2.5e-2 2.136e-2 1.983e-2
     1.747e-2 1.925e-2 2.225e-2 2.146e-2 2.248e-2 2.277e-2 2.951e-2
     3.559e-2 3.685e-2 3.458e-2 3.066e-2 2.999e-2 2.691e-2 2.863e-2
     3.178e-2 3.074e-2 3.334e-2 3.041e-2 2.738e-2 2.332e-2 2.059e-2
     1.815e-2 1.767e-2 2.039e-2 1.83e-2 1.63e-2 1.677e-2 1.681e-2
     1.883e-2 1.837e-2 1.688e-2 1.435e-2 9.677e-3 6.521e-3 4.255e-3
     3.667e-3 3.806e-3 5.058e-3 6.253e-3 5.519e-3 4.675e-3 3.696e-3
     2.781e-3 1.514e-3 3.633e-4 0
c
c xxxxxxxxxxxxxxxx TALLY CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
f5:n 0 -100 0 20.0 $ tally is centered on the rabbit
fc5  mrem/hr per n/s @ 0-deg off y-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de5  2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df5  3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f15:n 0 -100 0 20.0
fc15 ROSPEC Energy Bin Structure @ 0-deg off y-axis
e15  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
c
```

```
f205:n  0 -100 0 20 $ tally is centered on the rabbit
fc205   mrem/hr per n/s
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de205  1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
     5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
     0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
     2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df205  2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
     4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
     3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
     3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
     4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
     1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
     1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
     1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
     1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
     9.3600E-02
c
c
f25:n -25.8819 -96.5926 0 20.0 $ tally is centered on the rabbit
fc25 mrem/hr per n/s @ 15-deg off y-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de25 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df25 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f35:n -25.8819 -96.5926 0 20.0
fc35 ROSPEC Energy Bin Structure @ 15-deg off y-axis
e35  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
c
f225:n  -25.8819 -96.5926 0 20 $ tally is centered on the rabbit
fc225   mrem/hr per n/s @ 15-Deg off y axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de225  1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
     5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
     0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
     2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df225  2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
     4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
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     3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
     3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
     4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
     1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
     1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
     1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
     1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
     9.3600E-02
c
c
f45:n -50 -86.6025 0 20.0 $ tally is centered on the rabbit
fc45 mrem/hr per n/s @ 30-deg off y-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de45 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df45 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f55:n -50 -86.6025 0 20.0
fc55 ROSPEC Energy Bin Structure @ 30-deg off y-axis
e55  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
c
f245:n  -50 -86.6025 0 20 $ tally is centered on the rabbit
fc245   mrem/hr per n/s @ 30-Deg off y-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de245  1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
     5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
     0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
     2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df245  2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
     4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
     3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
     3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
     4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
     1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
     1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
     1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
     1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
     9.3600E-02
c
c
f65:n -96.5926 -25.8819 0 20.0 $ tally is centered on the rabbit
fc65 mrem/hr per n/s @ -15-deg off x-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
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c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de65 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df65 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f75:n -96.5926 -25.8819 0 20.0
fc75 ROSPEC Energy Bin Structure @ -15-deg off x-axis
e75  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
c
f265:n  0 -100 0 20 $ tally is centered on the rabbit
fc265   mrem/hr per n/s @ -15-deg of x-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de265  1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
     5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
     0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
     2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df265  2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
     4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
     3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
     3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
     4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
     1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
     1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
     1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
     1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
     9.3600E-02
c
c
f85:n -100 0 0 20.0 $ tally is centered on the rabbit
fc85 mrem/hr per n/s @ 0-deg off x-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de85 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df85 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
     9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f95:n -100 0 0 20.0
fc95 ROSPEC Energy Bin Structure @ 0-deg off x-axis
e95  .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
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     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
c
f285:n  -100 0 0 20 $ tally is centered on the rabbit
fc285   mrem/hr per n/s @ 0=deg off x-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de285  1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
     5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
     0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
     2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df285  2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
     4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
     3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
     3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
     4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
     1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
     1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
     1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
     1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
     9.3600E-02
c
c
f105:n -96.5926 25.8819 0 20.0 $ tally is centered on the rabbit
fc105 mrem/hr per n/s @ 15-deg off x-axis
c    NCRP-38 neutron flux-to-dose rate conversion factor
c    units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
de105 2.5e-8 1e-7 1e-6 1e-5 1e-4 1e-3 1e-2 0.1 0.5 1 2.5 5 7 10 14 20
df105 3.676e-3 3.676e-3 4.464e-3 4.464e-3 4.309e-3 3.676e-3 3.572e-3 2.174e-2
      9.259e-2 0.1315 0.125 0.156 0.147 0.147 0.208 0.227
f115:n -96.5926 -25.8819 0 20.0
fc115 ROSPEC Energy Bin Structure @ 15-deg off x-axis
e115 .1000E-05 .1000E-01 .5346E-01 .6156E-01 .6966E-01 .7911E-01 .8991E-01
     .1021E+00 .1156E+00 .1318E+00 .1493E+00 .1709E+00 .1939E+00 .2195E+00
     .2609E+00 .2896E+00 .3223E+00 .3591E+00 .4000E+00 .4409E+00 .4941E+00
     .5472E+00 .6086E+00 .6740E+00 .7954E+00 .8845E+00 .9817E+00 .1095E+01
     .1217E+01 .1346E+01 .1535E+01 .1739E+01 .1969E+01 .2249E+01 .2555E+01
     .2912E+01 .3295E+01 .3754E+01 .4264E+01 .4850E+01 .5690E+01 .6031E+01
     .6367E+01 .6699E+01 .7029E+01 .7354E+01 .7676E+01 .7995E+01 .8312E+01
     .8622E+01 .8929E+01 .9236E+01 .9542E+01 .9846E+01 .1015E+02 .1045E+02
     .1076E+02 .1106E+02 .1136E+02 .1166E+02 .1195E+02 .1225E+02 .1255E+02
     .1284E+02 .1314E+02 .1343E+02 .1372E+02 .1401E+02 .1430E+02 .1459E+02
c
c
f305:n  -96.5926 25.8819 0 20 $ tally is centered on the rabbit
fc305   mrem/hr per n/s @ 15 deg off x-axis
c       H*(10) neutron flux-to-dose rate conversion factor
c       units: mrem/hr per n/cm^2sec = (pSvcm^2/sec)(3.6e-4)
c
de305  1.00E-09 1.00E-08 2.53E-08 1.00E-07 2.00E-07 5.00E-07 1.00E-06 2.00E-
06
     5.00E-06 1.00E-05 2.00E-05 5.00E-05 1.00E-04 2.00E-04 5.00E-04 1.00E-03
```

```
     0.002 0.005 0.01 0.02 0.03 0.05 0.07 0.1 0.15 0.2 0.3 0.5 0.7 0.9 1 1.2
     2 3 4 5 6 7 8 9 10 12 14 15 16 18 20 30 50 75 100 125 150 175 201
c
df305  2.3760E-03 3.2400E-03 3.8160E-03 4.6440E-03 4.8600E-03 4.8960E-03
     4.7880E-03 4.6440E-03 4.3200E-03 4.0680E-03 3.8160E-03 3.5640E-03
     3.3840E-03 3.2040E-03 2.9880E-03 2.8440E-03 2.7720E-03 2.8800E-03
     3.7800E-03 5.9760E-03 8.5320E-03 1.4796E-02 2.1600E-02 3.1680E-02
     4.7520E-02 6.1200E-02 8.3880E-02 1.1592E-01 1.3500E-01 1.4400E-01
     1.4976E-01 1.5300E-01 1.5120E-01 1.4832E-01 1.4688E-01 1.4580E-01
     1.4400E-01 1.4580E-01 1.4724E-01 1.5120E-01 1.5840E-01 1.7280E-01
     1.8720E-01 1.9440E-01 1.9440E-01 2.0520E-01 2.1600E-01 1.8540E-01
     1.4400E-01 1.1880E-01 1.0260E-01 9.3600E-02 8.8200E-02 9.0000E-02
     9.3600E-02
c
c
c xxxxxxxxxxxxxxxx MATERIAL CARDS xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
c
c Air with 15 g/m3 water vapor
m1   1001.60c -0.0056 7014.60c -0.7447 8016.60c -0.24096 18000.35c -0.012823
c
c ANSI/ANS 6.6.1-1987 Concrete Composition den-2.3
m2   1001.60c 7.86e+21 8016.60c 4.38e+22 11023.60c 1.05e+21
     12000.60c 1.40e+20 13027.60c 2.39e+21 14000.60c 1.58e+22
     19000.60c 6.90e+20 20000.60c 2.92e+21 26000.55c 3.10e+20
c
c 304 Stainless Steel @ den-7.92
m3   26000.55c -0.695 24000.50c -0.190 28000.50c -0.095 25055.60c -0.020
c
m4   13027.60c 1 $ aluminum den 2.7 g/cm3
c
m7   26000.55c 1 $ iron - 8.0 g/cm^3
m8   1001.60c 9.77e+21 8016.60c 3.48e+22 13027.60c 4.88e+21
     14000.60c 1.16e+22 $ ground @ 1.7 g/cm3
m9   29000.50c -0.97 82000.50c -0.03 $ 360 brass @ 8.3656 g/cm3
c Modified ANSI/ANS 6.6.1-1987 Concrete Composition - den-2.3569 g/cc
c 0.75% by wt Boron additive
m10  1001.60c -0.0056 5010.60c -1.4925E-3 5011.60c -6.0075E-3
     8016.60c -0.4973 11023.60c -0.0171 12000.60c -0.0024
     13027.60c -0.0458 14000.60c -0.315 19000.60c -0.0191
     20000.60c -0.0831 26000.50c -0.0123
c
m11  4009.50c 1 $ Be at an effective density of 0.9 g/cc
prdmp 1j -180 0 2
ctme 900
```

APPENDIX G: NCRP-38 AND ICRP-74 FLUX-TO-DOSE EQUIVALENT RATE CONVERSION FACTORS

Energy (MeV)	NCRP-38[†] Factors	ICRP-74[†] Factors
1.00E-09		0.002376
1.00E-08		0.00324
2.50E-08	0.003676	0.003816
1.00E-07	0.003676	0.004644
2.00E-07		0.00486
5.00E-07		0.0048960
1.00E-06	0.004464	0.004788
2.00E-06		0.004644
5.00E-06		0.00432
1.00E-05	0.004464	0.004068
2.00E-05		0.003816
5.00E-05		0.003564
1.00E-04	0.004309	0.003384
2.00E-04		0.003204
5.00E-04		0.002988
1.00E-03	0.003676	0.002844
2.00E-03		0.002772
5.00E-03		0.00288
1.00E-02	0.003572	0.00378
2.00E-02		0.005976
3.00E-02		0.008532
5.00E-02		0.014796
7.00E-02		0.02160
1.00E-01	0.02174	0.03168
1.50E-01		0.04752
2.00E-01		0.06120
3.00E-01		0.08388
5.00E-01	0.09259	0.11592
7.00E-01		0.13500
9.00E-01		0.14400

Energy (MeV)	**NCRP-38[†] Factors**	**ICRP-74[†] Factors**
1.00E+00	0.13150	0.14976
1.20E+00		0.15300
2.00E+00		0.15120
2.50E+00	0.12500	
3.00E+00		0.14832
4.00E+00		0.14688
5.00E+00	0.15600	0.14580
6.00E+00		0.14400
7.00E+00	0.14700	0.14580
8.00E+00		0.14724
9.00E+00		0.15120
1.00E+01	0.14700	0.15840
1.20E+01		0.17280
1.40E+01	0.20800	0.18720
1.50E+01		0.19440
1.60E+01		0.19440
1.80E+01		0.20520
2.00E+01	0.22700	0.21600
3.00E+01		0.18540
5.00E+01		0.14400
7.50E+01		0.11880
1.00E+02		0.10260
1.25E+02		0.09360
1.50E+02		0.08820
1.75E+02		0.09000
2.01E+02		0.09360

† Units are mrem/hr per n/cm^2 s

APPENDIX H: SUMMARY OF CALCULATIONS AND SOURCE DESCRIPTIONS

Flux-to-Dose Equivalent Rate Conversion Factor: F

Source	Input File Used	Quantity Calculated	Subsequent Calculation	Result: F
Bare ^{252}Cf	CFFD.i, Appendix A	Uncollided, or Direct, Dose Equivalent Rate (mrem/hr) @ 50 cm from a point source, per source neutron per second. NCRP-38 = 3.08341 E-06 ICRP-74 = 4.3909 E-06	Divide uncollided dose rate by flux value @ 50 cm distance from source =. $(1 \text{ n/s})/(4\pi r^2)$ = $1/(4 *\pi *[50^2])$	NCRP-38 = 0.120 mrem/hr per n/cm^2 s ICRP-74 = 0.138 mrem/hr per n/cm^2 s
Bare ^{238}PuBe	PBFD.i Appendix B	Uncollided, or Direct, Dose Equivalent Rate (mrem/hr) @ 50 cm from a point source, per source neutron per second. NCRP-38 = 4.2671 E-06 ICRP-74 = 4.4950 E-06	Divide uncollided dose rate by flux value @ 50 cm distance from source =. $(1 \text{ n/s})/(4\pi r^2)$ = $1/(4 *\pi *[50^2])$	NCRP-38 = 0.134 mrem/hr per n/cm^2 s ICRP-74 = 0.141 mrem/hr per n/cm^2 s

Anisotropy Factor: A

<table>
<tr><th>Source</th><th>Input File Used</th><th>Quantity Calculated</th><th>Subsequent Calculation</th><th>Result: A</th></tr>
<tr>
<td>Bare ^{252}Cf</td>
<td>74CF, Appendix C</td>
<td>Uncollided, or Direct, Dose Equivalent Rate (mrem/hr) @ 100 cm from a modeled source, per source neutron per second. See Figure G-1
<table>
<tr><th></th><th>Modeled Source Value†</th><th>Point Source Value†</th></tr>
<tr><td>NCRP-38</td><td>0.9781 E-06</td><td>0.9585 E-06</td></tr>
<tr><td>ICRP-74</td><td>1.1230 E-06</td><td>1.0977 E-06</td></tr>
</table>
† mrem/hr per source neutron/s</td>
<td>Divide uncollided dose rate from modeled source by uncollided dose rate from point source.</td>
<td>NCRP-38 = 1.020
ICRP-74 = 1.023</td>
</tr>
<tr>
<td>Bare $^{238}PuBe$</td>
<td>74Pb Appendix D</td>
<td>Uncollided, or Direct, Dose Equivalent Rate (mrem/hr) @ 100 cm from a modeled source, per source neutron per second. See Figure G-1
<table>
<tr><th></th><th>Modeled Source Value†</th><th>Point Source Value†</th></tr>
<tr><td>NCRP-38</td><td>1.1086 E-06</td><td>1.0668 E-06</td></tr>
<tr><td>ICRP-74</td><td>1.1816 E-06</td><td>1.1238 E-06</td></tr>
</table>
† mrem/hr per source neutron/s</td>
<td>Divide uncollided dose rate from modeled source by uncollided dose rate from point source.</td>
<td>NCRP-38 = 1.039
ICRP-74 = 1.051</td>
</tr>
</table>

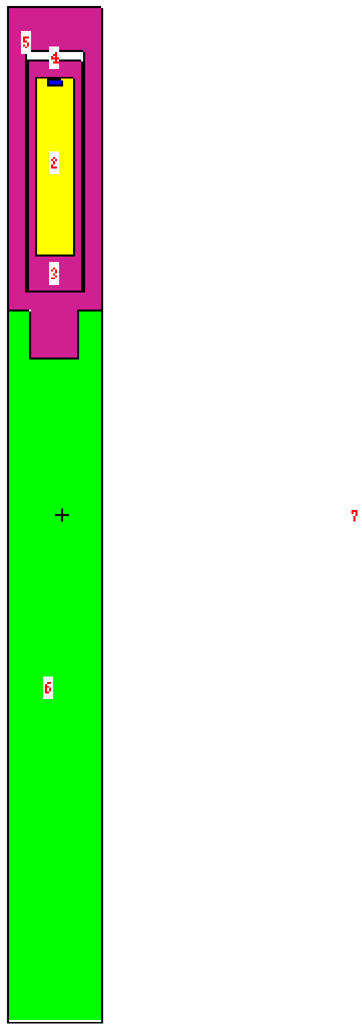

Figure H-1: Bare ^{252}Cf source, as modeled in Appendix C. The numbers appearing in this picture are cell numbers in the program. See Appendix C for a listing of cell materials.

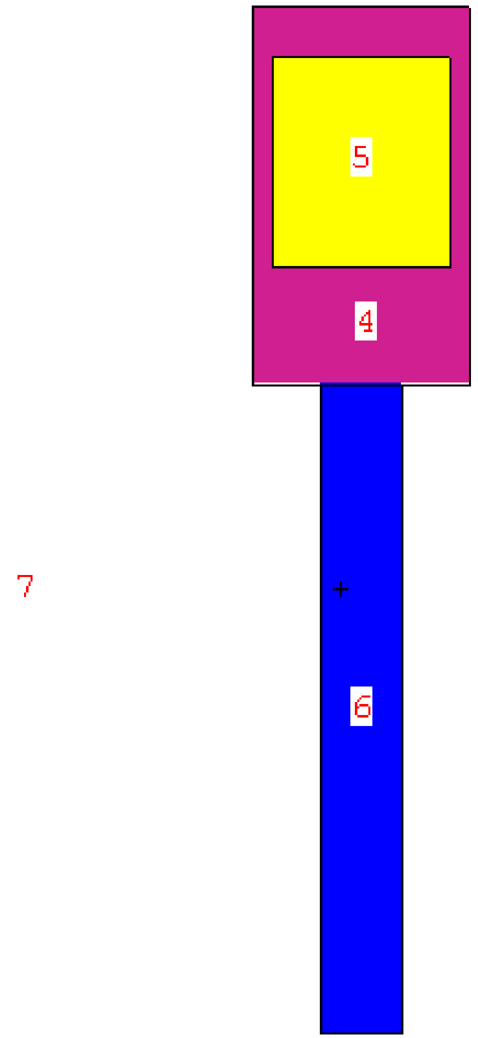

Figure H-2: Bare ^{238}PuBe source, as modeled in Appendix D. The numbers appearing in this picture are cell numbers in the program. See Appendix D for a listing of cell materials.

Scatter Factor: S

Source	Input File Used	Quantity Calculated	Subsequent Calculation	Result: S
Bare ^{252}Cf	XRCF, Appendix E	Total (Direct plus collided), Dose Equivalent Rate (mrem/hr) @ 100 cm from a modeled source, per source neutron per second. Includes all room return effects.	Divide Total Dose Equivalent Rate by the Anisotropy Factor. Then divide result by the Direct Point Source Dose Equivalent Rate.	NCRP-38 = 1.088 ICRP-74 = 1.092

	Total Dose Equivalent Rate†	Anisotropy Factor	Point Source Dose Rate [Appendix A]†
NCRP-38	1.0642 E-06	1.020	0.9585 E-06
ICRP-74	1.2264 E-06	1.023	1.0977 E-06

† mrem/hr per source neutron/s

Source	Input File Used	Quantity Calculated	Subsequent Calculation	Result: S
Bare $^{238}PuBe$	DRPb Appendix F	Total (direct plus collided) Dose Equivalent Rate (mrem/hr) @ 100 cm from a modeled source, per source neutron per second. Includes all room return effects.	Divide Total Dose Equivalent Rate by the Anisotropy Factor. Then divide result by the Direct Point Source Dose Equivalent Rate.	NCRP-38 = 1.072 ICRP-74 = 1.078

	Total Dose Equivalent Rate†	Anisotropy Factor	Point Source Dose Rate [Appendix A]†
NCRP-38	1.1880 E-06	1.039	1.0668 E-06
ICRP-74	1.2737 E-06	1.051	1.1238 E-06

† mrem/hr per source neutron/s

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