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SHIELD DESIGN FOR ROVER PROCESSING FACILITY

E. D. Arnold

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ABSTRACT

Design calculations have been performed using the IBM-7090 computer for the shielding requirements for the Rover Processing Facility. Shield thicknesses have been found to vary between 18 inches and four feet of ordinary concrete depending on the decay time and the equipment being shielded.

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Necessary shield thicknesses have been calculated for the Rover Processing Facility by the SDC code on the IBM-7090. These thicknesses were calculated for an irradiation time of 3000 seconds at 1000 Mw total power in 200 kg U-235 and for decay times of 90, 180, 360, 720 days. Source strengths were determined for a single irradiation of 3000 seconds using the PHOEBE code for fission product activities. Since the probable irradiation history will be 50 seconds at power followed by a seven-day shutdown period for a total of 10 such cycles, the calculated source strengths are about a factor of 1.5 to 2 high for the decay times considered. The actual calculation was attempted using the PHOEBE code but the answers appeared to oscillate rather than decrease with increasing decay time. The code failed to produce reasonable results for the actual case because the ratio of power time to down time was very small for each cycle.

Shield thicknesses were determined for the following cases:*

(a) A 12' x 2' x 4" slab dissolver containing 90 kgs U-235. Since this dissolver is a finite slab, two different cylinder sizes were used to approximate this case. (See result sheets.)

(b) A 12' x 7" diameter cylindrical dissolver containing 18.7 kgs U-235.

(c) A 12' x 7" diameter solvent extraction column (vol = 93.5 liters) containing 4 gms U-235 per liter.

(d) A critically safe storage cell for 200 kg U-235 stored in 100 cans spaced on 2 foot centers. Each can contains 2 kgs U-235.

The results of these calculations are as follows:

Thickness of Ordinary Concrete Required to Reduce Dose Rate to 1.0 mrad/hr at the Outside Shield Surface

Source	Thickness in Inches for a Decay Time of			
	90 days	180 days	360 days	720 days
Slab Dissolver	47	41	37	33
Cylindrical Dissolver	44	39	34	30
Extraction Column	30	26	22	17
Storage Cell	44	38	34	29

Pages 3 through 26 are copies of the output sheets from the SDC code. These sheets give the source strengths for each of nine energy groups and each group's contribution to the total gamma flux and dose rate at the outside shield surface. There are four pages for each case. These pages correspond, in order, to decay times of 90, 180, 360, 720 days, respectively.

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* In all cases the source was placed 60 cm from the inside face of the shield

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 118.802 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.667 MEV, DOSE AVERAGED ENERGY - 2.324 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 226000.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 14.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.2650E 14	0.300	1.3495E-06	0.000
2	2.5850E 14	0.630	1.2608E-02	0.002
3	8.7500E 13	1.100	1.2063E 00	0.097
4	1.5240E 13	1.550	2.5977E 00	0.168
5	7.8500E 11	1.990	1.5835E 00	0.070
6	1.7600E 12	2.380	9.4711E 00	0.384
7	1.8330E 11	2.750	2.4332E 00	0.088
8	8.9500E 10	3.250	3.0879E 00	0.099
9	4.7100E 10	3.700	3.0200E 00	0.091
TOTALS	4.9060E 14		2.3412E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 103.764 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.664 MEV, DOSE AVERAGED ENERGY - 1.965 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 226000.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 14.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	4.0400E 13	0.300	2.2242E-05	0.000
2	1.0250E 14	0.630	9.4830E-02	0.012
3	3.6500E 13	1.100	4.8927E 00	0.321
4	1.5750E 12	1.550	1.9408E 00	0.106
5	1.6900E 11	1.990	1.8528E 00	0.070
6	3.4550E 11	2.380	8.9674E 00	0.314
7	4.3150E 10	2.750	2.4864E 00	0.078
8	1.4550E 10	3.250	1.9500E 00	0.055
9	6.9400E 09	3.700	1.6086E 00	0.043
TOTALS	1.8155E 14		2.3794E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 92.206 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.642 MEV, DOSE AVERAGED ENERGY - 1.820 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 226000.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 14.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.2470E 13	0.300	1.4384E-04	0.000
2	2.2050E 13	0.630	1.9801E-01	0.021
3	8.3900E 12	1.100	6.5299E 00	0.366
4	4.4100E 11	1.550	2.5120E 00	0.117
5	5.1900E 10	1.990	2.0946E 00	0.070
6	1.0420E 11	2.380	9.1576E 00	0.283
7	2.3500E 10	2.750	4.2283E 00	0.118
8	1.7470E 09	3.250	6.7117E-01	0.017
9	5.3700E 08	3.700	3.3759E-01	0.008
TOTALS	4.3553E 13		2.5729E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 81.052 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.566 MEV, DOSE AVERAGED ENERGY - 2.002 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 226000.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 14.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	3.7850E 12	0.300	8.3145E-04	0.000
2	4.3400E 12	0.630	3.5314E-01	0.028
3	7.3500E 11	1.100	3.1562E 00	0.148
4	1.9050E 11	1.550	4.8043E 00	0.188
5	2.4550E 10	1.990	3.5365E 00	0.102
6	4.9600E 10	2.380	1.4288E 01	0.386
7	1.0770E 10	2.750	5.8733E 00	0.144
8	1.3950E 08	3.250	1.4955E-01	0.003
9	7.6900E 06	3.700	1.2788E-02	0.000
TOTALS	9.1356E 12		3.2174E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 120.217 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.667 MEV, DOSE AVERAGED ENERGY - 2.326 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 89300.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 8.8 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.2650E 14	0.300	1.2432E-06	0.000
2	2.5850E 14	0.630	1.2054E-02	0.002
3	8.7500E 13	1.100	1.1754E 00	0.097
4	1.5240E 13	1.550	2.5490E 00	0.167
5	7.8500E 11	1.990	1.5633E 00	0.070
6	1.7600E 12	2.380	9.3664E 00	0.385
7	1.8350E 11	2.750	2.4097E 00	0.088
8	8.9500E 10	3.250	3.0619E 00	0.099
9	4.7100E 10	3.700	2.9962E 00	0.092
TOTALS	4.9060E 14		2.3134E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 105.173 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.664 MEV, DOSE AVERAGED ENERGY - 1.969 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 89300.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 8.8 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	4.0400E 13	0.300	2.0531E-05	0.000
2	1.0250E 14	0.630	9.0808E-02	0.012
3	3.6500E 13	1.100	4.7744E 00	0.319
4	1.5750E 12	1.550	1.9069E 00	0.106
5	1.6980E 11	1.990	1.8315E 00	0.071
6	3.4550E 11	2.380	8.8792E 00	0.315
7	4.3150E 10	2.750	2.4655E 00	0.079
8	1.4550E 10	3.250	1.9359E 00	0.055
9	6.9400E 09	3.700	1.5977E 00	0.043
TOTALS	1.8155E 14		2.3482E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 93.633 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.642 MEV, DOSE AVERAGED ENERGY - 1.824 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 89300.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 8.8 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.2470E 13	0.300	1.3215E-04	0.000
2	2.2050E 13	0.630	1.8897E-01	0.020
3	8.3900E 12	1.100	6.3563E 00	0.364
4	4.4100E 11	1.550	2.4632E 00	0.117
5	5.1900E 10	1.990	2.0670E 00	0.070
6	1.0420E 11	2.380	9.0539E 00	0.285
7	2.3500E 10	2.750	4.1869E 00	0.119
8	1.7470E 09	3.250	6.6549E-01	0.017
9	5.3700E 08	3.700	3.3494E-01	0.008
TOTALS	4.3533E 13		2.5317E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SLAB DISSOLVER CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 82.526 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.566 MEV, DOSE AVERAGED ENERGY - 2.005 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 89300.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 8.8 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	3.7850E 12	0.300	7.5468E-04	0.000
2	4.3400E 12	0.630	3.3404E-01	0.028
3	7.3500E 11	1.100	3.0517E 00	0.146
4	1.9050E 11	1.550	4.6838E 00	0.188
5	2.4550E 10	1.990	3.4732E 00	0.102
6	4.9600E 10	2.380	1.4063E 01	0.387
7	1.0770E 10	2.750	5.7919E 00	0.145
8	1.3950E 08	3.250	1.4773E-01	0.003
9	7.6900E 06	3.700	1.2643E-02	0.000
TOTALS	9.1356E 12		3.1559E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - CYLINDRICAL DISSOLVER
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 111.809 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.668 MEV, DOSE AVERAGED ENERGY - 2.214 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ.CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	5.2100E 13	0.300	4.9292E-06	0.000
2	1.0650E 14	0.630	2.6943E-02	0.004
3	3.6100E 13	1.100	1.7922E 00	0.132
4	6.2900E 12	1.550	3.2783E 00	0.196
5	3.2400E 11	1.990	1.7013E 00	0.070
6	7.2700E 11	2.380	9.5478E 00	0.363
7	7.5600E 10	2.750	2.3079E 00	0.078
8	3.6900E 10	3.250	2.7490E 00	0.083
9	1.9450E 10	3.700	2.5844E 00	0.074
TOTALS	2.0217E 14		2.3988E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - CYLINDRICAL DISSOLVER
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 97.831 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.670 MEV, DOSE AVERAGED ENERGY - 1.818 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.6630E 13	0.300	6.1992E-05	0.000
2	4.2300E 13	0.630	1.6630E-01	0.019
3	1.6030E 13	1.100	6.6445E 00	0.404
4	6.4900E 11	1.550	2.1439E 00	0.108
5	7.0050E 10	1.990	1.7804E 00	0.063
6	1.4230E 11	2.380	8.1304E 00	0.268
7	1.7800E 10	2.750	2.1434E 00	0.064
8	6.0000E 09	3.250	1.5901E 00	0.042
9	2.8600E 09	3.700	1.2643E 00	0.032
TOTALS	7.5848E 13		2.3863E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - CYLINDRICAL DISSOLVER
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 86.266 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.642 MEV, DOSE AVERAGED ENERGY - 1.706 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	5.1450E 12	0.300	4.0551E-04	0.000
2	9.0900E 12	0.630	3.4988E-01	0.032
3	3.4600E 12	1.100	8.3966E 00	0.429
4	1.8100E 11	1.550	2.7989E 00	0.119
5	2.1400E 10	1.990	2.0277E 00	0.063
6	4.3000E 10	2.380	8.3845E 00	0.242
7	9.6800E 09	2.750	3.6680E 00	0.096
8	7.2000E 08	3.250	5.5116E-01	0.013
9	2.2200E 08	3.700	2.6820E-01	0.006
TOTALS	1.7952E 13		2.6445E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - CYLINDRICAL DISSOLVER
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 74.643 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.566 MEV, DOSE AVERAGED ENERGY - 1.902 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.5630E 12	0.300	2.6809E-03	0.000
2	1.7690E 12	0.630	6.9102E-01	0.049
3	3.0300E 11	1.100	4.3999E 00	0.182
4	7.8520E 10	1.550	5.7504E 00	0.204
5	1.0120E 10	1.990	3.6438E 00	0.096
6	2.0470E 10	2.380	1.3877E 01	0.343
7	4.4400E 09	2.750	5.3907E 00	0.122
8	5.7600E 07	3.250	1.2961E-01	0.003
9	3.1750E 06	3.700	1.0663E-02	0.000
TOTALS	3.7686E 12		3.3896E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SOLVENT EXTRACTION COL.
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 76.740 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.668 MEV, DOSE AVERAGED ENERGY - 1.694 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.0420E 12	0.300	1.1101E-03	0.000
2	2.1300E 12	0.630	5.7714E-01	0.043
3	7.2200E 11	1.100	7.9666E 00	0.344
4	1.2560E 11	1.550	7.2509E 00	0.266
5	6.4800E 09	1.990	1.9002E 00	0.052
6	1.4540E 10	2.380	8.1357E 00	0.207
7	1.5120E 09	2.750	1.5338E 00	0.036
8	7.3800E 08	3.250	1.4054E 00	0.030
9	3.8900E 08	3.700	1.1148E 00	0.023
TOTALS	4.0435E 12		2.9886E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SOLVENT EXTRACTION COL.
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 66.362 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.670 MEV, DOSE AVERAGED ENERGY - 1.337 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	3.3260E 11	0.300	5.6064E-03	0.001
2	8.4600E 11	0.630	1.8167E 00	0.106
3	3.2060E 11	1.100	1.7665E 01	0.621
4	1.2960E 10	1.550	3.0433E 00	0.093
5	1.4010E 09	1.990	1.3672E 00	0.032
6	2.8460E 09	2.380	4.8946E 00	0.108
7	3.5600E 08	2.750	1.0318E 00	0.021
8	1.2000E 08	3.250	6.0446E-01	0.011
9	5.7200E 07	3.700	4.1247E-01	0.008
TOTALS	1.5170E 12		3.0841E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SOLVENT EXTRACTION COL.
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 55.283 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.642 MEV, DOSE AVERAGED ENERGY - 1.276 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	1.0290E 11	0.300	3.3658E-02	0.002
2	1.8160E 11	0.630	3.6201E 00	0.150
3	6.9200E 10	1.100	2.1582E 01	0.596
4	3.6360E 09	1.550	3.8758E 00	0.095
5	4.2800E 08	1.990	1.5320E 00	0.030
6	8.6000E 08	2.380	4.9827E 00	0.092
7	1.9360E 08	2.750	1.7483E 00	0.030
8	1.4400E 07	3.250	2.0809E-01	0.003
9	4.4400E 06	3.700	8.7069E-02	0.001
TOTALS	3.5904E 11		3.7670E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 6 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - SOLVENT EXTRACTION COL.
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 42.292 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.566 MEV, DOSE AVERAGED ENERGY - 1.350 MEV

CYL. VOL. SOURCE, SHIELD AT SIDE, DOSE POINT 2, VOLUME - 93500.0 CC
H1 -183.0 CM, H2 -183.0 CM, TOTAL H -366.0 CM, RADIUS - 9.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	3.1260E 10	0.300	3.4140E-01	0.012
2	3.5780E 10	0.630	9.9987E 00	0.270
3	6.0600E 09	1.100	1.4854E 01	0.293
4	1.5700E 09	1.550	1.0166E 01	0.185
5	2.0240E 08	1.990	3.4188E 00	0.051
6	4.0940E 08	2.380	1.0127E 01	0.146
7	8.8800E 07	2.750	3.1226E 00	0.043
8	1.1520E 06	3.250	5.8816E-02	0.001
9	6.3500E 04	3.700	4.1307E-03	0.000
TOTALS	7.5372E 10		5.2091E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 3 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 106.376 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.667 MEV, DOSE AVERAGED ENERGY - 2.142 MEV

DISK SOURCE, RADIUS- 485.0 CM, DISP- 0. CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	2.7900E 14	0.300	1.4604E-05	0.000
2	5.7020E 14	0.630	4.7243E-02	0.006
3	1.9310E 14	1.100	2.3237E 00	0.158
4	3.3630E 13	1.550	3.7727E 00	0.212
5	1.7340E 12	1.990	1.7647E 00	0.069
6	3.8870E 12	2.380	9.5363E 00	0.343
7	4.0490E 11	2.750	2.2382E 00	0.072
8	1.9750E 11	3.250	2.5867E 00	0.075
9	1.0410E 11	3.700	2.3908E 00	0.065
TOTALS	1.0823E 15		2.4660E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 3 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 92.644 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.665 MEV, DOSE AVERAGED ENERGY - 1.745 MEV

DISK SOURCE, RADIUS- 485.0 CM, DISP- 0. CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	8.9040E 13	0.300	1.7076E-04	0.000
2	2.2610E 14	0.630	2.7500E-01	0.029
3	8.0580E 13	1.100	7.7272E 00	0.436
4	3.4770E 12	1.550	2.3701E 00	0.111
5	3.7480E 11	1.990	1.7774E 00	0.059
6	7.6270E 11	2.380	7.8495E 00	0.244
7	9.5300E 10	2.750	2.0066E 00	0.056
8	3.2130E 10	3.250	1.4476E 00	0.037
9	1.5310E 10	3.700	1.1323E 00	0.027
TOTALS	4.0048E 14	.	2.4586E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 3 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 81.301 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.642 MEV, DOSE AVERAGED ENERGY - 1.627 MEV

DISK SOURCE, RADIUS- 485.0 CM, DISP- 0. CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	2.7540E 13	0.300	1.0501E-03	0.000
2	4.8660E 13	0.630	5.5283E-01	0.045
3	1.8510E 13	1.100	1.0002E 01	0.470
4	9.7420E 11	1.550	2.9904E 00	0.117
5	1.1460E 11	1.990	1.9649E 00	0.057
6	2.3010E 11	2.380	7.8491E 00	0.213
7	5.1840E 10	2.750	3.3401E 00	0.082
8	3.8530E 09	3.250	4.8823E-01	0.011
9	1.1870E 09	3.700	2.3378E-01	0.005
TOTALS	9.6106E 13		2.7422E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 3 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 1
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT, 0., CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 69.309 CENTIMETERS

Z - 60.0 CM, SOURCE AVERAGED ENERGY - 0.566 MEV, DOSE AVERAGED ENERGY - 1.820 MEV

DISK SOURCE, RADIUS- 485.0 CM, DISP- 0. CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	8.3560E 12	0.300	7.6666E-03	0.001
2	9.5770E 12	0.630	1.1764E 00	0.074
3	1.6220E 12	1.100	5.5554E 00	0.206
4	4.2010E 11	1.550	6.4468E 00	0.209
5	5.4190E 10	1.990	3.6815E 00	0.090
6	1.0960E 11	2.380	1.3510E 01	0.311
7	2.3770E 10	2.750	5.0852E 00	0.108
8	3.0800E 08	3.250	1.1850E-01	0.002
9	1.6990E 07	3.700	9.5887E-03	0.000
TOTALS	2.0163E 13		3.5591E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 2 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 110.878 CENTIMETERS

Z - 545.0 CM, SOURCE AVERAGED ENERGY - 0.667 MEV, DOSE AVERAGED ENERGY - 2.133 MEV

LINE SOURCE, DOSE POINT TYPE 2, H1 - 485.0 CM, H2 - 485.0 CM, TOTAL H - 970.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	2.7900E 14	0.300	1.1175E-05	0.000
2	5.7020E 14	0.630	4.2010E-02	0.005
3	1.9310E 14	1.100	2.2066E 00	0.160
4	3.3630E 13	1.550	3.6324E 00	0.215
5	1.7340E 12	1.990	1.6977E 00	0.070
6	3.8870E 12	2.380	9.1224E 00	0.343
7	4.0490E 11	2.750	2.1228E 00	0.071
8	1.9750E 11	3.250	2.4208E 00	0.073
9	1.0410E 11	3.700	2.2123E 00	0.063
TOTALS	1.0823E 15		2.3457E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 2 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 96.764 CENTIMETERS

Z - 545.0 CM, SOURCE AVERAGED ENERGY - 0.665 MEV, DOSE AVERAGED ENERGY - 1.732 MEV

LINE SOURCE, DOSE POINT TYPE 2, H1 - 485.0 CM, H2 - 485.0 CM, TOTAL H - 970.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	8.9040E 13	0.300	1.3734E-04	0.000
2	2.2610E 14	0.630	2.5059E-01	0.029
3	8.0580E 13	1.100	7.3887E 00	0.442
4	3.4770E 12	1.550	2.2792E 00	0.113
5	3.7480E 11	1.990	1.6937E 00	0.059
6	7.6270E 11	2.380	7.4121E 00	0.241
7	9.5300E 10	2.750	1.8725E 00	0.055
8	3.2130E 10	3.250	1.3284E 00	0.035
9	1.5310E 10	3.700	1.0250E 00	0.026
TOTALS	4.0048E 14		2.3250E 01	1.001

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 2 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 85.099 CENTIMETERS

Z - 545.0 CM, SOURCE AVERAGED ENERGY - 0.642 MEV, DOSE AVERAGED ENERGY - 1.611 MEV

LINE SOURCE, DOSE POINT TYPE 2, H1 - 485.0 CM, H2 - 485.0 CM, TOTAL H - 970.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	2.7540E 13	0.300	8.7493E-04	0.000
2	4.8680E 13	0.630	5.1070E-01	0.046
3	1.8510E 13	1.100	9.5499E 00	0.479
4	9.7420E 11	1.550	2.8512E 00	0.119
5	1.1460E 11	1.990	1.8429E 00	0.056
6	2.3010E 11	2.380	7.2732E 00	0.207
7	5.1840E 10	2.750	3.0501E 00	0.079
8	3.8530E 09	3.250	4.3710E-01	0.010
9	1.1870E 09	3.700	2.0606E-01	0.005
TOTALS	9.6106E 13		2.5722E 01	1.000

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SHIELDING DESIGN CALCULATIONS - GEOMETRY OPTION 2 - MATERIAL NO. 6

ROVER CORE PROCESSING FACILITY SHIELD DESIGN - STORAGE CELL CASE 2
DESIGN DOSE RATE - 1.000 MREM/HOUR, DOSE POINT 0. CM IN FRONT OF SHIELD,

CALCULATED SHIELD THICKNESS - 72.487 CENTIMETERS

Z - 545.0 CM, SOURCE AVERAGED ENERGY - 0.566 MEV, DOSE AVERAGED ENERGY - 1.794 MEV

LINE SOURCE, DOSE POINT TYPE 2, H1 - 485.0 CM, H2 - 485.0 CM, TOTAL H - 970.0 CM

GROUP	SOURCE STRENGTH PHOTONS/SEC	GROUP ENERGY MEV	GAMMA FLUX PHOTONS/SQ CM/SEC	GAMMA DOSE RATE MREM/HOUR
1	8.3560E 12	0.300	7.0566E-03	0.001
2	9.5770E 12	0.630	1.1514E 00	0.078
3	1.6220E 12	1.100	5.4590E 00	0.216
4	4.2010E 11	1.550	6.2418E 00	0.213
5	5.4190E 10	1.990	3.4590E 00	0.088
6	1.0960E 11	2.380	1.2473E 01	0.300
7	2.3770E 10	2.750	4.6031E 00	0.102
8	3.0800E 08	3.250	1.0460E-01	0.002
9	1.6990E 07	3.700	8.3027E-03	0.000
TOTALS	2.0163E 13		3.3507E 01	1.000

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