

2. To: (Receiving Organization) Distribution		3. From: (Originating Organization) Criticality and Shielding		4. Related EDT No.: 621286	
5. Proj./Prog./Dept./Div.: W-320		6. Design Authority/ Design Agent/Cog. Engr.: H. J. Goldberg		7. Purchase Order No.: NA	
8. Originator Remarks:				9. Equip./Component No.: NA	
11. Receiver Remarks: 11A. Design Baseline Document? ☐ Yes ☒ No Calculation notes are used to document the originator's analysis. They are not to be used as the final or sole document for affecting changes to the authorization basis (authorize activities), to the design basis (justify facility modifications), or to a safety basis.				10. System/Bldg./Facility: 241-C-106 & 241-AY-102	
				12. Major Assm. Dwg. No.: NA	
				13. Permit/Permit Application No.: NA	
				14. Required Response Date:	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	HNF-SD-WM-CN-104		0	Calculation Note for an Underground Leak which Remains Underground	NA	1, 2	1	

16. KEY					
Approval Designator (F)		Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)		1. Approval 2. Release 3. Information		4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	
				1. Approved 2. Approved w/comment 3. Disapproved w/comment	
				4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged	

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority									
		Design Agent									
1		Cog. Eng. H. J. Goldberg	<i>Harry Goldberg</i>	4/30/97	H0-35						
1		Cog. Mgr. J. Greenberg	<i>J. Greenberg</i>	5/12/97	H0-35						
		QA									
		Safety									
		Env.									

18. <i>H. J. Goldberg</i> Signature of EDT Originator 12 May 97 Date		19. _____ Authorized Representative Date for Receiving Organization		20. <i>J. Greenberg</i> Design Authority Cognizant Manager 5/12/97 Date		21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	
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Calculation Note for an Underground Leak which Remains Underground

H. J. Goldberg

Fluor Daniel Northwest, Inc., Richland, WA 99352

U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 621286

UC: 2030

Org Code: 403

Charge Code: E09120

B&R Code: EW3130010

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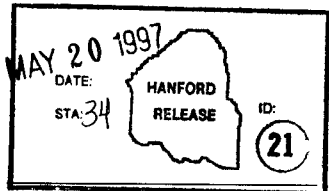
Key Words: Tank C-106, Waste, Pipe Leak

Abstract: The dose rate from a burst underground pipe which leaks Tank C-106 waste into the ground was calculated.

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Karen L. Holand 5/20/97
Release Approval Date



Approved for Public Release

**Calculation Note
for an
Underground Leak
which
Remains Underground**

This calculation note supports the subsurface leak accident scenario which remains subsurface. It is assumed that a single walled pipe carrying waste from tank 106-C ruptures, releasing the liquid waste into the soil. In this scenario, the waste does not form a surface pool, but remains subsurface. However, above the pipe is a berm, 0.762 m (2.5 ft) high and 2.44 m (8 ft) wide, and the liquid released from the leak rises into the berm.

The slurry line, which transports a source term of higher activity than the sludge line, leaks into the soil at a rate of 5% of the maximum flow rate of 28.4 L/s (450 gpm) for twelve hours. The dose recipient was placed a perpendicular distance of 100 m from the pipe. Two source terms were considered, mitigated and unmitigated release as described in section 3.4.1 of HANF-SD-WM-BIO-001, Addendum 1. The unmitigated consisted of two parts of AWF liquid and one part AWF solid. The mitigated release consisted of two parts SST liquid, eighteen parts AWF liquid, nine parts SST solid, and one part AWF solid. The isotopic breakdown of the release in these cases is presented in table 1.

Two geometries were considered in preliminary investigations, disk source, and rectangular source. Since the rectangular source results from the assumption that the contamination is wicked up into the berm, only six inches of shielding from uncontaminated earth is present, while the disk source, which remains six inches below the level of the surface of the land is often shielded by a thick shield due to the slant path to the dose point. For this reason, only the rectangular source was considered in the final analysis.

The source model was a rectangle 2.134 m (7 ft) thick, 0.6096 m (2 ft) high, and 130.899 m (131 ft) long. The top and sides of this rectangular source was covered with earth of density 1.6 g/cm^3 to a thickness of 15.24 cm (6 in). This soil is modeled as 40% void space. The source consisted of earth of the same density with the void spaces filled with the liquid waste which added 0.56 g/cm^3 to the density. The dose point was 100 m (328 ft) away from the berm in a perpendicular direction off the center.

The computer code MICROSKEYSHINE^o was used to calculate the skyshine from the source. This code calculates exposure rate at the receptor point. The photon spectrum from 2 MeV to 0.15 MeV, obtained from ISOSHLD (References 1 - 3), was used as input, although this did not differ substantially from the results obtained from using ^{60}Co , ^{137}mBa , and ^{154}Eu . However, this methodology allowed the bremsstrahlung contribution to be included in the skyshine calculation as well as in the direct radiation calculation.

Table 1: Sources				
Isotope	Unmitigated Release		Mitigated Release	
	Bq	Ci	Bq	Ci
⁶⁰ Co	1.12e+13	3.02e+02	9.77e+12	2.64e+02
⁹⁰ Sr	6.61e+16	1.79e+06	3.95e+16	1.07e+06
⁹⁰ Y	6.61e+16	1.79e+06	3.95e+16	1.07e+06
¹³⁷ Cs	6.24e+15	1.69e+05	5.98e+15	1.62e+05
^{137m} Ba	5.90e+15	1.60e+05	5.66e+15	1.53e+05
¹⁵⁴ Eu	2.50e+14	6.75e+03	1.54e+14	4.17e+03
²³⁷ Np	2.25e+13	6.08e+02	2.86e+12	7.74e+01
²³⁸ Pu	1.52e+12	4.11e+01	4.03e+12	1.09e+02
²³⁹ Pu	1.00e+13	2.71e+02	1.02e+13	2.76e+02
²⁴¹ Pu	3.86e+13	1.04e+03	7.04e+13	1.90e+03
²⁴¹ Am	2.50e+14	6.75e+03	2.99e+13	8.08e+02
²⁴⁴ Cm	1.39e+12	3.74e+01	1.88e+11	5.08e+00

The computer code ISOSHLD, which includes the contribution to the photon spectrum from bremsstrahlung, was used to calculate the direct contribution to the exposure rate. Because MICROSKYSHINE[®] calculated only exposure rate, the exposure rate results from ISOSHLD are reported. The exposure rates for the two cases are presented in Table 2.

The skyshine is less than, but comparable to, the direct radiation in this scenario. The mitigation scenario reduces the exposure by 10%, which is probably within the precision of this analysis. If we assume that one Roentgen equals one rad (which, for photons, equals one rem), the dose rate in rem/hr can be read directly off table 2.

Table 2: Exposure Rate at 100 m from the Birm				
	Unmitigated Release		Mitigated Release	
	Roentgen/hr	Amp/kg	Roentgen/hr	Amp/kg
Direct	6.56e-02	4.70e-09	5.90e-02	4.23e-09
Skyshine	2.47e-02	1.77e-09	2.21e-02	1.58e-09
Total	9.03e-02	6.47e-09	8.11e-02	5.81e-09

References

- 1) ISOSHL- A Computer Code for General Purpose Isotope Shielding Analysis, BNWL-236, R. L. Engel, J. Greenborg, M. M. Hendrickson, dated June 1966.
- 2) *ISOSHL-II: Code Revision to Include Calculation of Dose Rate from Shielded Bremsstrahlung Sources*, G. L. Simmons, J. J. Reginbal, J. Greenborg, E. L. Kelly, Jr., H. H. van Tuyl, dated March 1967.
- 3) *ISO-PC Version 1.98 - User's Guide*, WHC-SD-WM-UM-030, Rev 0, P. D. Rittmann, dated May 1995.

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED

NUMBER: HNF-SD-WM-CN-104TITLE: Calculation Note for an Underground Leak which Remains UndergroundAUTHOR(s): H. J. Goldberg

I. Method(s) of Review

- (☒) Input data checked for accuracy
- (☐) Independent calculation performed
 - (☐) Hand calculation
 - (☐) Alternate computer code: _____
- (☒) Comparison to experiment or previous results
- (☐) Alternate method (define) _____

II. Checklist (either check or enter NA if not applied)

- (☒) Task completely defined
- (☒) Activity consistent with task specification
- (☒) Necessary assumptions explicitly stated and supported
- (☒) Resources properly identified and referenced
- (☒) Resource documentation appropriate for this application
- (☒) Input data explicitly stated
- (☒) Input data verified to be consistent with original source
- (☒) Geometric model adequate representation of actual geometry
- (☒) Material properties appropriate and reasonable
- (☒) Mathematical derivations checked including dimensional consistency
- NA (☐) Hand calculations checked for errors
- (☒) Assumptions explicitly stated and justified
- (☒) Computer software appropriate for task and used within range of validity
- NA (☐) Use of resource outside range of established validity is justified
- (☒) Software runstreams correct and consistent with results
- (☒) Software output consistent with input
- (☒) Results consistent with applicable previous experimental or analytical findings
- (☒) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- NA (☐) Conclusions consistent with analytical results and established limits
- NA (☐) Uncertainty assesment appropriate and reasonable
- (☐) Other (define) _____

III. Comments: _____

IV. REVIEWER: Robert H. RubinDATE: 5/12/97

Computer Output Deck

Run started at 13:57:26 05/05/97

ISO-PC Version 1.98 August 1994
originally ISOSHLI-II; RIBD was removed

Please send questions or comments to:
Paul D. Rittmann, PhD CHP 509-376-8715
Westinghouse Hanford Company HO-36
PO Box 1970 Richland, WA 99352

Title Line from Library File (ISO-PC.LIB):

Attenuation & Buildup for 30 Groups; Photon & Beta Production 7/6/94 PDR

Run Title: PIPE LEAK INTO BIRM-TWELVE HOUR RELEASE

UNMITIGATED 12 HOUR RELEASE - 100 M AWAY

Table of Source Activity:

Scale Factor = 1.000E+00

Isotope Name	Initial Values	Final Curies
CO- 60	3.02E+02	3.020E+02
SR- 90	1.79E+06	1.790E+06
Y - 90	1.79E+06	1.790E+06
CS-137	1.69E+05	1.690E+05
BA-137M	1.60E+05	1.600E+05
EU-154	6.75E+03	6.750E+03
NP-237	6.08E+02	6.080E+02
PU-238	4.11E+01	4.110E+01
PU-239	2.71E+02	2.710E+02
PU-241	1.04E+03	1.040E+03
AM-241	6.75E+03	6.750E+03
CM-244	3.74E+01	3.740E+01

UNMITIGATED 12 HOUR RELEASE - 100 M AWAY

Shield Composition, g/cc

	Shield 1	Shield 2	Shield 3
WATER	5.600E-01	0.000E+00	0.000E+00
AIR	0.000E+00	0.000E+00	1.290E-03
HAN SOIL	1.600E+00	1.600E+00	0.000E+00
Totals:	2.160E+00	1.600E+00	1.290E-03

E, MeV	Linear Attenuation, per cm (last region is air)		
0.015	2.044E+01	1.952E+01	2.046E-03
0.025	4.813E+00	4.535E+00	6.138E-04
0.035	1.986E+00	1.817E+00	3.664E-04
0.045	1.119E+00	9.853E-01	2.837E-04
0.055	7.679E-01	6.493E-01	2.491E-04
0.065	5.980E-01	4.872E-01	2.314E-04
0.075	5.029E-01	3.981E-01	2.184E-04
0.085	4.446E-01	3.442E-01	2.090E-04
0.095	4.062E-01	3.091E-01	2.019E-04
0.150	3.135E-01	2.288E-01	1.758E-04
0.250	2.546E-01	1.835E-01	1.477E-04
0.350	2.229E-01	1.603E-01	1.298E-04
0.475	1.961E-01	1.408E-01	1.146E-04
0.650	1.710E-01	1.227E-01	1.001E-04
0.825	1.533E-01	1.099E-01	8.984E-05
1.000	1.397E-01	1.002E-01	8.194E-05
1.225	1.263E-01	9.058E-02	7.398E-05
1.475	1.150E-01	8.246E-02	6.718E-05
1.700	1.068E-01	7.669E-02	6.249E-05
1.900	1.008E-01	7.243E-02	5.889E-05
2.100	9.574E-02	6.882E-02	5.564E-05
2.300	9.133E-02	6.573E-02	5.263E-05
2.500	8.750E-02	6.304E-02	5.003E-05
2.700	8.418E-02	6.072E-02	4.778E-05
3.000	7.995E-02	5.776E-02	4.511E-05
3.600	7.338E-02	5.323E-02	4.158E-05
4.500	6.631E-02	4.842E-02	3.746E-05
5.500	6.089E-02	4.474E-02	3.381E-05
6.600	5.677E-02	4.198E-02	3.111E-05
8.600	5.210E-02	3.898E-02	2.771E-05

UNMITIGATED 12 HOUR RELEASE - 100 M AWAY

Photon Production Rate for Each Radionuclide:

ISOSHL D Energy Group Structure:

Group Number	Photon Energy, Mev		
	Low	Mid	High
1	0.010	0.015	0.020
2	0.020	0.025	0.030
3	0.030	0.035	0.040
4	0.040	0.045	0.050
5	0.050	0.055	0.060
6	0.060	0.065	0.070
7	0.070	0.075	0.080
8	0.080	0.085	0.090
9	0.090	0.095	0.100
10	0.100	0.150	0.200
11	0.200	0.250	0.300
12	0.300	0.350	0.400
13	0.400	0.475	0.550
14	0.550	0.650	0.750
15	0.750	0.825	0.900

Group Number	Photon Energy, Mev		
	Low	Mid	High
16	0.900	1.000	1.100
17	1.100	1.225	1.350
18	1.350	1.475	1.600
19	1.600	1.700	1.800
20	1.800	1.900	2.000
21	2.000	2.100	2.200
22	2.200	2.300	2.400
23	2.400	2.500	2.600
24	2.600	2.700	2.800
25	2.800	3.000	3.200
26	3.200	3.600	4.000
27	4.000	4.500	5.000
28	5.000	5.500	6.000
29	6.000	6.600	7.200
30	7.200	8.600	10.000

Nuclide 472 is CO- 60 (Z = 27)

Weight(472) = 3.020E+02 Ci

Group No.	Gamma X-ray	Brems	Total photon/sec
1	0.000E+00	2.863E+10	2.863E+10
2	0.000E+00	9.936E+09	9.936E+09
3	0.000E+00	5.395E+09	5.395E+09
4	0.000E+00	3.180E+09	3.180E+09
5	0.000E+00	2.055E+09	2.055E+09
6	0.000E+00	1.432E+09	1.432E+09
7	0.000E+00	9.910E+08	9.910E+08
8	0.000E+00	7.088E+08	7.088E+08
9	0.000E+00	5.151E+08	5.151E+08
10	0.000E+00	1.350E+09	1.350E+09
11	0.000E+00	3.705E+07	3.705E+07
12	0.000E+00	1.555E+04	1.555E+04
15	1.117E+09	0.000E+00	1.117E+09

Group No.	Gamma X-ray	Brems	Total photon/sec
16	0.000E+00	0.000E+00	0.000E+00
17	2.235E+13	0.000E+00	2.235E+13
18	0.000E+00	0.000E+00	0.000E+00
19	0.000E+00	0.000E+00	0.000E+00
20	0.000E+00	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00	0.000E+00
23	0.000E+00	0.000E+00	0.000E+00
24	0.000E+00	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00	0.000E+00
27	0.000E+00	0.000E+00	0.000E+00
30	0.000E+00	0.000E+00	0.000E+00

Totals: 2.235E+13 5.423E+10 2.240E+13

Nuclide 82 is SR- 90 (Z = 38)				Weight(82) = 1.790E+06 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	2.807E+14	2.807E+14	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	1.737E+14	1.737E+14	17	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	9.778E+13	9.778E+13	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	4.905E+13	4.905E+13	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	3.667E+13	3.667E+13	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	2.554E+13	2.554E+13	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	1.899E+13	1.899E+13	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	1.507E+13	1.507E+13	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	1.131E+13	1.131E+13	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	4.324E+13	4.324E+13	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	6.885E+12	6.885E+12	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	1.019E+12	1.019E+12	27	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	1.074E+11	1.074E+11	28	0.000E+00	0.000E+00	0.000E+00
-----				-----			
Totals:				0.000E+00 7.601E+14 7.601E+14			

Nuclide 84 is Y - 90 (Z = 39)				Weight(84) = 1.790E+06 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	5.033E+12	1.849E+15	1.854E+15	16	0.000E+00	1.872E+13	1.872E+13
2	0.000E+00	9.384E+14	9.384E+14	17	0.000E+00	9.646E+12	9.646E+12
3	0.000E+00	5.850E+14	5.850E+14	18	0.000E+00	3.191E+12	3.191E+12
4	0.000E+00	4.210E+14	4.210E+14	19	2.252E+12	7.278E+11	2.980E+12
5	0.000E+00	3.039E+14	3.039E+14	20	0.000E+00	1.610E+11	1.610E+11
6	0.000E+00	2.654E+14	2.654E+14	21	9.272E+10	1.350E+10	1.062E+11
7	0.000E+00	2.455E+14	2.455E+14	22	0.000E+00	1.981E+08	1.981E+08
8	0.000E+00	2.255E+14	2.255E+14	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	2.056E+14	2.056E+14	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	1.044E+15	1.044E+15	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	3.303E+14	3.303E+14	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	1.626E+14	1.626E+14	27	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	1.248E+14	1.248E+14	28	0.000E+00	0.000E+00	0.000E+00
14	0.000E+00	7.574E+13	7.574E+13	29	0.000E+00	0.000E+00	0.000E+00
15	0.000E+00	2.744E+13	2.744E+13	30	0.000E+00	0.000E+00	0.000E+00
-----				-----			
Totals:				7.378E+12 6.837E+15 6.844E+15			

Nuclide 335 is CS-137 (Z = 55)				Weight(335) = 1.690E+05 Ci			
Group No.	Gamma X-ray	Brems	Total photon/sec	Group No.	Gamma X-ray	Brems	Total photon/sec
1	0.000E+00	2.755E+13	2.755E+13	16	0.000E+00	7.425E+08	7.425E+08
2	0.000E+00	1.603E+13	1.603E+13	17	0.000E+00	5.579E+06	5.579E+06
3	0.000E+00	8.536E+12	8.536E+12	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	5.075E+12	5.075E+12	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	3.828E+12	3.828E+12	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	2.680E+12	2.680E+12	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	2.059E+12	2.059E+12	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	1.492E+12	1.492E+12	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	1.138E+12	1.138E+12	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	4.583E+12	4.583E+12	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	8.900E+11	8.900E+11	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	2.367E+11	2.367E+11	27	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	1.075E+11	1.075E+11	28	0.000E+00	0.000E+00	0.000E+00
14	0.000E+00	3.543E+10	3.543E+10	29	0.000E+00	0.000E+00	0.000E+00
15	0.000E+00	4.971E+09	4.971E+09	30	0.000E+00	0.000E+00	0.000E+00
				Totals: 0.000E+00 7.424E+13 7.424E+13			

Nuclide 336 is BA-137M (Z = 56)				Weight(336) = 1.600E+05 Ci			
Group No.	Gamma X-ray	Brems	Total photon/sec	Group No.	Gamma X-ray	Brems	Total photon/sec
3	4.310E+14	0.000E+00	4.310E+14	18	0.000E+00	0.000E+00	0.000E+00
14	5.327E+15	0.000E+00	5.327E+15	29	0.000E+00	0.000E+00	0.000E+00
				Totals: 5.758E+15 0.000E+00 5.758E+15			

Nuclide 415 is EU-154 (Z = 63)				Weight(415) = 6.750E+03 Ci			
Group No.	Gamma X-ray	Brems	Total photon/sec	Group No.	Gamma X-ray	Brems	Total photon/sec
1	0.000E+00	1.525E+12	1.525E+12	16	7.073E+13	2.858E+09	7.073E+13
2	0.000E+00	7.732E+11	7.732E+11	17	9.268E+13	1.032E+09	9.268E+13
3	0.000E+00	5.051E+11	5.051E+11	18	8.816E+12	1.639E+08	8.816E+12
4	6.374E+13	3.184E+11	6.405E+13	19	0.000E+00	6.873E+06	6.873E+06
5	0.000E+00	2.397E+11	2.397E+11	20	0.000E+00	6.541E+03	6.541E+03
6	0.000E+00	1.831E+11	1.831E+11	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	1.511E+11	1.511E+11	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	1.286E+11	1.286E+11	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	1.071E+11	1.071E+11	24	0.000E+00	0.000E+00	0.000E+00
10	1.016E+14	4.269E+11	1.021E+14	25	0.000E+00	0.000E+00	0.000E+00
11	1.648E+13	1.227E+11	1.661E+13	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	5.128E+10	5.128E+10	27	0.000E+00	0.000E+00	0.000E+00
13	2.323E+12	3.342E+10	2.356E+12	28	0.000E+00	0.000E+00	0.000E+00
14	8.454E+13	1.686E+10	8.456E+13	29	0.000E+00	0.000E+00	0.000E+00
15	3.504E+13	5.098E+09	3.505E+13	30	0.000E+00	0.000E+00	0.000E+00

Totals: 4.760E+14 4.592E+12 4.806E+14

Nuclide 502 is NP-237 (Z = 93)				Weight(502) = 6.080E+02 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	1.332E+13	1.330E+09	1.332E+13	16	0.000E+00	0.000E+00	0.000E+00
2	3.147E+12	2.330E+08	3.147E+12	17	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	5.441E+07	5.441E+07	18	0.000E+00	0.000E+00	0.000E+00
4	3.149E+10	1.458E+07	3.151E+10	19	0.000E+00	0.000E+00	0.000E+00
5	9.448E+10	4.404E+06	9.449E+10	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	1.432E+06	1.432E+06	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	4.801E+05	4.801E+05	22	0.000E+00	0.000E+00	0.000E+00
8	2.870E+12	1.554E+05	2.870E+12	23	0.000E+00	0.000E+00	0.000E+00
9	1.125E+12	3.832E+04	1.125E+12	24	0.000E+00	0.000E+00	0.000E+00
10	7.424E+11	1.499E+04	7.424E+11	25	0.000E+00	0.000E+00	0.000E+00
11	3.599E+10	0.000E+00	3.599E+10	26	0.000E+00	0.000E+00	0.000E+00

Totals: 2.136E+13 1.638E+09 2.136E+13

Nuclide 492 is PU-238 (Z = 94)				Weight(492) = 4.110E+01 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	1.764E+11	0.000E+00	1.764E+11	16	0.000E+00	0.000E+00	0.000E+00
4	6.083E+08	0.000E+00	6.083E+08	19	0.000E+00	0.000E+00	0.000E+00
10	1.521E+08	0.000E+00	1.521E+08	25	0.000E+00	0.000E+00	0.000E+00

Totals: 1.772E+11 0.000E+00 1.772E+11

Nuclide 493 is PU-239 (Z = 94)				Weight(493) = 2.710E+02 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	4.412E+11	0.000E+00	4.412E+11	16	2.106E+04	0.000E+00	2.106E+04
3	2.005E+08	0.000E+00	2.005E+08	18	0.000E+00	0.000E+00	0.000E+00
4	5.715E+07	0.000E+00	5.715E+07	19	0.000E+00	0.000E+00	0.000E+00
5	2.908E+07	0.000E+00	2.908E+07	20	0.000E+00	0.000E+00	0.000E+00
6	3.309E+07	0.000E+00	3.309E+07	21	0.000E+00	0.000E+00	0.000E+00
7	3.108E+07	0.000E+00	3.108E+07	22	0.000E+00	0.000E+00	0.000E+00
8	1.304E+06	0.000E+00	1.304E+06	23	0.000E+00	0.000E+00	0.000E+00
9	2.707E+07	0.000E+00	2.707E+07	24	0.000E+00	0.000E+00	0.000E+00
10	7.520E+08	0.000E+00	7.520E+08	25	0.000E+00	0.000E+00	0.000E+00
11	5.114E+07	0.000E+00	5.114E+07	26	0.000E+00	0.000E+00	0.000E+00
12	3.610E+08	0.000E+00	3.610E+08	27	0.000E+00	0.000E+00	0.000E+00
13	1.705E+08	0.000E+00	1.705E+08	28	0.000E+00	0.000E+00	0.000E+00
14	6.417E+06	0.000E+00	6.417E+06	29	0.000E+00	0.000E+00	0.000E+00
15	1.504E+06	0.000E+00	1.504E+06	30	0.000E+00	0.000E+00	0.000E+00

Totals: 4.429E+11 0.000E+00 4.429E+11

Nuclide 495 is PU-241 (Z = 94)				Weight(495) = 1.040E+03 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	5.684E+07	5.684E+07	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	5.325E+02	5.325E+02	17	0.000E+00	0.000E+00	0.000E+00
4	2.155E+06	0.000E+00	2.155E+06	19	0.000E+00	0.000E+00	0.000E+00
5	1.424E+06	0.000E+00	1.424E+06	20	0.000E+00	0.000E+00	0.000E+00
7	1.039E+07	0.000E+00	1.039E+07	22	0.000E+00	0.000E+00	0.000E+00
10	4.618E+08	0.000E+00	4.618E+08	25	0.000E+00	0.000E+00	0.000E+00
Totals: 4.757E+08 5.684E+07 5.326E+08							

Nuclide 496 is AM-241 (Z = 95)				Weight(496) = 6.750E+03 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	1.074E+14	4.177E+09	1.074E+14	16	0.000E+00	0.000E+00	0.000E+00
2	5.994E+12	4.337E+08	5.994E+12	17	0.000E+00	0.000E+00	0.000E+00
3	2.747E+11	5.112E+07	2.748E+11	18	0.000E+00	0.000E+00	0.000E+00
4	2.248E+11	5.589E+06	2.248E+11	19	0.000E+00	0.000E+00	0.000E+00
5	8.916E+13	8.508E+05	8.916E+13	20	0.000E+00	0.000E+00	0.000E+00
6	4.995E+09	1.611E+05	4.995E+09	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	2.304E+04	2.304E+04	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	1.532E+03	1.532E+03	23	0.000E+00	0.000E+00	0.000E+00
9	5.245E+10	1.085E+01	5.245E+10	24	0.000E+00	0.000E+00	0.000E+00
10	6.993E+10	0.000E+00	6.993E+10	25	0.000E+00	0.000E+00	0.000E+00
11	2.148E+09	0.000E+00	2.148E+09	26	0.000E+00	0.000E+00	0.000E+00
12	3.247E+09	0.000E+00	3.247E+09	27	0.000E+00	0.000E+00	0.000E+00
13	1.948E+08	0.000E+00	1.948E+08	28	0.000E+00	0.000E+00	0.000E+00
14	1.723E+09	0.000E+00	1.723E+09	29	0.000E+00	0.000E+00	0.000E+00
15	5.494E+07	0.000E+00	5.494E+07	30	0.000E+00	0.000E+00	0.000E+00
Totals: 2.032E+14 4.668E+09 2.032E+14							

Nuclide 500 is CM-244 (Z = 96)				Weight(500) = 3.740E+01 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	2.491E+11	0.000E+00	2.491E+11	16	0.000E+00	0.000E+00	0.000E+00
4	1.245E+09	0.000E+00	1.245E+09	19	0.000E+00	0.000E+00	0.000E+00
Totals: 2.503E+11 0.000E+00 2.503E+11							

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Source          Shields          Distance to Detector, X = 1.023E+04 cm
Slab            Slab            Source Volume = 1.703E+08 cc
                Source Mass = 3.677E+08 grams
Thickness = 2.134E+02 cm  Height = 6.096E+01 cm  Width = 1.309E+04 cm
Integration Specs:  NTHETA = 15  NPSI = 15  DELR = 5.080E+00 cm
Total Intervals:  9.450E+03  (photon source is the 1st region)
Shield Thickness:  2.134E+02, 1.524E+01, 1.000E+04 cm
Distances from Dose Point to the Outside of
(1) Source Region: 1.002E+04 cm  (2) Next Layer: 1.000E+04 cm
Dose Buildup Data for Shield 2 with Effective Atomic Number 10.78
Fluence-to-Dose Conversion: Photons in Air

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Average E, MeV	Source Total photons/sec	Fluence to Dose Factor	Energy Fluence MeV/sq.cm/sec	Dose Rate R/hr
0.015	2.286E+15	8.183E-05	0.000E+00	0.000E+00
0.025	1.138E+15	1.656E-05	2.473E-28	4.096E-33
0.035	1.123E+15	6.084E-06	3.183E-09	1.937E-14
0.045	5.394E+14	3.203E-06	8.309E-04	2.661E-09
0.055	4.339E+14	2.216E-06	1.144E-01	2.535E-07
0.065	2.938E+14	1.827E-06	1.927E-01	1.695E-06
0.075	2.667E+14	1.664E-06	3.991E+00	6.642E-06
0.085	2.451E+14	1.603E-06	9.083E+00	1.456E-05
0.095	2.193E+14	1.592E-06	1.607E+01	2.558E-05
0.150	1.195E+15	1.728E-06	2.456E+02	4.244E-04
0.250	3.547E+14	1.935E-06	2.831E+02	5.477E-04
0.350	1.640E+14	2.019E-06	2.666E+02	5.383E-04
0.475	1.273E+14	2.043E-06	3.629E+02	7.413E-04
0.650	5.874E+15	2.029E-06	2.757E+02	5.594E-02
0.825	6.249E+13	1.983E-06	4.929E+02	9.775E-04
1.000	8.945E+13	1.923E-06	1.013E+03	1.948E-03
1.225	1.247E+14	1.850E-06	2.030E+03	3.755E-03
1.475	1.201E+13	1.775E-06	2.713E+02	4.816E-04
1.700	2.980E+12	1.712E-06	8.682E+01	1.486E-04
1.900	1.610E+11	1.660E-06	5.729E+00	9.509E-06
2.100	1.062E+11	1.613E-06	4.511E+00	7.276E-06
2.300	1.981E+08	1.592E-06	9.855E-03	1.569E-08
Totals:	1.416E+16 photons/sec		3.266E+04	6.557E-02 R/hr = 4.699E-09 amp/kv

Dose Equivalent Rates (rem/hr) for Other Fluence-to-Dose Factors						
Average E, Mev	Anterior DUNIT = 1	Posterior DUNIT = 2	Lateral DUNIT = 3	Rotational DUNIT = 4	Isometric DUNIT = 5	Orig ANSI DUNIT = 6
0.025	1.026E-33	4.690E-34	2.431E-34	4.990E-34	4.112E-34	7.916E-33
0.035	1.120E-14	6.484E-15	3.426E-15	5.950E-15	4.834E-15	3.981E-14
0.045	2.475E-09	1.582E-09	9.039E-10	1.401E-09	1.133E-09	5.855E-09
0.055	2.973E-07	2.014E-07	1.214E-07	1.760E-07	1.425E-07	5.703E-07
0.065	2.167E-06	1.533E-06	9.475E-07	1.326E-06	1.078E-06	3.704E-06
0.075	8.600E-06	6.304E-06	3.919E-06	5.397E-06	4.408E-06	1.375E-05
0.085	1.842E-05	1.393E-05	8.619E-06	1.181E-05	9.677E-06	2.828E-05
0.095	3.117E-05	2.422E-05	1.485E-05	2.035E-05	1.671E-05	4.664E-05
0.150	4.423E-04	3.693E-04	2.340E-04	3.168E-04	2.577E-04	6.211E-04
0.250	5.295E-04	4.379E-04	2.945E-04	3.813E-04	3.149E-04	7.144E-04
0.350	4.986E-04	4.191E-04	2.919E-04	3.685E-04	3.076E-04	6.688E-04
0.475	6.669E-04	5.731E-04	4.118E-04	5.080E-04	4.285E-04	8.531E-04
0.650	4.894E-02	4.312E-02	3.199E-02	3.851E-02	3.287E-02	6.117E-02
0.825	8.426E-04	7.565E-04	5.748E-04	6.789E-04	5.852E-04	1.028E-03
1.000	1.668E-03	1.519E-03	1.177E-03	1.368E-03	1.189E-03	2.004E-03
1.225	3.197E-03	2.949E-03	2.333E-03	2.663E-03	2.338E-03	3.789E-03
1.475	4.083E-04	3.805E-04	3.067E-04	3.444E-04	3.053E-04	4.792E-04
1.700	1.258E-04	1.180E-04	9.651E-05	1.070E-04	9.555E-05	1.467E-04
1.900	8.051E-06	7.585E-06	6.271E-06	6.887E-06	6.183E-06	9.342E-06
2.100	6.161E-06	5.825E-06	4.863E-06	5.295E-06	4.778E-06	7.120E-06
2.300	1.311E-08	1.243E-08	1.047E-08	1.131E-08	1.025E-08	1.509E-08
Totals	5.739E-02	5.071E-02	3.774E-02	4.530E-02	3.874E-02	7.159E-02

Fluence-to-Dose Factors, rem/hr per Mev/sq.cm/sec						
Average E, Mev	Anterior DUNIT = 1	Posterior DUNIT = 2	Lateral DUNIT = 3	Rotational DUNIT = 4	Isometric DUNIT = 5	Orig ANSI DUNIT = 6
0.025	4.148E-06	1.896E-06	9.827E-07	2.017E-06	1.663E-06	3.201E-05
0.035	3.518E-06	2.037E-06	1.076E-06	1.869E-06	1.519E-06	1.251E-05
0.045	2.979E-06	1.904E-06	1.088E-06	1.686E-06	1.363E-06	7.047E-06
0.055	2.598E-06	1.760E-06	1.061E-06	1.538E-06	1.245E-06	4.985E-06
0.065	2.336E-06	1.652E-06	1.021E-06	1.429E-06	1.162E-06	3.993E-06
0.075	2.155E-06	1.580E-06	9.820E-07	1.352E-06	1.104E-06	3.444E-06
0.085	2.028E-06	1.534E-06	9.489E-07	1.300E-06	1.065E-06	3.113E-06
0.095	1.940E-06	1.507E-06	9.243E-07	1.266E-06	1.040E-06	2.903E-06
0.150	1.801E-06	1.504E-06	9.526E-07	1.290E-06	1.049E-06	2.529E-06
0.250	1.870E-06	1.547E-06	1.040E-06	1.347E-06	1.113E-06	2.524E-06
0.350	1.870E-06	1.572E-06	1.095E-06	1.382E-06	1.154E-06	2.509E-06
0.475	1.838E-06	1.579E-06	1.135E-06	1.400E-06	1.181E-06	2.351E-06
0.650	1.775E-06	1.564E-06	1.160E-06	1.397E-06	1.192E-06	2.219E-06
0.825	1.709E-06	1.535E-06	1.166E-06	1.377E-06	1.187E-06	2.086E-06
1.000	1.647E-06	1.500E-06	1.162E-06	1.350E-06	1.174E-06	1.979E-06
1.225	1.575E-06	1.453E-06	1.149E-06	1.312E-06	1.152E-06	1.867E-06
1.475	1.505E-06	1.402E-06	1.130E-06	1.269E-06	1.125E-06	1.766E-06
1.700	1.449E-06	1.359E-06	1.112E-06	1.233E-06	1.100E-06	1.690E-06

1.900	1.405E-06	1.324E-06	1.095E-06	1.202E-06	1.079E-06	1.631E-06
2.100	1.366E-06	1.291E-06	1.078E-06	1.174E-06	1.059E-06	1.578E-06
2.300	1.330E-06	1.261E-06	1.062E-06	1.147E-06	1.040E-06	1.531E-06

MITIGATED 12 HOUR RELEASE - 100 M AWAY

Table of Source Activity:

Scale Factor = 1.000E+00

Isotope Name	Initial Values	Final Curies
CO- 60	2.64E+02	2.640E+02
SR- 90	1.07E+06	1.070E+06
Y - 90	1.07E+06	1.070E+06
CS-137	1.62E+05	1.620E+05
BA-137M	1.53E+05	1.530E+05
EU-154	4.17E+03	4.170E+03
NP-237	7.74E+01	7.740E+01
PU-238	1.09E+02	1.090E+02
PU-239	2.76E+02	2.760E+02
PU-241	1.90E+03	1.900E+03
AM-241	8.08E+02	8.080E+02
CM-244	5.08E+00	5.080E+00

MITIGATED 12 HOUR RELEASE - 100 M AWAY

Shield Composition, g/cc

	Shield 1	Shield 2	Shield 3
WATER	5.600E-01	0.000E+00	0.000E+00
AIR	0.000E+00	0.000E+00	1.290E-03
HAN SOIL	1.600E+00	1.600E+00	0.000E+00
Totals:	2.160E+00	1.600E+00	1.290E-03

E, MeV Linear Attenuation, per cm (last region is air)

0.015	2.044E+01	1.952E+01	2.046E-03
0.025	4.813E+00	4.535E+00	6.138E-04
0.035	1.986E+00	1.817E+00	3.664E-04
0.045	1.119E+00	9.853E-01	2.837E-04
0.055	7.679E-01	6.493E-01	2.491E-04
0.065	5.980E-01	4.872E-01	2.314E-04
0.075	5.029E-01	3.981E-01	2.184E-04
0.085	4.446E-01	3.442E-01	2.090E-04
0.095	4.062E-01	3.091E-01	2.019E-04
0.150	3.135E-01	2.288E-01	1.758E-04
0.250	2.546E-01	1.835E-01	1.477E-04
0.350	2.229E-01	1.603E-01	1.298E-04
0.475	1.961E-01	1.408E-01	1.146E-04
0.650	1.710E-01	1.227E-01	1.001E-04
0.825	1.533E-01	1.099E-01	8.984E-05
1.000	1.397E-01	1.002E-01	8.194E-05
1.225	1.263E-01	9.058E-02	7.398E-05
1.475	1.150E-01	8.246E-02	6.718E-05
1.700	1.068E-01	7.669E-02	6.249E-05
1.900	1.008E-01	7.243E-02	5.889E-05
2.100	9.574E-02	6.882E-02	5.564E-05
2.300	9.133E-02	6.573E-02	5.263E-05
2.500	8.750E-02	6.304E-02	5.003E-05
2.700	8.418E-02	6.072E-02	4.778E-05
3.000	7.995E-02	5.776E-02	4.511E-05
3.600	7.338E-02	5.323E-02	4.158E-05
4.500	6.631E-02	4.842E-02	3.746E-05
5.500	6.089E-02	4.474E-02	3.381E-05
6.600	5.677E-02	4.198E-02	3.111E-05
8.600	5.210E-02	3.898E-02	2.771E-05

MITIGATED 12 HOUR RELEASE - 100 M AWAY

Photon Production Rate for Each Radionuclide:

Nuclide 472 is CO- 60 (Z = 27)				Weight(472) = 2.640E+02 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	2.502E+10	2.502E+10	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	8.685E+09	8.685E+09	17	1.954E+13	0.000E+00	1.954E+13
3	0.000E+00	4.716E+09	4.716E+09	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	2.780E+09	2.780E+09	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	1.797E+09	1.797E+09	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	1.252E+09	1.252E+09	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	8.663E+08	8.663E+08	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	6.196E+08	6.196E+08	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	4.503E+08	4.503E+08	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	1.180E+09	1.180E+09	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	3.238E+07	3.238E+07	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	1.359E+04	1.359E+04	27	0.000E+00	0.000E+00	0.000E+00
15	9.768E+08	0.000E+00	9.768E+08	30	0.000E+00	0.000E+00	0.000E+00
				Totals: 1.954E+13 4.740E+10 1.958E+13			

Nuclide 82 is SR- 90 (Z = 38)				Weight(82) = 1.070E+06 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	1.678E+14	1.678E+14	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	1.038E+14	1.038E+14	17	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	5.845E+13	5.845E+13	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	2.932E+13	2.932E+13	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	2.192E+13	2.192E+13	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	1.527E+13	1.527E+13	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	1.135E+13	1.135E+13	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	9.010E+12	9.010E+12	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	6.763E+12	6.763E+12	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	2.585E+13	2.585E+13	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	4.116E+12	4.116E+12	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	6.094E+11	6.094E+11	27	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	6.421E+10	6.421E+10	28	0.000E+00	0.000E+00	0.000E+00
				Totals: 0.000E+00 4.543E+14 4.543E+14			

Nuclide 84 is Y - 90 (Z = 39)				Weight(84) = 1.070E+06 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	3.009E+12	1.105E+15	1.108E+15	16	0.000E+00	1.119E+13	1.119E+13
2	0.000E+00	5.609E+14	5.609E+14	17	0.000E+00	5.766E+12	5.766E+12
3	0.000E+00	3.497E+14	3.497E+14	18	0.000E+00	1.908E+12	1.908E+12
4	0.000E+00	2.516E+14	2.516E+14	19	1.346E+12	4.350E+11	1.781E+12
5	0.000E+00	1.817E+14	1.817E+14	20	0.000E+00	9.623E+10	9.623E+10
6	0.000E+00	1.587E+14	1.587E+14	21	5.543E+10	8.072E+09	6.350E+10
7	0.000E+00	1.467E+14	1.467E+14	22	0.000E+00	1.184E+08	1.184E+08
8	0.000E+00	1.348E+14	1.348E+14	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	1.229E+14	1.229E+14	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	6.241E+14	6.241E+14	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	1.974E+14	1.974E+14	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	9.722E+13	9.722E+13	27	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	7.459E+13	7.459E+13	28	0.000E+00	0.000E+00	0.000E+00
14	0.000E+00	4.528E+13	4.528E+13	29	0.000E+00	0.000E+00	0.000E+00
15	0.000E+00	1.640E+13	1.640E+13	30	0.000E+00	0.000E+00	0.000E+00
				Totals: 4.410E+12 4.087E+15 4.091E+15			

Nuclide 335 is CS-137 (Z = 55)				Weight(335) = 1.620E+05 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	2.641E+13	2.641E+13	16	0.000E+00	7.117E+08	7.117E+08
2	0.000E+00	1.536E+13	1.536E+13	17	0.000E+00	5.348E+06	5.348E+06
3	0.000E+00	8.182E+12	8.182E+12	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	4.864E+12	4.864E+12	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	3.670E+12	3.670E+12	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	2.569E+12	2.569E+12	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	1.974E+12	1.974E+12	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	1.430E+12	1.430E+12	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	1.091E+12	1.091E+12	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	4.393E+12	4.393E+12	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	8.532E+11	8.532E+11	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	2.269E+11	2.269E+11	27	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	1.031E+11	1.031E+11	28	0.000E+00	0.000E+00	0.000E+00
14	0.000E+00	3.397E+10	3.397E+10	29	0.000E+00	0.000E+00	0.000E+00
15	0.000E+00	4.765E+09	4.765E+09	30	0.000E+00	0.000E+00	0.000E+00
				Totals: 0.000E+00 7.117E+13 7.117E+13			

Nuclide 336 is BA-137M (Z = 56)				Weight(336) = 1.530E+05 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
3	4.121E+14	0.000E+00	4.121E+14	18	0.000E+00	0.000E+00	0.000E+00
14	5.094E+15	0.000E+00	5.094E+15	29	0.000E+00	0.000E+00	0.000E+00

Totals: 5.506E+15 0.000E+00 5.506E+15

Nuclide 415 is EU-154 (Z = 63)				Weight(415) = 4.170E+03 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	9.421E+11	9.421E+11	16	4.369E+13	1.765E+09	4.370E+13
2	0.000E+00	4.777E+11	4.777E+11	17	5.726E+13	6.375E+08	5.726E+13
3	0.000E+00	3.120E+11	3.120E+11	18	5.446E+12	1.013E+08	5.447E+12
4	3.937E+13	1.967E+11	3.957E+13	19	0.000E+00	4.246E+06	4.246E+06
5	0.000E+00	1.481E+11	1.481E+11	20	0.000E+00	4.041E+03	4.041E+03
6	0.000E+00	1.131E+11	1.131E+11	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	9.334E+10	9.334E+10	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	7.942E+10	7.942E+10	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	6.619E+10	6.619E+10	24	0.000E+00	0.000E+00	0.000E+00
10	6.278E+13	2.637E+11	6.304E+13	25	0.000E+00	0.000E+00	0.000E+00
11	1.018E+13	7.582E+10	1.026E+13	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	3.168E+10	3.168E+10	27	0.000E+00	0.000E+00	0.000E+00
13	1.435E+12	2.065E+10	1.456E+12	28	0.000E+00	0.000E+00	0.000E+00
14	5.223E+13	1.042E+10	5.224E+13	29	0.000E+00	0.000E+00	0.000E+00
15	2.165E+13	3.150E+09	2.165E+13	30	0.000E+00	0.000E+00	0.000E+00
				Totals: 2.940E+14 2.837E+12 2.969E+14			

Nuclide 502 is NP-237 (Z = 93)				Weight(502) = 7.740E+01 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	1.695E+12	1.693E+08	1.695E+12	16	0.000E+00	0.000E+00	0.000E+00
2	4.006E+11	2.967E+07	4.007E+11	17	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	6.926E+06	6.926E+06	18	0.000E+00	0.000E+00	0.000E+00
4	4.009E+09	1.857E+06	4.011E+09	19	0.000E+00	0.000E+00	0.000E+00
5	1.203E+10	5.607E+05	1.203E+10	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	1.823E+05	1.823E+05	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	6.112E+04	6.112E+04	22	0.000E+00	0.000E+00	0.000E+00
8	3.654E+11	1.978E+04	3.654E+11	23	0.000E+00	0.000E+00	0.000E+00
9	1.432E+11	4.878E+03	1.432E+11	24	0.000E+00	0.000E+00	0.000E+00
10	9.451E+10	1.909E+03	9.451E+10	25	0.000E+00	0.000E+00	0.000E+00
11	4.582E+09	0.000E+00	4.582E+09	26	0.000E+00	0.000E+00	0.000E+00
				Totals: 2.719E+12 2.086E+08 2.720E+12			

Nuclide 492 is PU-238 (Z = 94)				Weight(492) = 1.090E+02 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	4.678E+11	0.000E+00	4.678E+11	16	0.000E+00	0.000E+00	0.000E+00
4	1.613E+09	0.000E+00	1.613E+09	19	0.000E+00	0.000E+00	0.000E+00
10	4.033E+08	0.000E+00	4.033E+08	25	0.000E+00	0.000E+00	0.000E+00
				Totals: 4.698E+11 0.000E+00 4.698E+11			

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Nuclide 493 is PU-239 (Z = 94)				Weight(493) = 2.760E+02 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	4.493E+11	0.000E+00	4.493E+11	16	2.145E+04	0.000E+00	2.145E+04
3	2.042E+08	0.000E+00	2.042E+08	18	0.000E+00	0.000E+00	0.000E+00
4	5.821E+07	0.000E+00	5.821E+07	19	0.000E+00	0.000E+00	0.000E+00
5	2.961E+07	0.000E+00	2.961E+07	20	0.000E+00	0.000E+00	0.000E+00
6	3.370E+07	0.000E+00	3.370E+07	21	0.000E+00	0.000E+00	0.000E+00
7	3.166E+07	0.000E+00	3.166E+07	22	0.000E+00	0.000E+00	0.000E+00
8	1.328E+06	0.000E+00	1.328E+06	23	0.000E+00	0.000E+00	0.000E+00
9	2.757E+07	0.000E+00	2.757E+07	24	0.000E+00	0.000E+00	0.000E+00
10	7.659E+08	0.000E+00	7.659E+08	25	0.000E+00	0.000E+00	0.000E+00
11	5.208E+07	0.000E+00	5.208E+07	26	0.000E+00	0.000E+00	0.000E+00
12	3.676E+08	0.000E+00	3.676E+08	27	0.000E+00	0.000E+00	0.000E+00
13	1.736E+08	0.000E+00	1.736E+08	28	0.000E+00	0.000E+00	0.000E+00
14	6.536E+06	0.000E+00	6.536E+06	29	0.000E+00	0.000E+00	0.000E+00
15	1.532E+06	0.000E+00	1.532E+06	30	0.000E+00	0.000E+00	0.000E+00
Totals:				4.511E+11	0.000E+00	4.511E+11	

Nuclide 495 is PU-241 (Z = 94)				Weight(495) = 1.900E+03 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	1.038E+08	1.038E+08	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	9.729E+02	9.729E+02	17	0.000E+00	0.000E+00	0.000E+00
4	3.937E+06	0.000E+00	3.937E+06	19	0.000E+00	0.000E+00	0.000E+00
5	2.601E+06	0.000E+00	2.601E+06	20	0.000E+00	0.000E+00	0.000E+00
7	1.898E+07	0.000E+00	1.898E+07	22	0.000E+00	0.000E+00	0.000E+00
10	8.436E+08	0.000E+00	8.436E+08	25	0.000E+00	0.000E+00	0.000E+00
Totals:				8.691E+08	1.038E+08	9.730E+08	

Nuclide 496 is AM-241 (Z = 95)
 Group Gamma Total
 No. X-ray Brems photon/sec

1	1.286E+13	5.000E+08	1.286E+13
2	7.175E+11	5.192E+07	7.176E+11
3	3.289E+10	6.120E+06	3.289E+10
4	2.691E+10	6.691E+05	2.691E+10
5	1.067E+13	1.018E+05	1.067E+13
6	5.979E+08	1.929E+04	5.979E+08
7	0.000E+00	2.758E+03	2.758E+03
8	0.000E+00	1.834E+02	1.834E+02
9	6.278E+09	1.298E+00	6.278E+09
10	8.371E+09	0.000E+00	8.371E+09
11	2.571E+08	0.000E+00	2.571E+08
12	3.886E+08	0.000E+00	3.886E+08
13	2.332E+07	0.000E+00	2.332E+07
14	2.063E+08	0.000E+00	2.063E+08
15	6.577E+06	0.000E+00	6.577E+06

Weight(496) = 8.080E+02 Ci
 Group Gamma Total
 No. X-ray Brems photon/sec

16	0.000E+00	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00	0.000E+00
19	0.000E+00	0.000E+00	0.000E+00
20	0.000E+00	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00	0.000E+00
23	0.000E+00	0.000E+00	0.000E+00
24	0.000E+00	0.000E+00	0.000E+00
25	0.000E+00	0.000E+00	0.000E+00
26	0.000E+00	0.000E+00	0.000E+00
27	0.000E+00	0.000E+00	0.000E+00
28	0.000E+00	0.000E+00	0.000E+00
29	0.000E+00	0.000E+00	0.000E+00
30	0.000E+00	0.000E+00	0.000E+00

Totals: 2.432E+13 5.588E+08 2.432E+13

Nuclide 500 is CM-244 (Z = 96)
 Group Gamma Total
 No. X-ray Brems photon/sec

1	3.383E+10	0.000E+00	3.383E+10
4	1.692E+08	0.000E+00	1.692E+08

Weight(500) = 5.080E+00 Ci
 Group Gamma Total
 No. X-ray Brems photon/sec

16	0.000E+00	0.000E+00	0.000E+00
19	0.000E+00	0.000E+00	0.000E+00

Totals: 3.400E+10 0.000E+00 3.400E+10

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Source          Shields          Distance to Detector, X = 1.023E+04 cm
Slab            Slab            Source Volume = 1.703E+08 cc
                Source Mass = 3.677E+08 grams
Thickness = 2.134E+02 cm  Height = 6.096E+01 cm  Width = 1.309E+04 cm
Integration Specs:  NTHETA = 15  NSPI = 15  DELR = 5.080E+00 cm
Total Intervals:  9.450E+03  (photon source is the 1st region)
Shield Thickness:  2.134E+02, 1.524E+01, 1.000E+04 cm
Distances from Dose Point to the Outside of
(1) Source Region: 1.002E+04 cm  (2) Next Layer: 1.000E+04 cm
Dose Buildup Data for Shield 2 with Effective Atomic Number 10.78
Fluence-to-Dose Conversion: Photons in Air

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Average E, MeV	Source Total photons/sec	Fluence to Dose Factor	Energy Fluence MeV/sq.cm/sec	Dose Rate R/hr
0.015	1.319E+15	8.183E-05	0.000E+00	0.000E+00
0.025	6.817E+14	1.656E-05	1.482E-09	2.454E-33
0.035	8.288E+14	6.084E-06	2.349E-08	1.429E-14
0.045	3.254E+14	3.203E-06	5.013E-04	1.606E-09
0.055	2.181E+14	2.216E-06	5.751E-02	1.274E-07
0.065	1.766E+14	1.827E-06	5.576E-01	1.019E-06
0.075	1.602E+14	1.664E-06	2.397E+00	3.989E-06
0.085	1.457E+14	1.603E-06	5.399E+00	8.655E-06
0.095	1.310E+14	1.592E-06	9.595E+00	1.528E-05
0.150	7.175E+14	1.728E-06	1.475E+02	2.549E-04
0.250	2.126E+14	1.935E-06	1.697E+02	3.284E-04
0.350	9.809E+13	2.019E-06	1.595E+02	3.220E-04
0.475	7.621E+13	2.043E-06	2.172E+02	4.436E-04
0.650	5.191E+15	2.029E-06	2.609E+04	5.293E-02
0.825	3.806E+13	1.983E-06	3.002E+02	5.953E-04
1.000	5.489E+13	1.923E-06	6.214E+02	1.195E-03
1.225	8.256E+13	1.850E-06	1.344E+03	2.486E-03
1.475	7.354E+12	1.775E-06	1.662E+02	2.950E-04
1.700	1.781E+12	1.712E-06	5.190E+01	8.885E-05
1.900	9.623E+10	1.660E-06	3.424E+00	5.684E-06
2.100	6.350E+10	1.613E-06	2.696E+00	4.349E-06
2.300	1.184E+08	1.592E-06	5.891E-03	9.379E-09
Totals:	1.047E+16 photons/sec		2.929E+04	5.898E-02 R/hr = 4.227E-09 amp/ka

Dose Equivalent Rates (rem/hr) for Other Fluence-to-Dose Factors						
Average E, Mev	Anterior DUNIT = 1	Posterior DUNIT = 2	Lateral DUNIT = 3	Rotational DUNIT = 4	Isometric DUNIT = 5	Orig ANSI DUNIT = 6
0.025	6.145E-34	2.810E-34	1.456E-34	2.989E-34	2.463E-34	4.742E-33
0.035	8.264E-15	4.785E-15	2.528E-15	4.391E-15	3.568E-15	2.938E-14
0.045	1.493E-09	9.544E-10	5.453E-10	8.451E-10	6.833E-10	3.532E-09
0.055	1.494E-07	1.012E-07	6.101E-08	8.845E-08	7.161E-08	2.867E-07
0.065	1.303E-06	9.213E-07	5.695E-07	7.970E-07	6.480E-07	2.226E-06
0.075	5.165E-06	3.786E-06	2.354E-06	3.241E-06	2.647E-06	8.255E-06
0.085	1.095E-05	8.281E-06	5.124E-06	7.018E-06	5.752E-06	1.681E-05
0.095	1.861E-05	1.446E-05	8.869E-06	1.215E-05	9.977E-06	2.785E-05
0.150	2.656E-04	2.218E-04	1.405E-04	1.903E-04	1.548E-04	3.730E-04
0.250	3.174E-04	2.625E-04	1.766E-04	2.286E-04	1.888E-04	4.283E-04
0.350	2.983E-04	2.508E-04	1.747E-04	2.205E-04	1.840E-04	4.002E-04
0.475	3.991E-04	3.430E-04	2.464E-04	3.040E-04	2.564E-04	5.105E-04
0.650	4.630E-02	4.080E-02	3.026E-02	3.644E-02	3.110E-02	5.787E-02
0.825	5.131E-04	4.607E-04	3.501E-04	4.134E-04	3.564E-04	6.262E-04
1.000	1.024E-03	9.319E-04	7.222E-04	8.391E-04	7.297E-04	1.230E-03
1.225	2.117E-03	1.952E-03	1.545E-03	1.763E-03	1.549E-03	2.509E-03
1.475	2.501E-04	2.330E-04	1.878E-04	2.110E-04	1.870E-04	2.935E-04
1.700	7.521E-05	7.055E-05	5.769E-05	6.398E-05	5.712E-05	8.769E-05
1.900	4.812E-06	4.534E-06	3.749E-06	4.117E-06	3.696E-06	5.584E-06
2.100	3.683E-06	3.482E-06	2.907E-06	3.165E-06	2.856E-06	4.256E-06
2.300	7.836E-09	7.429E-09	6.256E-09	6.759E-09	6.127E-09	9.021E-09
Totals	5.160E-02	4.556E-02	3.388E-02	4.070E-02	3.479E-02	6.440E-02

Closing: DAT'S ALL PHOLQUES!!!!!!

Finish run at 13:57:49 05/05/97

Input File (D:\ISOSHL\INPUT\BIRMLEAK.) is shown below:

```
0      2 PIPE LEAK INTO BIRM-TWELVE HOUR RELEASE
UNMITIGATED 12 HOUR RELEASE - 100 M AWAY
&INPUT NEXT=1, IGEOM=10, NTHETA=15, NPSI=15, DELR=5.0,
  T(1)=213.36, T(2)=15.24, X=10228.6, SLTH=13089.99, Y=60.96,
  IPRNT=0, OPTION=1, ISPEC=3, NSHLD=2, JBUF=2, DUNIT=7,
  WEIGHT(472)=3.02E+2, WEIGHT(082)=1.79E+6, WEIGHT(084)=1.79E+6,
  WEIGHT(335)=1.69E+5, WEIGHT(336)=1.60E+5, WEIGHT(415)=6.75E+3,
  WEIGHT(502)=6.08E+2, WEIGHT(492)=4.11E+1, WEIGHT(493)=2.71E+2,
  WEIGHT(495)=1.04E+3, WEIGHT(496)=6.75E+3, WEIGHT(500)=3.74E+1,
&
  SOIL  21 1.6      1.6
1 WATER  1 0.56
MITIGATED 12 HOUR RELEASE - 100 M AWAY
&INPUT NEXT=1, IGEOM=10, NTHETA=15, NPSI=15, DELR=5.0,
  T(1)=213.36, T(2)=15.24, X=10228.6, SLTH=13089.99, Y=60.96,
  IPRNT=0, OPTION=1, ISPEC=3, NSHLD=2, JBUF=2, DUNIT=7,
  WEIGHT(472)=2.64E+2, WEIGHT(082)=1.07E+6, WEIGHT(084)=1.07E+6,
  WEIGHT(335)=1.62E+5, WEIGHT(336)=1.53E+5, WEIGHT(415)=4.17E+3,
  WEIGHT(502)=7.74E+1, WEIGHT(492)=1.09E+2, WEIGHT(493)=2.76E+2,
  WEIGHT(495)=1.90E+3, WEIGHT(496)=8.08E+2, WEIGHT(500)=5.08E+0,
&
  SOIL  21 1.6      1.6
1 WATER  1 0.56
DAT'S ALL PHOLQUES!!!!!!
&INPUT NEXT=6, &
```

1 ,BUILDUP INDEX

16 ,QUADRATURE ORDER

"20 energies:"

2

1.7

1.475

1.225

1

.825

.65

.475

.35

.25

.15

0

0

0

0

0

0

0

0

0

"20 activities:"

267200000000

2.98e+12

1.201e+13

1.247e+14

8.945e+13

6.249e+13

5.487e+15

1.273e+14

1.64e+14

3.547e+14

1.195e+15

0

0

0

0

0

0

0

0

0

1 ,1=RESULTS EXIST 0=NO

"20 results - reference (or single) case:"

1.39225e-21

1.27566e-21

1.16583e-21

1.24592e-21

1.12573e-21

9.59863e-22

9.12636e-22

7.84988e-22

5.91555e-22

4.68345e-22

2.44705e-22

0

0

0

0

0

0

0

0

"end of results."

3 ,SOURCE MODE

"isotope bit flags:"

000

4 ,NUMBER OF ISOTOPES

"4 source inputs in curies:"

319000

603

337000

13500

"end of source inputs. 5 decay times:"

0

0

0

0

0

1 ,BUILDUP INDEX

16 ,QUADRATURE ORDER

"20 energies:"

2
1.7
1.475
1.225
1
.825
.65
.475
.35
.25
.15

0
0
0
0
0
0
0
0
0

"20 activities:"

159730000000
1.781e+12
7.354e+12
8.256e+13
5.489e+13
3.806e+13
5.191e+15
7.621e+13
9.809e+13
2.126e+14
7.175e+14

0
0
0
0
0
0
0
0
0

1 ,1=RESULTS EXIST 0=NO

"20 results - reference (or single) case:"

1.39225e-21
1.27566e-21
1.16583e-21
1.24592e-21
1.12573e-21

9.59863e-22
9.12636e-22
7.84988e-22
5.91555e-22
4.68345e-22
2.44705e-22

0
0
0
0
0
0
0
0
0

"end of results."

3 ,SOURCE MODE

"isotope bit flags:"

0000

4 ,NUMBER OF ISOTOPES

"4 source inputs in curies:"

319000

603

337000

13500

"end of source inputs. 5 decay times:"

0
0
0
0
0

DISTRIBUTION SHEET

To Distribution	From Criticality and Shielding	Page 1 of 1			
Project Title/Work Order Calculation Note for an Underground Leak which Remains Underground		Date May 12, 1997			
		EDT No. 621286			
		ECN No.			
Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only

J. C. Conner	A2-25	X	
H. J. Goldberg	H0-35	X	
J. Greenborg	H0-35	X	
J. P. Harris	S2-48	X	
B. E. Hey	A3-34	X	
R. H. Ruben	H0-35	X	
R. G. Stickney	R1-49	X	
R. J. Van Vleet	A3-34	X	
Project Files	R1-29	X	
Docket Files (2)	B1-17	X	
TWRS S&L Files (2)	A2-26	X	
Central Files (1 + Original)	A3-88	X	