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Dose Consequence Analysis for Transporting Plutonium Recycle Test Reactor (PRTR) Rupture Loop Ion Exchange Columns

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Key Words: Ion Exchange Column, 309 Building, PRTR, Dose Consequences,
SARP

Abstract: Ion exchange columns from the 309 Plutonium Recycle Test
Reactor rupture loop must be shipped to the solid waste
burial ground. The enclosed calculational note documents
the calculations used to calculate the absorbed doses
expected in the case of a postulated accident.

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**Dose Consequence Analysis for Transporting
Plutonium Recycle Test Reactor (PRTR)
Rupture Loop Ion Exchange Columns**

Harvey Goldberg
May 8, 1996

Purpose

This calculational note documents the calculation of absorbed doses expected for a postulated accident during shipment of Plutonium Recycle Test Reactor (PRTR) rupture loop ion exchange columns per Internal Memo 8M730-HJG-96-007 (Reference 1).

Methodology

The methodology of performing these calculations in support of the radiological dose section of an SARP is set forth in Reference 3. It is based on the Q-system outlined in Reference 4, originally developed for calculation of A_1/A_2 values used in the determination of packaging requirements. Reference 3 and this analysis use this methodology to determine dose, given an activity, rather than determining an activity, given a dose limit.

Assumptions

The following is written to facilitate inclusion into the SARP.

2.0 CONTENTS EVALUATION

2.1 CHARACTERIZATION

Twelve ion exchange (IX) columns from the 309 Plutonium Recycle Test Reactor (PRTR) rupture loop will be placed in three 12.23 m³ metal boxes (6'x6'x12'). These columns have been designated as a non-dangerous waste in accordance with the Washington State Dangerous Waste Regulations (Ch 173-303, Washington Administrative Code). Two of the boxes (Boxes 1 & 2) have been classified as category three and one (Box 3) will be category one. The void space existing after the IX columns are loaded into the boxes will be filled with grout.

Input Data

2.1.1 Source Term

The following source term has been supplied by the customer (Reference 12).

Table 1 Box 1 (IX Columns L3, L1, R1, and R2)(Ci)					
Isotope	L3	L1	R1	R2	Total
²⁴¹ Am	2.40e-01				2.40e-01
²³³ Pa	2.32e-06				2.32e-06
²³⁷ Np	2.32e-06				2.32e-06
²³⁴ U	1.51e-05				1.51e-05
²³⁵ U	6.69e-07				6.69e-07
²³⁶ U	3.45e-07				3.45e-07
²³⁸ U	1.55e-05				1.55e-05
²³⁸ Pu	4.25e-03				4.25e-03
²³⁹ Pu	4.91e-02				4.91e-02
²⁴⁰ Pu	2.22e-02				2.22e-02
²⁴¹ Pu	4.53e-01				4.53e-01
²⁴² Pu	6.37e-06				6.37e-06
Total TRU	7.69e-01	0.00e+00	0.00e+00	0.00e+00	7.69e-01
¹³⁷ Cs	2.10e+00	4.30e-03	1.01e-02	4.67e-01	2.58e+00
^{137m} Ba	1.99e+00	4.07e-03	9.55e-03	4.42e-01	2.45e+00
⁹⁰ Sr	3.40e-01	6.90e-04	1.60e-03	7.50e-02	4.17e-01
⁹⁰ Y	3.40e-01	6.90e-04	1.60e-03	7.50e-02	4.17e-01
⁶⁰ Co	1.33e-04	4.20e-05	8.19e-05	7.52e-04	1.01e-03
Total	5.54e+00	9.79e-03	2.29e-02	1.06e+00	6.63e+00

Table 2 Box 2 (IX Columns R3, C2, L2, and L4)(C1)					
Isotope	R3	C2	L2	L4	Total
²⁴¹ Am	3.23e-02	1.72e-01		7.54e-02	2.80e-01
²³³ Pa	3.13e-07	1.67e-06		7.31e-07	2.71e-06
²³⁷ Np	3.13e-07	1.67e-06		7.31e-07	2.71e-06
²³⁴ U	2.04e-06	1.09e-05		4.76e-06	1.77e-05
²³⁵ U	9.01e-08	4.81e-07		2.10e-07	7.81e-07
²³⁶ U	4.65e-08	2.48e-07		1.09e-07	4.04e-07
²³⁸ U	2.09e-06	1.12e-05		4.88e-06	1.82e-05
²³⁸ Pu	5.73e-04	3.06e-03		1.34e-03	4.97e-03
²³⁹ Pu	6.62e-03	3.53e-02		1.55e-02	5.74e-02
²⁴⁰ Pu	2.99e-03	1.60e-02		6.99e-03	2.60e-02
²⁴¹ Pu	6.11e-02	3.26e-01		1.43e-01	5.30e-01
²⁴² Pu	8.59e-07	4.58e-06		2.00e-06	7.44e-06
Total TRU	1.04e-01	5.52e-01	0.00e+00	2.42e-01	8.98e-01
¹³⁷ Cs	1.10e+00	3.35e-03	1.36e-01	1.08e-02	1.25e+00
^{137m} Ba	1.04e+00	3.17e-03	1.29e-01	1.02e-02	1.18e+00
⁹⁰ Sr	1.80e-01	5.40e-04	2.20e-02	1.70e-03	2.04e-01
⁹⁰ Y	1.80e-01	5.40e-04	2.20e-02	1.70e-03	2.04e-01
⁶⁰ Co	1.57e-03	8.94e-05	1.73e-04	1.24e-04	1.96e-03
Total	2.61e+00	5.60e-01	3.09e-01	2.67e-01	3.74e+00

Table 3 Box 3 (IX Columns C3, C4, R4, and R5/RLIX1)(Ci)					
Isotope	C3	C4	R4	R5/RLIX1	Total
²⁴¹ Am					0.00e+00
²³³ Pa					0.00e+00
²³⁷ Np					0.00e+00
²³⁴ U					0.00e+00
²³⁵ U					0.00e+00
²³⁶ U					0.00e+00
²³⁸ U					0.00e+00
²³⁸ Pu					0.00e+00
²³⁹ Pu					0.00e+00
²⁴⁰ Pu					0.00e+00
²⁴¹ Pu					0.00e+00
²⁴² Pu					0.00e+00
Total TRU	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
¹³⁷ Cs	1.36e-09	1.36e-09	3.76e-02		3.76e-02
^{137m} Ba	1.29e-09	1.29e-09	3.56e-02		3.56e-02
⁹⁰ Sr	2.20e-10	2.20e-10	6.00e-03		6.00e-03
⁹⁰ Y	2.20e-10	2.20e-10	6.00e-03		6.00e-03
⁶⁰ Co	1.55e-08	1.55e-08	5.32e-04	7.70e-05	6.09e-04
Total	1.86e-08	1.86e-08	8.58e-02	7.70e-05	8.58e-02

The actinides have not been decayed. However, the ⁹⁰Sr and ¹³⁷Cs have had their respective daughter products added and the short lives isotope ²³³Pa has had its precursor, ²³⁷Np added. Note that TRU stands for the english word transuranic. In regulatory parlance the acronym TRU only includes those transuranic isotopes with halflives of 20 years or more and occasionally includes some non-transuranic elements.

Calculations

4.5 DOSE CONSEQUENCES OF ACCIDENTS

4.5.1 INTRODUCTION

It has been assumed that the IX columns undergo an accident in which the enclosing box is completely compromised and one of the columns is broken open. The IX columns are cylinders of Amberlite or Duolite enclosed in a 1/8" steel enclosure. No credit was taken for the enclosure, i.e. the filter medium was assumed to be completely exposed.

Only one cylinder, the worst case cylinder (L3) was analyzed so as to provide a worst case situation which would be an upper bound on any other situation. As a more conservative scenario, the dose calculation of the dose from β -particles and photons assumes an accident where the entire worst case box (four columns) is completely released. Although the material is not flammable, an engulfing fire was analyzed as well as the non-fire situation.

The methodology is based on the IAEA Q-system (Reference 4) outlined in Reference 3 and then amended (Reference 12). The IAEA Q-system was developed as an all-encompassing generalized methodology using only the isotope as the defining variable. In this document, the specifics of the package are considered. Some of the pathways for dose may be considered as not credible and, although these pathways may be covered in the IAEA guide, they are disregarded in the analysis.

4.5.2 RESULTS

4.5.2.1 Photon Dose

In the chosen scenario the source is modeled as a point source. No credit is taken for any self-shielding by the source. The entire contents of one of the boxes is assumed to be completely released from its steel enclosure. While only one column has been assumed to be compromised, the onsite receptor is exposed to photons from the other undamaged cylinders also. Although the steel enclosures of these cylinders will decrease this exposure, no credit was taken for this diminution of the dose.

Following the assumptions of Reference 4 it was assumed that the worker stood one meter from the accident for one half of an hour. In the fire scenario the conditions remain the same, despite the fact that the conflagration would tend to strongly discourage a worker from standing within one meter of the source for this amount of time.

The computer code ISOSHL (References 5, 6, and 7) was used to calculate the dose rate one meter from the source. Bremsstrahlung from the β -particle emitting radionuclides was accounted for. The fluence-to-dose conversion factors used in the calculation were the anterior-to-posterior irradiation pattern as presented in Reference 8. The receptor is expected to receive 4.0×10^{-3} Sv (4.0×10^{-1} rem).

4.5.2.2 β -Particle Dose

The IAEA methodology (Reference 4) assumes a point source of the material for this case also. As with the photon analysis, it has been assumed in this case that an entire box is completely released. The worst case box is box 1, containing IX columns L1, L3, R1, and R2. Due to the limited range of β -particles as compared to photons, a shielding factor due to residual shielding from material such as package debris is used by the IAEA and is also adopted here. The variation of shielding factor as a function of the maximum energy of the β -particle is graphed in Reference 4. Except for this factor no effort is made to account for either self shielding or shielding from an accurate model of the damaged package. A one half hour stay time is again assumed.

The two graphs in Reference 4 have been incorporated into a spreadsheet in order to facilitate the calculational process. The total β -ray dose was calculated as 4.4×10^{-2} Sv (4.4×10^{-1} rem). Of course, this is a skin dose which, by itself is counted as an organ dose, and when being included in the EDE is multiplied by the tissue weighting factor for skin (0.01). As expected, the majority of the β -ray dose was due to ^{90}Y .

4.5.2.3 Airborne Inhalation Dose

The computer code GXQ (Reference 9) was used to calculate the Ψ/Q s for the distances and directions for the nearest site boundary. The meteorological data used were the 1983 to 1991 averages for ground (actually 10m) releases in the 200 and 300 areas. For the onsite receptor a constant distance between the release point and the receptor of 100 m was used. Since the 309 building is not a public exclusion area, the distance from the release to the receptor was also assumed to be 100 m. A value for Ψ/Q was chosen which was not exceeded more than 0.5% of the time using the NRC methodology.

The worst case of these was then chosen for each receptor and used in this analysis. Since it has been assumed that an accident would lead to the confiscation of any foodstuffs found to be contaminated, ingestion by the public was not considered. The worst case for both cases was 100 m to the north of the release in the 300 area. The Ψ/Q value used was 4.21×10^{-2} sec/ m^3 .

The computer code GENII (Reference 10) was then used to calculate the dose to the affected individual. The following libraries were accessed;

GENII Default Parameter Values (28-Mar-90 RAP)
Radionuclide Library - Times < 100 years (23-July-93 PDR)
PNL Food Transfer Factor Library (by Z, with Fr&Os 7/19/93 PDR)
Bioaccumulation Factor Library - (30-Aug-88 RAP)
External Dose Factors for GENII in person Sv/yr per Bq/n (8-May-90 RAP)
Worst-Case Solubilities, Yearly Dose Increments (23-July-93 PDR)
For the public receptors, the dose is due to the inhalation pathway alone. In order to compensate for the fact that the onsite dose was calculated at a source-to-receptor distance of 100 m, this dose was multiplied by a factor of thirty as recommended in Reference 3.

The analysis assumes that 100% of the inventory of the worst case column (L3) will be released in the accident. What fraction of this term is suspended in the air in respirable particles is quite a problem. Mishima's review of the published data (Reference 11) was used as the source of these data. For the non-fire case the value in Mishima for the free-fall drop of an enclosed HEPA filter onto a hard unyielding surface was chosen.

While these filters are not HEPA filters, it was felt that this value would be a bounding value which would not be exceeded in this case. In a HEPA filter the contamination is deposited on the surface of the filter medium, while for an ion exchange filter medium the contamination is adsorbed onto the medium. The release should not exceed that of a HEPA filter. Mishima gives an upper bound of 5×10^{-4} for the airborne release fraction (ARF), and 1.0 for the respirable fraction (RF). Thus the respirable airborne release fraction (RARF) would be 5×10^{-4} .

Mishima has also reviewed burning of ion exchange resins. These columns use a clay medium rather than a resin, however these data were used for the present situation. Only three experiments were performed yielding a set so restricted that a medium value and spread are not meaningful concepts. However, Hanford has made a practice of choosing the upper bound, which in this case is $ARF = 7.8 \times 10^{-3}$ and $RF = 9 \times 10^{-1}$, yielding a RARF of 7.0×10^{-3} . This is the value that was used in this analysis.

The results of these various terms being factored into the dose estimates leads to the following table.

Table 2: Expected Inhalation Doses in Sv (rem)					
Public			Onsite		
No Fire		Fire	No Fire		Fire
EDE		1.0×10^{-2}	1.4×10^{-1}	3.0×10^{-1}	4.2×10^{-2}
Organ Dose		1.8×10^{-1}	2.5×10^0	5.4×10^0	7.6×10^{-1}
		(1.8×10^{-1})	(2.5×10^2)	(5.4×10^2)	(7.6×10^3)

The limiting organ is the bone surfaces due to the dose from ²⁴¹Am.

4.5.2.4 Skin Contamination and Ingestion Dose

In Reference 4 it is assumed that 1% of the package contents are spread over an area of 1 m² and handling of the debris results in contamination of the hands to 10% of this level. It is also assumed that the person is not wearing gloves but that a recognition of the possibility of contamination results in a washing of the hands within a period of 5 hrs. The effective dose equivalent to the skin received by the individual is then taken from a graph in that guide.

The IAEA scenario for the uptake of activity due to ingestion of the material assumes that the person ingests all of the contamination from 10 cm² of skin over a 24 hour period. Since the dose per unit uptake via inhalation is generally the same order or larger than that via ingestion, the inhalation pathway will normally be limiting for internal contamination due to B-ray emitters. In particular, if the skin contamination dose is much larger than the inhalation dose, the ingestion pathway is not considered.

The shipments will be transported in a truck with all personnel being in the cab of the truck. All occupants of the cab are required by administrative procedure to be restrained by seat belts. Thus the accepted scenario of the accident considered is that all personnel are restrained within the cab of the truck. It is considered unlikely that the driver or any other occupant of the cab will exit from the cab and approach close enough to the spill of radioactive material to become contaminated.

Also, being in the enclosed cab during the accident would render it extremely unlikely that the material would be spilled over them in the accident. However, if the above assumptions do not hold for any particular shipment, this route of exposure will have to be evaluated.

4.2.2.5 Gaseous Vapor Dose

This term is due to submersion in a cloud of gaseous isotopes which do not become incorporated into the body. A rapid 100% release of the contents of the package is assumed. The description of this pathway in the IAEA guide concentrates entirely on releases within confining structures. No guidance is given for outside releases. However, since it has been assumed that the package considered in this document has nonexistent or negligible concentrations of these gases, the problem is moot.

This route for this particular package is not significant as there are no gaseous isotopes trapped in the material and the production rate is trivial.

4.2.2.6 Neutron Dose

The amount of TRU material is so low that neutron emissions are not of concern in this shipment. In addition to spontaneous and induced fission neutrons, neutrons from the (α ,n) reaction were considered and dismissed as negligible.

4.2.2.7 Special Considerations

Alpha particle emitters are not of significance in the material considered in this document, neither are tritium nor radon. The alpha particle emitters are of a low concentration and their effect will be through the mechanism of inhalation and ingestion. These effects have been considered separately. Bremsstrahlung has been included in the consideration of photon effects and the effects of short lived daughter products have been included in all of the calculations. Where these isotopes were significant they were assumed to be in equilibrium with their longer lived parent isotopes.

Results

4.2.2.8 Total Dose

The results of these analyses, although reported with two significant figures, can only be trusted to one. For this reason, the highest of the doses are generally chosen except when two or more dose pathways yield comparable results, in which case they are added. However, the inhalation results are the limiting case.

Table 3: Expected Total Doses in Sv (rem)				
	Public		Onsite	
	No Fire	Fire	No Fire	Fire
EDE	1.0×10^{-2} ($1.0 \times 10^{+0}$)	1.4×10^{-1} ($1.4 \times 10^{+1}$)	3.0×10^{-1} ($3.0 \times 10^{+1}$)	$4.2 \times 10^{+0}$ ($4.2 \times 10^{+2}$)
Organ Dose Bone Surface	1.8×10^{-1} ($1.8 \times 10^{+1}$)	$2.5 \times 10^{+0}$ ($2.5 \times 10^{+2}$)	$5.4 \times 10^{+0}$ ($5.4 \times 10^{+2}$)	$7.6 \times 10^{+1}$ ($7.6 \times 10^{+3}$)

Conclusions

No conclusions can be drawn from this analysis. The allowable limits on packages used in shipping are variable depending on the expected frequency of the accident under consideration. The determination of conformity to the limits is left to the customer.

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- 12) Janet Green, 1996, Private Communication

Computer Output

GXQ Version 3.1 B
June 8, 1993

General Purpose Atmospheric Dispersion Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-3002 Rev. 0.
Validation documented in WHC-SD-GN-SWD-3003 Rev. 0.
Code Custodian is Brit E. Hey, WHC, ext. 6-2921.

Run Date = 5/ 8/1995
Run Time = 13:18 11.67

INPUT ECHO:

300 Area - Worker

c GXQ Ver. 3.1 Input File

c mode

1

c

c MODE CHOICE:

c mode = 1 then X/Q based on Hanford site specific meteorology

c mode = 2 then X/Q based on atmospheric stability class and wind speed

c mode = 3 then X/Q plot file is created

c

c LOGICAL CHOICES:

c ifox inorm icdf ichk isite ipop icon

T F F F F F F

c ifox = t then joint frequency used to compute frequency to exceed X/Q

c = f then joint frequency used to compute annual average X/Q

c inorm = t then joint frequency data is normalized (as in GENII)

c = f then joint frequency data is un-normalized

c icdf = t then cumulative distribution file created (CDF.OUT)

c = f then no cumulative distribution file created

c ichk = t then X/Q parameter print option turned on

c = f then no parameter print

c isite = t then X/Q based on joint frequency data for all 16 sectors

c = f then X/Q based on joint frequency data of individual sectors

c ipop = t then X/Q is population weighted

c = f then no population weighting

c icon = t then X/Q is air concentration

c = f then X/Q is integrated exposure

c

c MODEL CHOICES:

```

c   idep  iwake ipm   irise igrav iwash iflow iwind
c       0    0    0    0    0    0    0    0
c   idep = 1 then plume depletion model turned on (Chamberlain model)
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c   irise = 1 then momentum/buoyancy plume rise model turned on, buoyancy
c       = 2 then momentum/buoyancy plume rise model turned on, buoyancy
c       = 3 then momentum/buoyancy plume rise model turned on, buoyancy
c       = 4 then momentum/buoyancy plume rise model turned on, buoyancy
c       = 5 then momentum/buoyancy plume rise model turned on, buoyancy
c   igrav = 1 then gravitational settling model turned on
c   iwash = 1 then stack downwash model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   iwind = 1 then wind speed corrected for plume height
c       = 0 to turn any of the above models off

```

c PARAMETER INPUT:

```

c   stack      wind      frequency
c   release    speed      to      scaling
c   height     height     height   exceed   factor
c   (m)        (m)        (m)      (%)      (?)
c   0.00000E+00  1.00000E+01  1.00000E+03  5.00000E-01  1.00000E+00

c   building    building    release    deposition    gravitational
c   width       height     duration   velocity     settling
c   (m)         (m)        (hr)      (m/s)        velocity
c   5.00000E+00  5.00000E+00  1.00000E+00  1.00000E-03  1.00000E-03

c   initial     initial     sensible
c   plume       plume       heat
c   density     flow        emission
c   (g/cc)      rate        rate
c   (m3/s)      (m3/s)      (m)
c   1.22000E-03  0.00000E+00  1.00000E+00  4.18000E+05

```

c RECEPTOR DEPENDENT DATA

```

c   FOR MODE make RECEPTOR DEPENDENT DATA
c   1 (site specific) sector distance z-height
c   2 (by class & wind speed) class windspeed distance offset z-height
c   3 (create plot file) class windspeed xmax ymax jmax xmin power

```


c RECEPTOR PARAMETER DESCRIPTION:

c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = meters
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = m/s
c offset = meters offset from plume centerline
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:

Site specific X/Q calculated

LOGICAL CHOICES:

Joint frequency used to calculate X/Q based on
frequency of exceedance.

No normalization of joint frequency.

X/Q calculated for single sector.

Output is atmospheric dispersion coefficient.

MODELS SELECTED:

WARNING/ERROR MESSAGES:

WARNING #3 - Scaled X/Q units (shown as s/m³ or l/m³
below) do not reflect the user specified
scaling factor.

JOINT FREQUENCY DATA:

300 AREA - 10 M - Pasquill A - G (1983 - 1991 Average)

Created 8/26/92 KR

300 Area - Worker

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	11.55	1	3.18E-02	3.18E-02	F	.89
SSW	100	0	5.07	1	1.16E-02	1.16E-02	F	2.65
SW	100	0	2.39	1	4.39E-03	4.39E-03	F	7.15
WSW	100	0	1.82	1	3.88E-03	3.88E-03	C	.89
W	100	0	4.20	1	1.51E-02	1.51E-02	E	.89
WNW	100	0	6.49	1	2.90E-02	2.90E-02	G	2.65
NW	100	0	8.60	1	3.28E-02	3.28E-02	F	.89
NNW	100	0	5.97	1	3.29E-02	3.29E-02	F	.89
N	100	0	8.76	1	4.21E-02	4.21E-02	F	.89
NNE	100	0	8.50	1	2.89E-02	2.89E-02	G	2.65
NE	100	0	9.64	1	2.93E-02	2.93E-02	G	2.65
ENE	100	0	6.13	1	1.60E-02	1.60E-02	G	4.70
E	100	0	4.55	1	3.16E-02	3.16E-02	F	.89
ESE	100	0	2.86	1	2.99E-02	2.99E-02	G	2.65
SE	100	0	5.20	1	3.16E-02	3.16E-02	F	.89
SSE	100	0	7.95	1	3.23E-02	3.23E-02	F	.89

Execution Time = 0 hr 0 min 1.05 sec

Stop - Program terminated.

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Ion Exchange Column L3 - Worker

Executed on: 03/22/96 at 11:25:14

Page A. 1

This is a far-field (wide-scale release, multiple site) scenario.
Release is acute
Individual dose

THE FOLLOWING TRANSPORT MODES ARE CONSIDERED
Air

THE FOLLOWING EXPOSURE PATHS ARE CONSIDERED:
Infinite plume, external
Inhalation uptake

THE FOLLOWING TIMES ARE USED:
Intake ends after (yr): 1.0
Dose calculations ends after (yr): 50.0

===== FILENAMES AND TITLES OF FILES/LIBRARIES USED =====

Input file name: \GENII\ix-w.in
GENII Default Parameter Values (28-Mar-90 RAP)
Radionuclide Library - Times<100 years (23-July-93 PDR)
External Dose Factors for GENII in person Sv/yr per Bq/n (8-May-90 R)
Worst-Case Solubilities, Yearly Dose Increments (23-Jul-93 PDR)
=====

-----Release Terms-----			
Release Radio- nuclide	Air Ci/yr	Surface Water Ci/yr	Buried Source Ci/m3
C060	1.3E-04	0.0E+00	0.0E+00
SR90	3.4E-01	0.0E+00	0.0E+00
Y 90	3.4E-01	0.0E+00	0.0E+00
CS137	2.1E+00	0.0E+00	0.0E+00
PA233	2.3E-06	0.0E+00	0.0E+00
U 234	1.5E-05	0.0E+00	0.0E+00
U 235	6.7E-07	0.0E+00	0.0E+00
U 236	3.4E-07	0.0E+00	0.0E+00
U 238	1.5E-05	0.0E+00	0.0E+00
NP237	2.3E-06	0.0E+00	0.0E+00
PU238	4.3E-03	0.0E+00	0.0E+00
PU239	4.9E-02	0.0E+00	0.0E+00
PU240	2.2E-02	0.0E+00	0.0E+00
PU241	4.5E-01	0.0E+00	0.0E+00
PU242	6.4E-06	0.0E+00	0.0E+00
AM241	2.4E-01	0.0E+00	0.0E+00

===== AIR TRANSPORT =====
1.0E+00 Input E/Q value (s/m3)

===== EXTERNAL EXPOSURE =====
1.0E+00 Fraction of time spent in cloud

===== INHALATION =====
Resuspension not considered

Input prepared by: _____ Date: _____

Input checked by: _____ Date: _____

=====

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Ion Exchange Column L3 - Worker

Executed on: 03/22/96 at 11:25:51

Page C. 1

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	1.2E+04	2.5E-01	3.0E+03
Breast	2.1E+01	1.5E-01	3.2E+00
R Marrow	6.7E+04	1.2E-01	8.1E+03
Lung	6.9E+03	1.2E-01	8.3E+02
Thyroid	2.1E+01	3.0E-02	6.3E-01
Bone Sur	8.6E+05	3.0E-02	2.6E+04
Liver	1.5E+05	6.0E-02	9.1E+03
LL Int.	4.2E+01	6.0E-02	2.5E+00
UL Int.	3.0E+01	6.0E-02	1.8E+00
S Int.	2.5E+01	6.0E-02	1.5E+00
Stomach	2.4E+01	6.0E-02	1.4E+00
Internal Effective Dose Equivalent			4.7E+04
External Dose			2.5E-01
Annual Effective Dose Equivalent			4.7E+04

Controlling Organ:	Bone Sur
Controlling Pathway:	Inh
Controlling Radionuclide:	AM241

Total Inhalation EDE:	4.7E+04
Total Ingestion EDE:	0.0E+00

 GENII Dose Calculation Program
 (Version 1.485 3-Dec-90)

Case title: Ion Exchange Column L3 - Worker

Executed on: 03/22/96 at 11:25:51

Page C. 2

Acute release

Uptake/exposure period:

1.0

Dose commitment period:

50.0

Dose units:

Rem

	Dose Commitment Year				
	1	2	3	...	
Internal Intake Year:	3		0.0E+00	...	
			+		
	2	0.0E+00	0.0E+00	...	Internal Effective Dose Equivalent
		+	+		
	1	2.1E+03	+ 1.4E+03	+ 1.3E+03 + ... = 4.7E+04	
Internal Annual Dose		2.1E+03	+ 1.4E+03	+ 1.3E+03 + ... = 4.7E+04	Cumulative Internal Dose
		+	+	+	
External Annual Dose		2.5E-01	0.0E+00	0.0E+00 ... 2.5E-01	
Annual Dose		2.1E+03	+ 1.4E+03	+ 1.3E+03 + ... = 4.7E+04	Cumulative Dose
				2.1E+03	Maximum Annual Dose Occurred In Year 1

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Ion Exchange Column L3 - Worker

Executed on: 03/22/96 at 11:25:51

Page C. 3

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Radio-nuclide	Inhalation Effective Dose Equivalent	Ingestion Effective Dose Equivalent	External Dose	Internal Effective Dose Equivalent	Annual Effective Dose Equivalent
CO 60	8.7E-03	0.0E+00	6.5E-05	8.7E-03	8.7E-03
SR 90	2.2E+01	0.0E+00	1.4E-05	2.2E+01	2.2E+01
Y 90	9.6E-01	0.0E+00	5.2E-04	9.6E-01	9.6E-01
CS 137	2.1E+01	0.0E+00	2.4E-01	2.1E+01	2.1E+01
PU 240	3.2E+03	0.0E+00	6.8E-07	3.2E+03	3.2E+03
U 236	1.4E-02	0.0E+00	1.1E-11	1.4E-02	1.4E-02
PU 238	5.5E+02	0.0E+00	1.4E-07	5.5E+02	5.5E+02
PU 242	8.5E-01	0.0E+00	0.0E+00	8.5E-01	8.5E-01
U 234	6.5E-01	0.0E+00	6.3E-10	6.5E-01	6.5E-01
U 238	5.8E-01	0.0E+00	4.3E-10	5.8E-01	5.8E-01
TH 234	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PA 234	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 241	1.2E+03	0.0E+00	3.4E-11	1.2E+03	1.2E+03
U 237	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
AM 241	3.5E+04	0.0E+00	5.3E-04	3.5E+04	3.5E+04
NP 237	4.8E-01	0.0E+00	0.0E+00	4.8E-01	4.8E-01
PA 233	7.3E-06	0.0E+00	1.1E-07	7.3E-06	7.4E-06
PU 239	6.9E+03	0.0E+00	1.1E-06	6.9E+03	6.9E+03
U 235	2.7E-02	0.0E+00	1.3E-08	2.7E-02	2.7E-02
TH 231	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Run started at 15:51:02 03/27/96

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

Please send questions or comments to:
Paul D. Rittmann, PhD CHP 509-376-8715
Westinghouse Hanford Company HQ-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: IX Column Transfer Box

L-3

Table of Source Activity:

Scale Factor = 1.000E+00

Isotope Name	Initial Values	Final Curies
CO- 60	1.01E-03	1.010E-03
SR- 90	4.17E-01	4.170E-01
Y - 90	4.17E-01	4.170E-01
CS-137	2.58E+00	2.580E+00
BA-137M	2.45E+00	2.450E+00
PA-233	2.32E-06	2.320E-06
U -234	1.51E-05	1.510E-05
U -235	6.69E-07	6.690E-07
U -238	1.55E-05	1.550E-05
NP-237	2.32E-06	2.320E-06
PU-238	4.25E-03	4.250E-03
PU-239	4.91E-02	4.910E-02
PU-240	2.22E-02	2.220E-02
PU-241	4.53E-01	4.530E-01
PU-242	6.37E-06	6.370E-06
AM-241	2.40E-01	2.400E-01

L-3

Shield Composition, g/cc

	Shield 1	Shield 2
AIR	0.000E+00	1.290E-03
HAN SOIL	1.000E+00	0.000E+00
Totals:	1.000E+00	1.290E-03

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

0.015	1.220E+01	2.046E-03
0.025	2.835E+00	6.138E-04
0.035	1.135E+00	3.664E-04
0.045	6.158E-01	2.837E-04
0.055	4.058E-01	2.491E-04
0.065	3.045E-01	2.314E-04
0.075	2.488E-01	2.184E-04
0.085	2.151E-01	2.090E-04
0.095	1.932E-01	2.019E-04
0.150	1.430E-01	1.758E-04
0.250	1.147E-01	1.477E-04
0.350	1.002E-01	1.298E-04
0.475	8.797E-02	1.146E-04
0.650	7.669E-02	1.001E-04
0.825	6.869E-02	8.984E-05
1.000	6.260E-02	8.194E-05
1.225	5.661E-02	7.398E-05
1.475	5.154E-02	6.718E-05
1.700	4.793E-02	6.249E-05
1.900	4.527E-02	5.889E-05
2.100	4.301E-02	5.564E-05
2.300	4.108E-02	5.263E-05
2.500	3.940E-02	5.003E-05
2.700	3.795E-02	4.778E-05
3.000	3.610E-02	4.511E-05
3.600	3.327E-02	4.158E-05
4.500	3.026E-02	3.746E-05
5.500	2.796E-02	3.381E-05
6.600	2.624E-02	3.111E-05
8.600	2.436E-02	2.771E-05

L-3

Photon Production Rate for Each Radionuclide:

ISOSHLD 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)
 Group Gamma Total
 No. X-ray Brems photon/sec

1	0.000E+00	1.155E+05	1.155E+05
2	0.000E+00	3.993E+04	3.993E+04
3	0.000E+00	2.164E+04	2.164E+04
4	0.000E+00	1.274E+04	1.274E+04
5	0.000E+00	8.219E+03	8.219E+03
6	0.000E+00	5.721E+03	5.721E+03
7	0.000E+00	3.954E+03	3.954E+03
8	0.000E+00	2.824E+03	2.824E+03
9	0.000E+00	2.050E+03	2.050E+03
10	0.000E+00	5.340E+03	5.340E+03
11	0.000E+00	1.426E+02	1.426E+02
12	0.000E+00	5.635E-02	5.635E-02
15	3.737E+03	0.000E+00	3.737E+03

Weight(472) = 1.010E-03 Ci
 Group Gamma Total
 No. X-ray Brems photon/sec

16	0.000E+00	0.000E+00	0.000E+00
17	7.474E+07	0.000E+00	7.474E+07
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: 7.474E+07 2.180E+05 7.496E+07

Nuclide 82 is SR- 90 (Z = 38)			
Group	Gamma		Total
No.	X-ray	Brems	photon/sec
1	0.000E+00	7.894E+07	7.894E+07
2	0.000E+00	4.874E+07	4.874E+07
3	0.000E+00	2.738E+07	2.738E+07
4	0.000E+00	1.368E+07	1.368E+07
5	0.000E+00	1.022E+07	1.022E+07
6	0.000E+00	7.102E+06	7.102E+06
7	0.000E+00	5.272E+06	5.272E+06
8	0.000E+00	4.179E+06	4.179E+06
9	0.000E+00	3.130E+06	3.130E+06
10	0.000E+00	1.189E+07	1.189E+07
11	0.000E+00	1.857E+06	1.857E+06
12	0.000E+00	2.680E+05	2.680E+05
13	0.000E+00	2.751E+04	2.751E+04

Weight(82) = 4.170E-01 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

Totals: 0.000E+00 2.127E+08 2.127E+08

Nuclide 84 is Y - 90 (Z = 39)			
Group	Gamma		Total
No.	X-ray	Brems	photon/sec
1	1.173E+06	5.243E+08	5.255E+08
2	0.000E+00	2.657E+08	2.657E+08
3	0.000E+00	1.654E+08	1.654E+08
4	0.000E+00	1.186E+08	1.186E+08
5	0.000E+00	8.546E+07	8.546E+07
6	0.000E+00	7.462E+07	7.462E+07
7	0.000E+00	6.900E+07	6.900E+07
8	0.000E+00	6.338E+07	6.338E+07
9	0.000E+00	5.776E+07	5.776E+07
10	0.000E+00	2.924E+08	2.924E+08
11	0.000E+00	9.160E+07	9.160E+07
12	0.000E+00	4.478E+07	4.478E+07
13	0.000E+00	3.408E+07	3.408E+07
14	0.000E+00	2.046E+07	2.046E+07
15	0.000E+00	7.322E+06	7.322E+06

Weight(84) = 4.170E-01 Ci			
Group	Gamma		Total
No.	X-ray	Brems	photon/sec
16	0.000E+00	4.935E+06	4.935E+06
17	0.000E+00	2.502E+06	2.502E+06
18	0.000E+00	8.119E+05	8.119E+05
19	5.246E+05	1.817E+05	7.062E+05
20	0.000E+00	3.951E+04	3.951E+04
21	2.160E+04	3.256E+03	2.486E+04
22	0.000E+00	4.737E+01	4.737E+01
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: 1.719E+06 1.923E+09 1.925E+09

Nuclide 335 is CS-137 (Z = 55)				Weight(335) = 2.580E+00 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	5.081E+08	5.081E+08	16	0.000E+00	1.203E+04	1.203E+04
2	0.000E+00	2.948E+08	2.948E+08	17	0.000E+00	8.789E+01	8.789E+01
3	0.000E+00	1.566E+08	1.566E+08	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	9.289E+07	9.289E+07	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	7.001E+07	7.001E+07	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	4.893E+07	4.893E+07	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	3.754E+07	3.754E+07	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	2.713E+07	2.713E+07	23	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	2.065E+07	2.065E+07	24	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	8.273E+07	8.273E+07	25	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	1.583E+07	1.583E+07	26	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	4.165E+06	4.165E+06	27	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	1.874E+06	1.874E+06	28	0.000E+00	0.000E+00	0.000E+00
14	0.000E+00	6.042E+05	6.042E+05	29	0.000E+00	0.000E+00	0.000E+00
15	0.000E+00	8.241E+04	8.241E+04	30	0.000E+00	0.000E+00	0.000E+00
-----				-----			
Totals:				0.000E+00 1.362E+09 1.362E+09			

Nuclide 336 is BA-137M (Z = 56)				Weight(336) = 2.450E+00 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
3	6.599E+09	0.000E+00	6.599E+09	18	0.000E+00	0.000E+00	0.000E+00
14	8.157E+10	0.000E+00	8.157E+10	29	0.000E+00	0.000E+00	0.000E+00
-----				-----			
Totals:				8.817E+10 0.000E+00 8.817E+10			

Nuclide 490 is PA-233 (Z = 91)
 Group Gamma Total
 No. X-ray Brems photon/sec

Weight(490) = 2.320E-06 Ci
 Group Gamma Total
 No. X-ray Brems photon/sec

1	4.199E+04	2.181E+02	4.221E+04
2	0.000E+00	7.664E+01	7.664E+01
3	0.000E+00	3.898E+01	3.898E+01
4	0.000E+00	2.104E+01	2.104E+01
5	0.000E+00	1.313E+01	1.313E+01
6	0.000E+00	8.430E+00	8.430E+00
7	1.082E+03	5.478E+00	1.087E+03
8	1.622E+03	3.738E+00	1.626E+03
9	2.439E+04	2.542E+00	2.439E+04
10	7.837E+03	6.629E+00	7.844E+03
11	2.575E+02	5.426E-01	2.581E+02
12	4.434E+04	8.045E-02	4.434E+04
13	1.391E+03	7.986E-03	1.391E+03
14	0.000E+00	1.541E-06	1.541E-06

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

Totals: 1.229E+05 3.954E+02 1.233E+05

Nuclide 520 is U -234 (Z = 92)
 Group Gamma Total
 No. X-ray Brems photon/sec

Weight(520) = 1.510E-05 Ci
 Group Gamma Total
 No. X-ray Brems photon/sec

1	5.866E+04	4.933E+00	5.867E+04
2	0.000E+00	4.609E-01	4.609E-01
3	0.000E+00	5.537E-02	5.537E-02
4	0.000E+00	1.066E-02	1.066E-02
5	6.649E+02	3.376E-03	6.649E+02
6	0.000E+00	1.013E-03	1.013E-03
7	0.000E+00	2.355E-04	2.355E-04
8	0.000E+00	3.335E-05	3.335E-05
9	0.000E+00	1.538E-06	1.538E-06
10	2.235E+02	5.702E-11	2.235E+02
13	2.235E+01	0.000E+00	2.235E+01
14	6.704E-02	0.000E+00	6.704E-02

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
28	0.000E+00	0.000E+00	0.000E+00
29	0.000E+00	0.000E+00	0.000E+00

Totals: 5.957E+04 5.465E+00 5.958E+04

Nuclide 476 is U -235 (Z = 92)				Weight(476) = 6.690E-07 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	7.651E+03	1.340E+00	7.652E+03	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	3.397E-01	3.397E-01	17	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	1.251E-01	1.251E-01	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	5.405E-02	5.405E-02	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	2.595E-02	2.595E-02	20	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	1.322E-02	1.322E-02	21	0.000E+00	0.000E+00	0.000E+00
7	2.723E+01	6.961E-03	2.724E+01	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	3.653E-03	3.653E-03	23	0.000E+00	0.000E+00	0.000E+00
9	1.780E+03	1.899E-03	1.780E+03	24	0.000E+00	0.000E+00	0.000E+00
10	1.835E+04	3.356E-03	1.835E+04	25	0.000E+00	0.000E+00	0.000E+00
11	1.500E+03	0.000E+00	1.500E+03	26	0.000E+00	0.000E+00	0.000E+00
12	3.218E+01	0.000E+00	3.218E+01	27	0.000E+00	0.000E+00	0.000E+00
13	2.970E+00	0.000E+00	2.970E+00	28	0.000E+00	0.000E+00	0.000E+00
14	9.901E-02	0.000E+00	9.901E-02	29	0.000E+00	0.000E+00	0.000E+00
15	1.485E-01	0.000E+00	1.485E-01	30	0.000E+00	0.000E+00	0.000E+00
Totals: 2.934E+04 1.914E+00 2.934E+04							

Nuclide 526 is U -238 (Z = 92)				Weight(526) = 1.550E-05 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	5.064E+04	2.929E+00	5.064E+04	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	2.422E-01	2.422E-01	17	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	2.754E-02	2.754E-02	18	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	6.281E-03	6.281E-03	19	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	1.722E-03	1.722E-03	20	0.000E+00	0.000E+00	0.000E+00
6	5.735E+02	3.554E-04	5.735E+02	21	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	4.507E-05	4.507E-05	22	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	2.182E-06	2.182E-06	23	0.000E+00	0.000E+00	0.000E+00
Totals: 5.121E+04 3.207E+00 5.122E+04							

Nuclide 502 is NP-237 (Z = 93)

Group	Gamma		Total
No.	X-ray	Brems	photon/sec
1	5.081E+04	6.135E+00	5.081E+04
2	1.201E+04	1.077E+00	1.201E+04
3	0.000E+00	2.517E-01	2.517E-01
4	1.202E+02	6.741E-02	1.202E+02
5	3.605E+02	2.033E-02	3.605E+02
6	0.000E+00	6.598E-03	6.598E-03
7	0.000E+00	2.208E-03	2.208E-03
8	1.095E+04	7.131E-04	1.095E+04
9	4.292E+03	1.750E-04	4.292E+03
10	2.833E+03	6.816E-05	2.833E+03
11	1.373E+02	0.000E+00	1.373E+02

Weight(502) = 2.320E-06 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

Totals: 8.151E+04 7.562E+00 8.152E+04

Nuclide 492 is PU-238 (Z = 94)

Group	Gamma		Total
No.	X-ray	Brems	photon/sec
1	1.824E+07	0.000E+00	1.824E+07
4	6.290E+04	0.000E+00	6.290E+04
10	1.572E+04	0.000E+00	1.572E+04

Weight(492) = 4.250E-03 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
25	0.000E+00	0.000E+00	0.000E+00

Totals: 1.832E+07 0.000E+00 1.832E+07

Nuclide 493 is PU-239 (Z = 94)

Group	Gamma		Total
No.	X-ray	Brems	photon/sec
1	7.993E+07	0.000E+00	7.993E+07
3	3.633E+04	0.000E+00	3.633E+04
4	1.036E+04	0.000E+00	1.036E+04
5	5.268E+03	0.000E+00	5.268E+03
6	5.995E+03	0.000E+00	5.995E+03
7	5.632E+03	0.000E+00	5.632E+03
8	2.362E+02	0.000E+00	2.362E+02
9	4.905E+03	0.000E+00	4.905E+03
10	1.363E+05	0.000E+00	1.363E+05
11	9.265E+03	0.000E+00	9.265E+03
12	6.540E+04	0.000E+00	6.540E+04
13	3.088E+04	0.000E+00	3.088E+04
14	1.163E+03	0.000E+00	1.163E+03
15	2.725E+02	0.000E+00	2.725E+02

Weight(493) = 4.910E-02 Ci

Group	Gamma		Total
No.	X-ray	Brems	photon/sec
16	3.815E+00	0.000E+00	3.815E+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: 8.025E+07 0.000E+00 8.025E+07

Nuclide 494 is PU-240 (Z = 94)				Weight(494) = 2.220E-02 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
4	3.696E+05	0.000E+00	3.696E+05	19	0.000E+00	0.000E+00	0.000E+00
10	6.243E+04	0.000E+00	6.243E+04	25	0.000E+00	0.000E+00	0.000E+00
14	1.479E+02	0.000E+00	1.479E+02	29	0.000E+00	0.000E+00	0.000E+00
Totals: 4.322E+05 0.000E+00 4.322E+05							

Nuclide 495 is PU-241 (Z = 94)				Weight(495) = 4.530E-01 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	0.000E+00	3.031E+04	3.031E+04	16	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	2.870E-01	2.870E-01	17	0.000E+00	0.000E+00	0.000E+00
4	9.386E+02	0.000E+00	9.386E+02	19	0.000E+00	0.000E+00	0.000E+00
5	6.202E+02	0.000E+00	6.202E+02	20	0.000E+00	0.000E+00	0.000E+00
7	4.525E+03	0.000E+00	4.525E+03	22	0.000E+00	0.000E+00	0.000E+00
10	2.011E+05	0.000E+00	2.011E+05	25	0.000E+00	0.000E+00	0.000E+00
Totals: 2.072E+05 3.031E+04 2.375E+05							

Nuclide 497 is PU-242 (Z = 94)				Weight(497) = 6.370E-06 Ci			
Group	Gamma		Total	Group	Gamma		Total
No.	X-ray	Brems	photon/sec	No.	X-ray	Brems	photon/sec
1	5.657E+04	0.000E+00	5.657E+04	16	0.000E+00	0.000E+00	0.000E+00
4	9.428E+01	0.000E+00	9.428E+01	19	0.000E+00	0.000E+00	0.000E+00
Totals: 5.666E+04 0.000E+00 5.666E+04							

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

Weight(496) = 2.400E-01 Ci
 Group Gamma Total
 No. X-ray Brems photon/sec

1	3.818E+09	1.800E+05	3.819E+09
2	2.131E+08	1.877E+04	2.131E+08
3	9.768E+06	2.216E+03	9.770E+06
4	7.992E+06	2.420E+02	7.992E+06
5	3.170E+09	3.672E+01	3.170E+09
6	1.776E+05	6.943E+00	1.776E+05
7	0.000E+00	9.894E-01	9.894E-01
8	0.000E+00	6.526E-02	6.526E-02
9	1.865E+06	4.553E-04	1.865E+06
10	2.486E+06	0.000E+00	2.486E+06
11	7.637E+04	0.000E+00	7.637E+04
12	1.154E+05	0.000E+00	1.154E+05
13	6.926E+03	0.000E+00	6.926E+03
14	6.127E+04	0.000E+00	6.127E+04
15	1.954E+03	0.000E+00	1.954E+03

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: 7.224E+09 2.012E+05 7.224E+09

(-3

```
Source          Shields      Distance to Detector, X = 9.910E+01 cm
Spherical       Spherical
                Source Volume = 3.054E+00 cc
                Source Mass   = 3.054E+00 grams
Shield Thickness: 9.000E-01, 9.820E+01 cm
Distances from Dose Point to the Outside of
(1) Source Region: 9.820E+01 cm    (2) Next Layer: 1.550E-06 cm
Dose Buildup Data for Shield 1 with Effective Atomic Number 10.78
Fluence-to-Dose Conversion: Frontal (AP)
```

Average E, MeV	Source Total photons/sec	Fluence to Dose Factor	Energy Fluence MeV/sq.cm/sec	Dose Rate rem/hr
0.015	5.030E+09	3.871E-06	5.684E+01	2.200E-04
0.025	8.224E+08	4.148E-06	7.015E+01	2.909E-04
0.035	6.959E+09	3.518E-06	1.426E+03	5.015E-03
0.045	2.337E+08	2.979E-06	7.686E+01	2.289E-04
0.055	3.336E+09	2.598E-06	1.482E+03	3.849E-03
0.065	1.308E+08	2.336E-06	7.147E+01	1.670E-04
0.075	1.118E+08	2.155E-06	7.226E+01	1.557E-04
0.085	9.470E+07	2.028E-06	7.068E+01	1.433E-04
0.095	8.345E+07	1.940E-06	7.072E+01	1.372E-04
0.150	3.900E+08	1.801E-06	5.079E+02	9.146E-04
0.250	1.094E+08	1.870E-06	2.388E+02	4.467E-04
0.350	4.944E+07	1.870E-06	1.493E+02	2.793E-04
0.475	3.602E+07	1.838E-06	1.447E+02	2.660E-04
0.650	8.159E+07	1.775E-06	4.408E+05	7.824E-01
0.825	7.410E+06	1.709E-06	5.035E+01	8.606E-05
1.000	4.947E+06	1.647E-06	4.050E+01	6.671E-05
1.225	7.724E+07	1.575E-06	7.700E+02	1.213E-03
1.475	8.119E+05	1.505E-06	9.705E+00	1.460E-05
1.700	7.062E+05	1.449E-06	9.708E+00	1.407E-05
1.900	3.951E+04	1.405E-06	6.061E-01	8.518E-07
2.100	2.486E+04	1.366E-06	4.210E-01	5.750E-07
2.300	4.737E+01	1.330E-06	8.779E-04	1.168E-09
Totals:	9.906E+10 photons/sec		4.461E+05	7.959E-01 rem/hr = 7.959E-03 Sv/hr

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

Finish run at 15:51:07 03/27/96

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

```
0      2 IX Column Transfer Box
L-3
&INPUT NEXT=1, IGEOM=3, NSHLD=1, JBUF=1, DUNIT=1,
  T(1)=.90, X=99.1, IPRNT=0, OPTION=1, ISPEC=3,
  WEIGHT(496)=2.40E-01, WEIGHT(490)=2.32E-06, WEIGHT(520)=1.51E-05,
  WEIGHT(476)=6.69E-07, WEIGHT(526)=1.55E-05, WEIGHT(492)=4.25E-03,
  WEIGHT(493)=4.91E-02, WEIGHT(494)=2.22E-02, WEIGHT(495)=4.53E-01,
  WEIGHT(497)=6.37E-06, WEIGHT(335)=2.58E+00, WEIGHT(336)=2.45E+00,
  WEIGHT(082)=4.17E-01, WEIGHT(084)=4.17E-01, WEIGHT(472)=1.01E-03,
  WEIGHT(502)=2.32E-06, &
1 SOURCE21 1.00
DAT'S ALL PHOLQUES!!!!!!
&INPUT NEXT=6, &
```

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED

NUMBER: WHC-SD-WM-CN-024TITLE: CALCULATIONAL NOTE IN SUPPORT OF INTERNAL MEMO 8M730-HJG-96-007Reviewer(s): P. D. Rittmann

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
- ☐ Hand calculations checked for errors
- ☐ Assumptions explicitly stated and justified
- ☐ Computer software appropriate for task and used within range of validity
- ☐ 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
- ☐ Conclusions consistent with analytical results and established limits
- ☐ Uncertainty assessment appropriate and reasonable
- ☐ Other (define) _____

III. Comments: _____

IV. REVIEWER: _____

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED

NUMBER: WHC-SD-WM-CN-024TITLE: CALCULATIONAL NOTE IN SUPPORT OF INTERNAL MEMO 8M730-HJG-96-007Reviewer(s): D. E. Lessor

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
- ☐ Hand calculations checked for errors
- ☐ Assumptions explicitly stated and justified
- ☐ Computer software appropriate for task and used within range of validity
- ☐ 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
- ☐ Conclusions consistent with analytical results and established limits
- ☐ Uncertainty assessment appropriate and reasonable
- ☐ Other (define) _____

III. Comments: _____

IV. REVIEWER: _____

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document Reviewed:

CALCULATIONAL NOTE IN SUPPORT OF INTERNAL MEMO 8M730-HJG-96-007

Submitted by: H. J. Goldberg Date Submitted: May 2 1996

Scope of Review: GXQ and GENII Calculations

YES NO* N/A

☐	☐	☐	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
☐	☐	☐	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
☐	☐	☐	3.	HEDOP-approved code(s) were used.
☐	☐	☐	4.	Receptor locations were selected according to HEDOP recommendations.
☐	☐	☐	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
☐	☐	☐	6.	Hanford site data were used.
☐	☐	☐	7.	Model adjustments external to the computer program were justified and performed correctly.
☐	☐	☐	8.	The analysis is consistent with HEDOP recommendations.
☐	☐	☐	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
☐	☐		10.	Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "NO" responses must be explained and use of nonstandard methods justified.

Reviewer Name: Paul D. Rittmann, B.A., M.S., Ph.D., C.H.P.
(print or type)

HEDOP-Approved Reviewer (Signature)

Date

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		ECN No.			
Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only

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