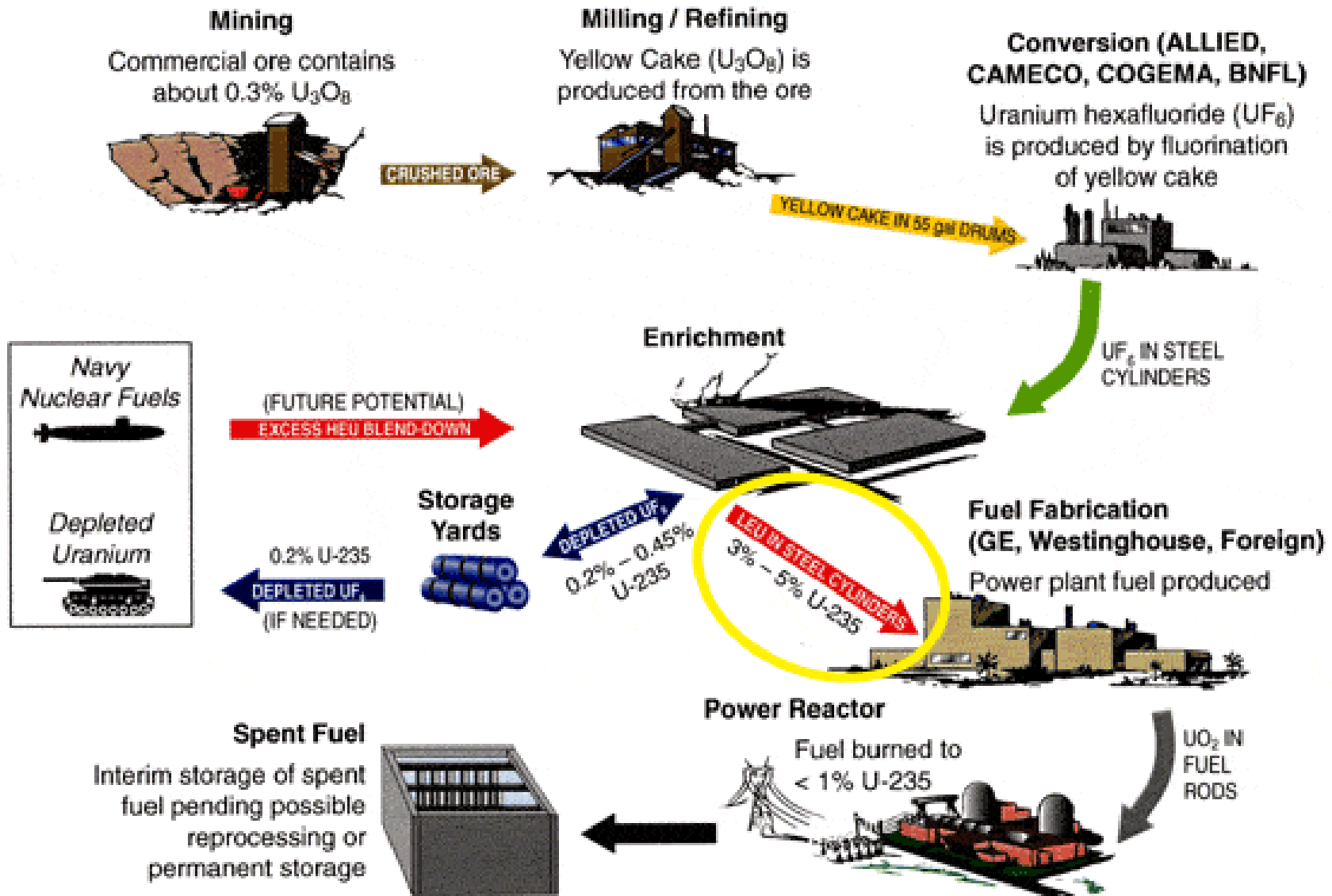


Recycled Uranium Photon Dose Determination

Presented by Allen Mabry, CHP
February 22, 2007
NCHPS Spring Meeting
Charlotte, NC





Low Enriched Uranium

$< 5\% \text{ }^{235}\text{U}$

SpA = 1 to 3 $\mu\text{Ci/g}$

Mainly α

Low level $\beta\gamma$

DDE $< 5 \text{ mrem/hr}$

CEDE_{Inhalation} ; 26 rem/ μCi



Reprocessed Uranium

$< 5\% \text{ }^{235}\text{U}$

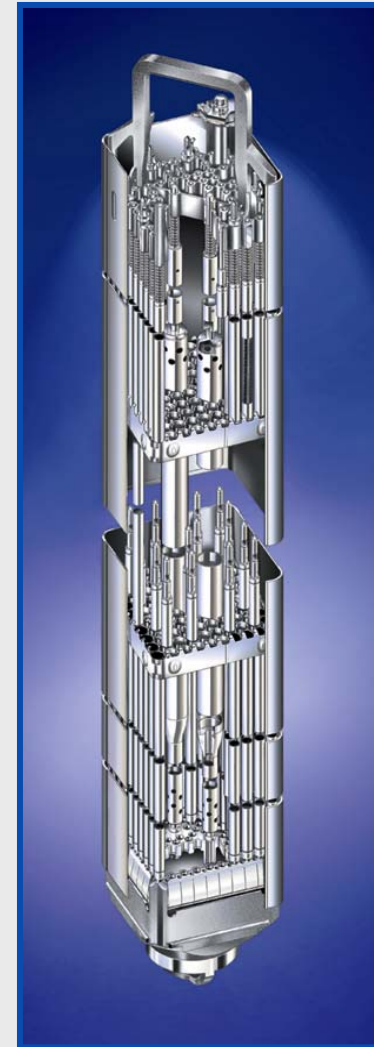
SpA = 5 to 10 $\mu\text{Ci/g}$

Mainly α

Significant $\beta\gamma$

DDE = 5 to 100 mrem/hr

CEDE is the same, but the higher SpA can result in more exposure.



GNF

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ALARA

Current ops:

- > Individual DDE from 0 to 500 mrem/yr
- > Collective DDE ~ 10 rem/yr
- > Collective CEDE ~ 50 rem/yr



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High radiation area considerations

Access controls

Alarms, visible or audible

Interlock(s) that reduce dose rate



Transportation

Type B package

Will the higher dose rate meet DOT limits?

Footnote (g): applies to unirradiated uranium only

§ 173.435

49 CFR Ch. I (10-1-06 Edition)

Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TBq/g)	(Ci/g)
Tl-204	1.0×10 ¹	2.7×10 ²	7.0×10 ⁻¹	1.9×10 ¹	1.7×10 ¹	4.6×10 ²
Tm-167	Thulium (69)	7.0	1.9×10 ²	8.0×10 ⁻¹	2.2×10 ¹	3.1×10 ³	8.5×10 ⁴
Tm-170	3.0	8.1×10 ¹	6.0×10 ⁻¹	1.6×10 ¹	2.2×10 ²	6.0×10 ³
Tm-171	4.0×10 ¹	1.1×10 ³	4.0×10 ¹	1.1×10 ³	4.0×10 ¹	1.1×10 ³
U-230 (fast lung absorption) (a)(d).	Uranium (92)	4.0×10 ¹	1.1×10 ³	1.0×10 ⁻¹	2.7	1.0×10 ³	2.7×10 ⁴
U-230 (medium lung absorption) (a)(e).	4.0×10 ¹	1.1×10 ³	4.0×10 ⁻³	1.1×10 ⁻¹	1.0×10 ³	2.7×10 ⁴
U-230 (slow lung absorption) (a)(f).	3.0×10 ¹	8.1×10 ²	3.0×10 ⁻³	8.1×10 ⁻²	1.0×10 ³	2.7×10 ⁴
U-232 (fast lung absorption) (d).	4.0×10 ¹	1.1×10 ³	1.0×10 ⁻²	2.7×10 ⁻¹	8.3×10 ⁻¹	2.2×10 ¹
U-232 (medium lung absorption) (e).	4.0×10 ¹	1.1×10 ³	7.0×10 ⁻³	1.9×10 ⁻¹	8.3×10 ⁻¹	2.2×10 ¹
U-232 (slow lung absorption) (f).	1.0×10 ¹	2.7×10 ²	1.0×10 ⁻³	2.7×10 ⁻²	8.3×10 ⁻¹	2.2×10 ¹
U-233 (fast lung absorption) (d).	4.0×10 ¹	1.1×10 ³	9.0×10 ⁻²	2.4	3.6×10 ⁻⁴	9.7×10 ⁻³
U-233 (medium lung absorption) (e).	4.0×10 ¹	1.1×10 ³	2.0×10 ⁻²	5.4×10 ⁻¹	3.6×10 ⁻⁴	9.7×10 ⁻³
U-233 (slow lung absorption) (f).	4.0×10 ¹	1.1×10 ³	6.0×10 ⁻³	1.6×10 ⁻¹	3.6×10 ⁻⁴	9.7×10 ⁻³
U-234 (fast lung absorption) (d).	4.0×10 ¹	1.1×10 ³	9.0×10 ⁻²	2.4	2.3×10 ⁻⁴	6.2×10 ⁻³
U-234 (medium lung absorption) (e).	4.0×10 ¹	1.1×10 ³	2.0×10 ⁻²	5.4×10 ⁻¹	2.3×10 ⁻⁴	6.2×10 ⁻³
U-234 (slow lung absorption) (f).	4.0×10 ¹	1.1×10 ³	6.0×10 ⁻³	1.6×10 ⁻¹	2.3×10 ⁻⁴	6.2×10 ⁻³
U-235 (all lung absorption types) (a),(d),(e),(f).	Unlimited	Unlimited	Unlimited	Unlimited	8.0×10 ⁻⁸	2.2×10 ⁻⁶
U-236 (fast lung absorption) (d).	Unlimited	Unlimited	Unlimited	Unlimited	2.4×10 ⁻⁶	6.5×10 ⁻⁵
U-236 (medium lung absorption) (e).	4.0×10 ¹	1.1×10 ³	2.0×10 ⁻²	5.4×10 ⁻¹	2.4×10 ⁻⁶	6.5×10 ⁻⁵
U-236 (slow lung absorption) (f).	4.0×10 ¹	1.1×10 ³	6.0×10 ⁻³	1.6×10 ⁻¹	2.4×10 ⁻⁶	6.5×10 ⁻⁵

U (enriched to 20% or less)(g).

Unlimited

Unlimited

Unlimited

Unlimited

U (dep)	Unlimited	Unlimited	Unlimited	Unlimited	see § 173.434	see § 173.434
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Contaminants

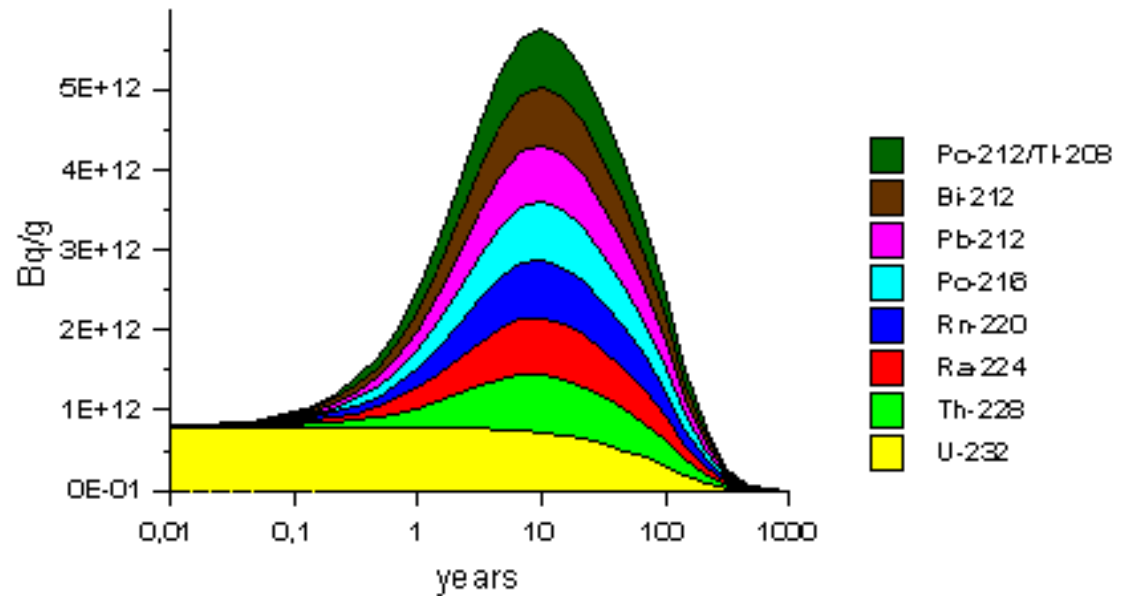
Ru-106

U-232

Np-237

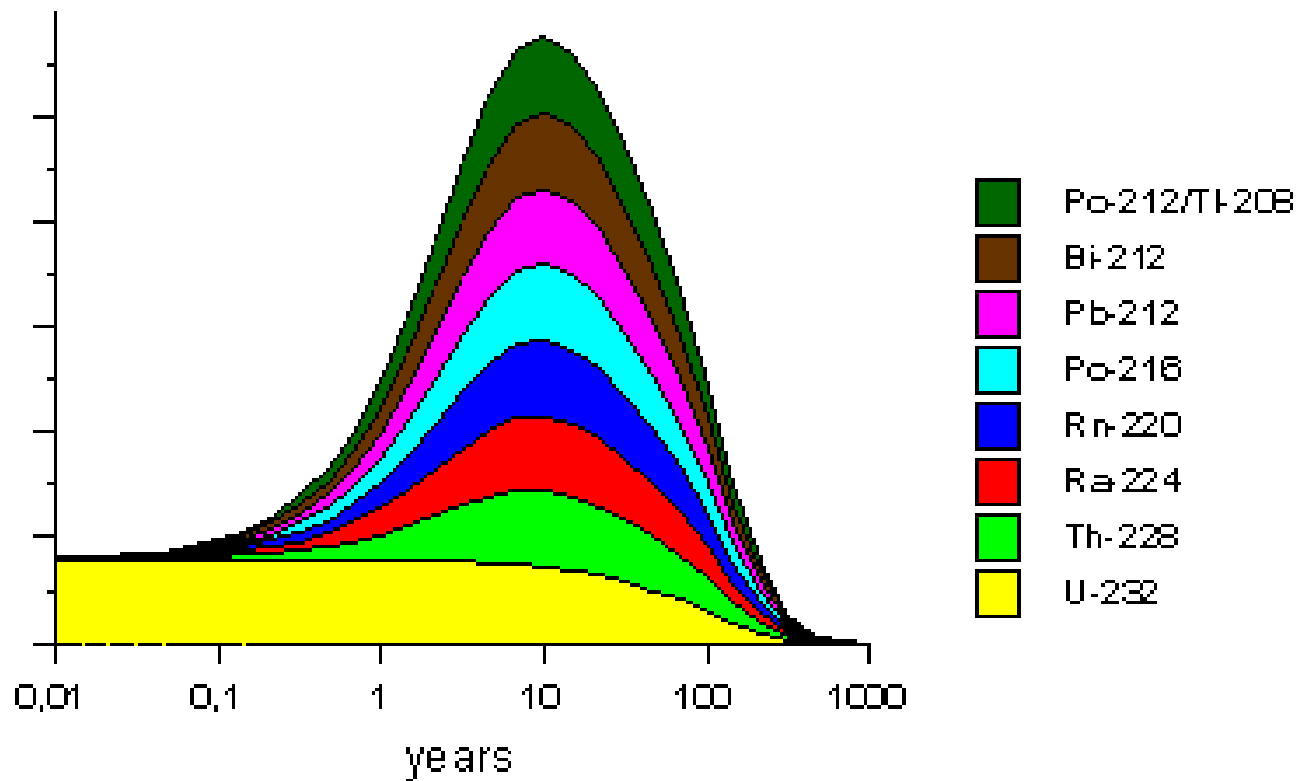
Tc-99

U-232 Series Activity
(stacked diagram)



U-232 Series Activity

(stacked diagram)



^{232}U contaminant level

Contaminant level ranges from 1 to 12 ppb

10 ppb ^{232}U contaminant level equates to about 320 mCi of ^{232}U in a standard UF6 cylinder containing 1,500 kg of uranium

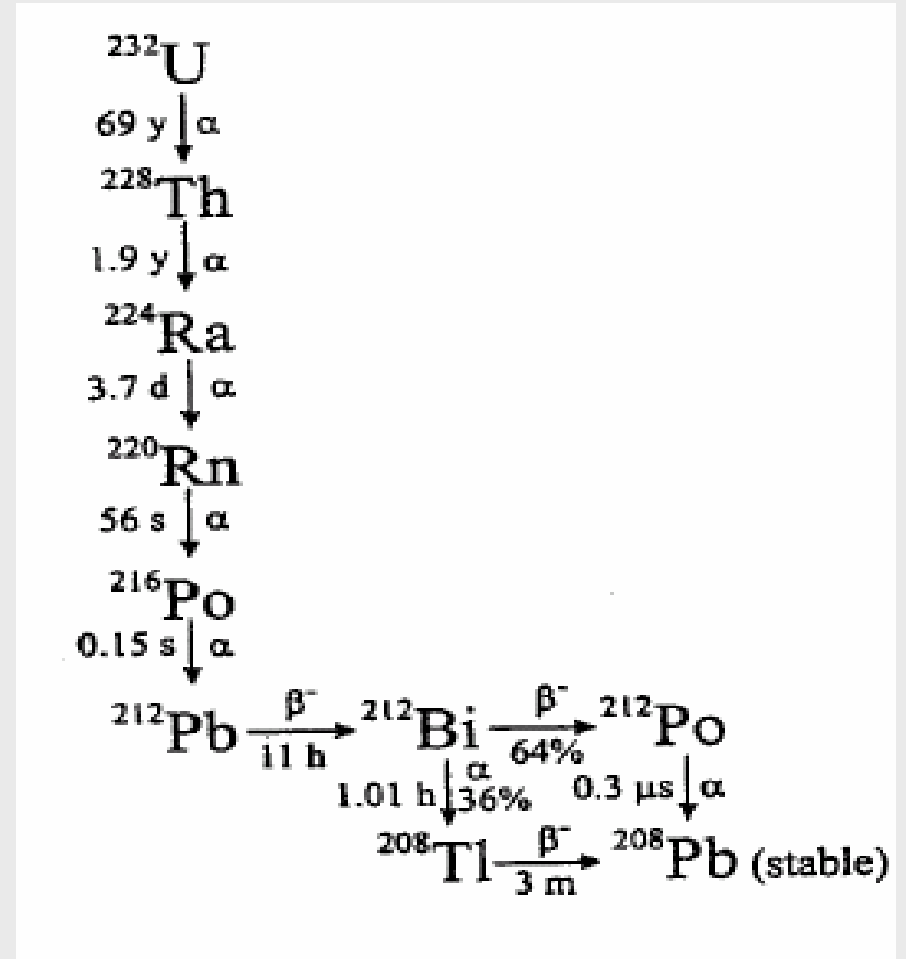
- .015 g ^{232}U
- ^{232}U specific activity is 21.42 Ci/g

^{208}Tl

3 min. half-life

2.6 MeV gamma

36% branching from
 ^{212}Bi decay

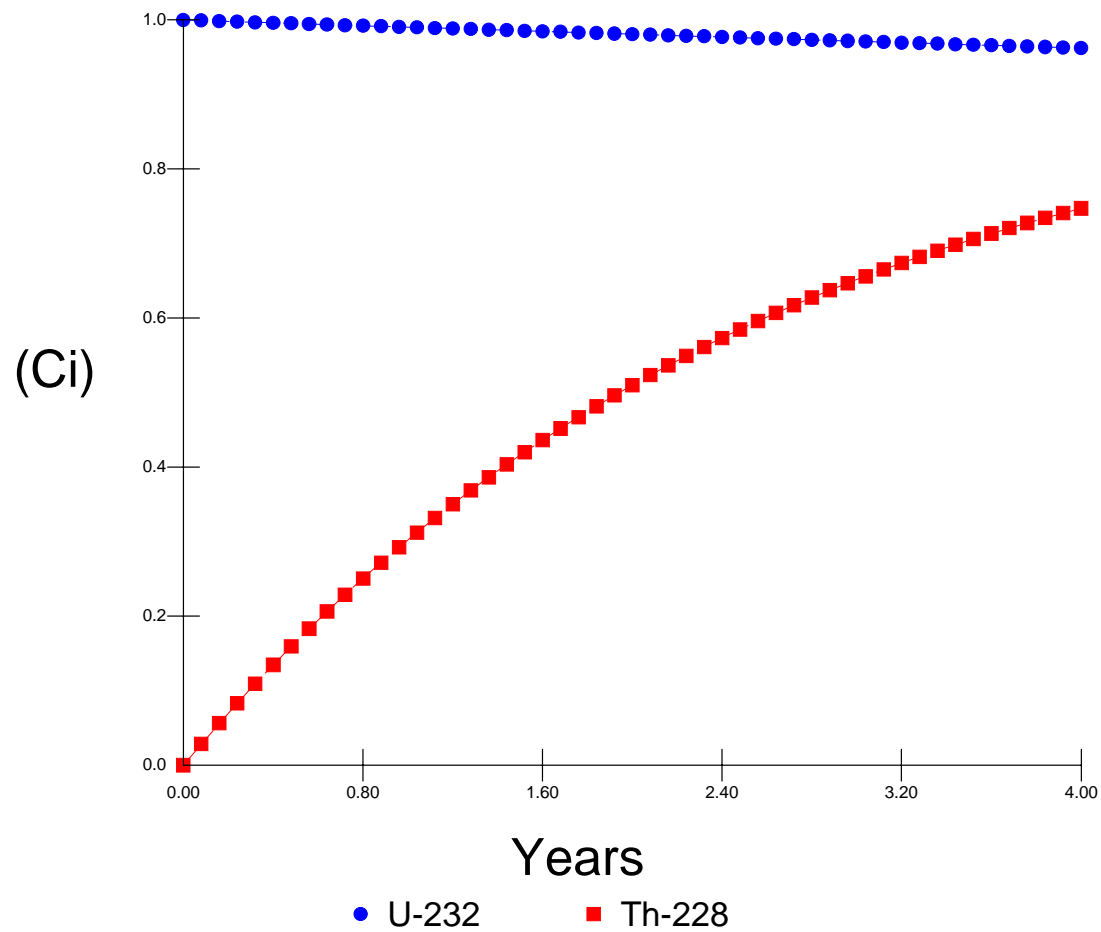


^{208}Tl Activity calculation

$$A_{\text{Tl}208} = A_{\text{U}232} * \left(1 - e^{-\lambda_{\text{Th}228}t}\right) * 0.36$$

Months	Tl-208 (mCi)
1	3.443347
6	19.18085
12	35.17803
18	48.51997
24	59.64739
30	68.92787
36	76.66795
42	83.12332
48	88.50722

Decay Graph of U-232



Model 30B UF₆ cylinder

Diameter	30"
Length	76"
Wall Thickness	1/2"
Material	steel



2,277 kg UF₆ max.

Full UF₆ cylinder dose rate

Self shielding by uranium is significant

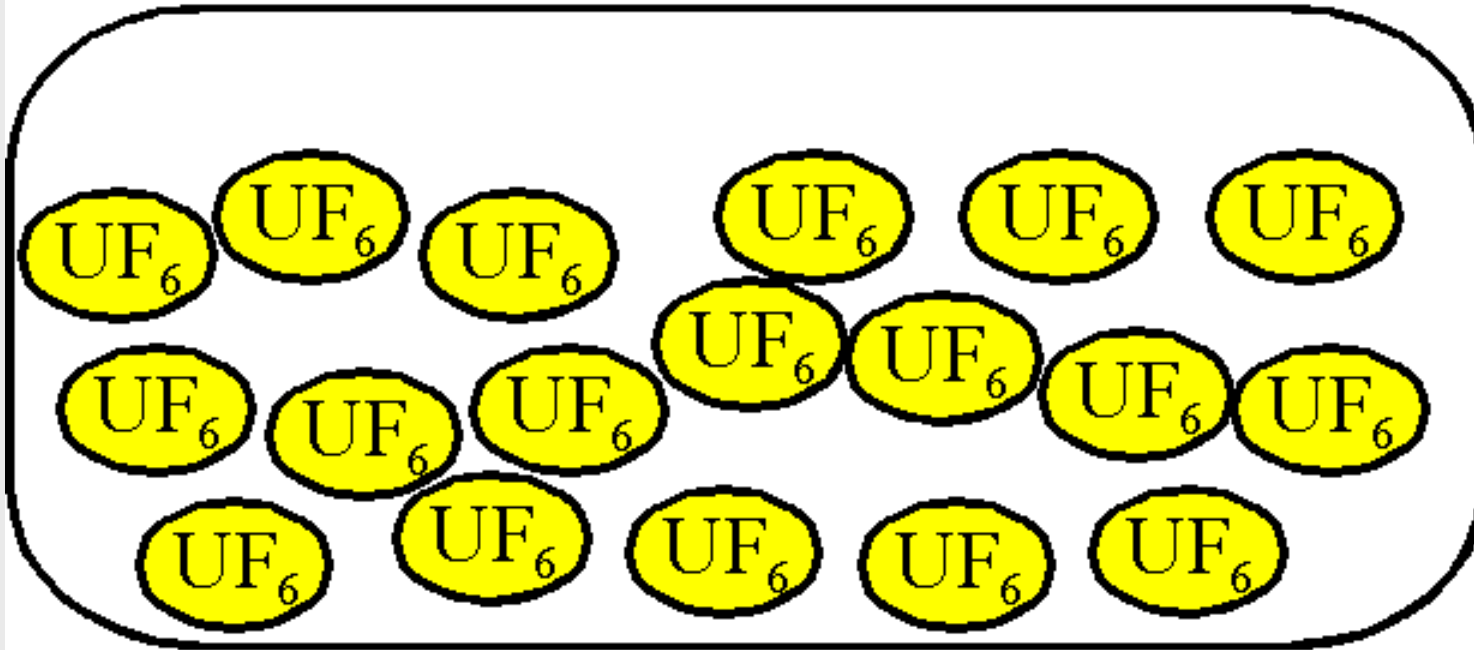
Typically 1 to 5 mrem/hr contact

RU cylinder calculated with MCNP:

1 to 20 mrem/hr contact depending on age up to 48 months

Not a worker dose or transportation issue

Vaporization animation

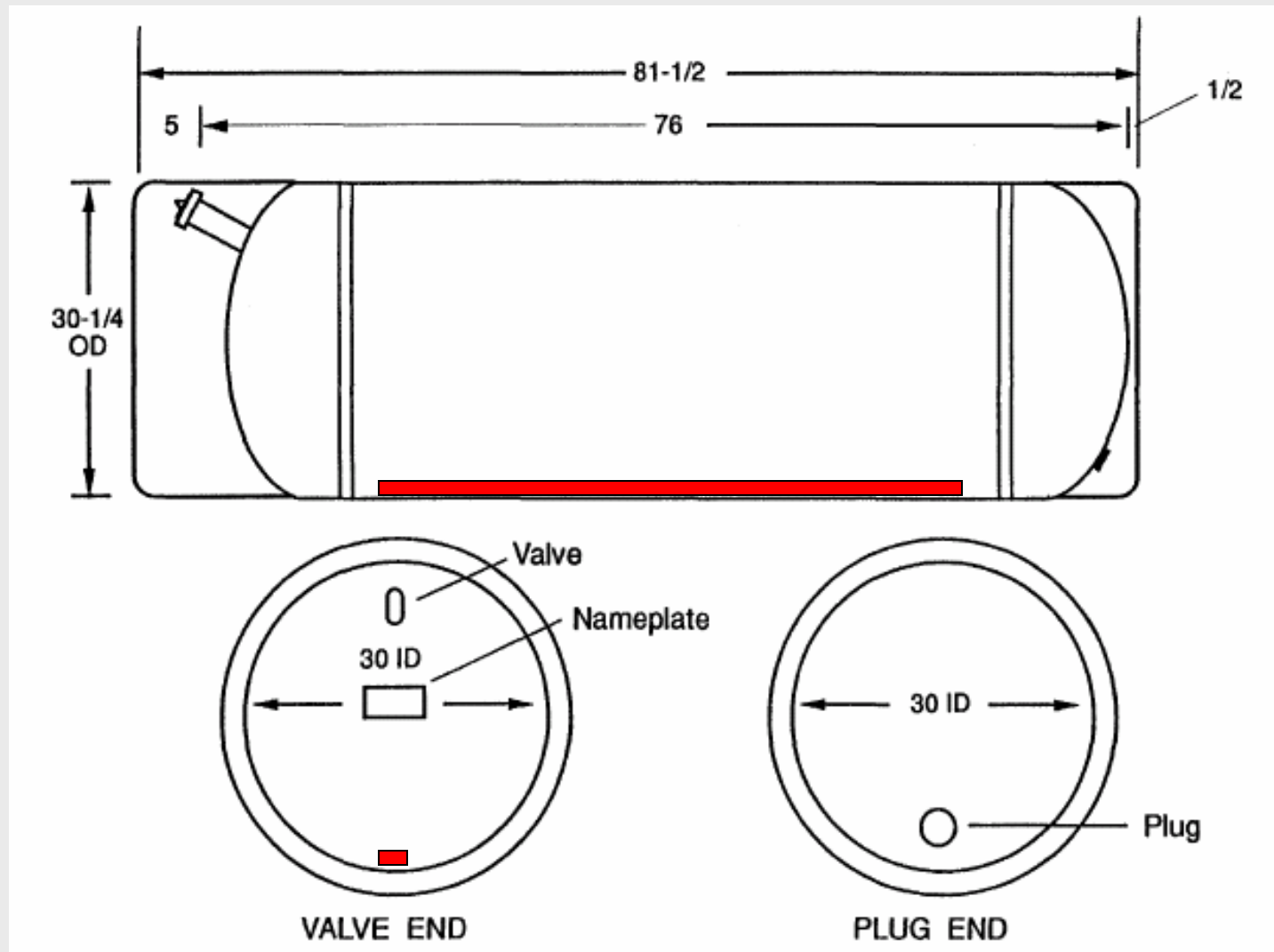


GNF-J measurements

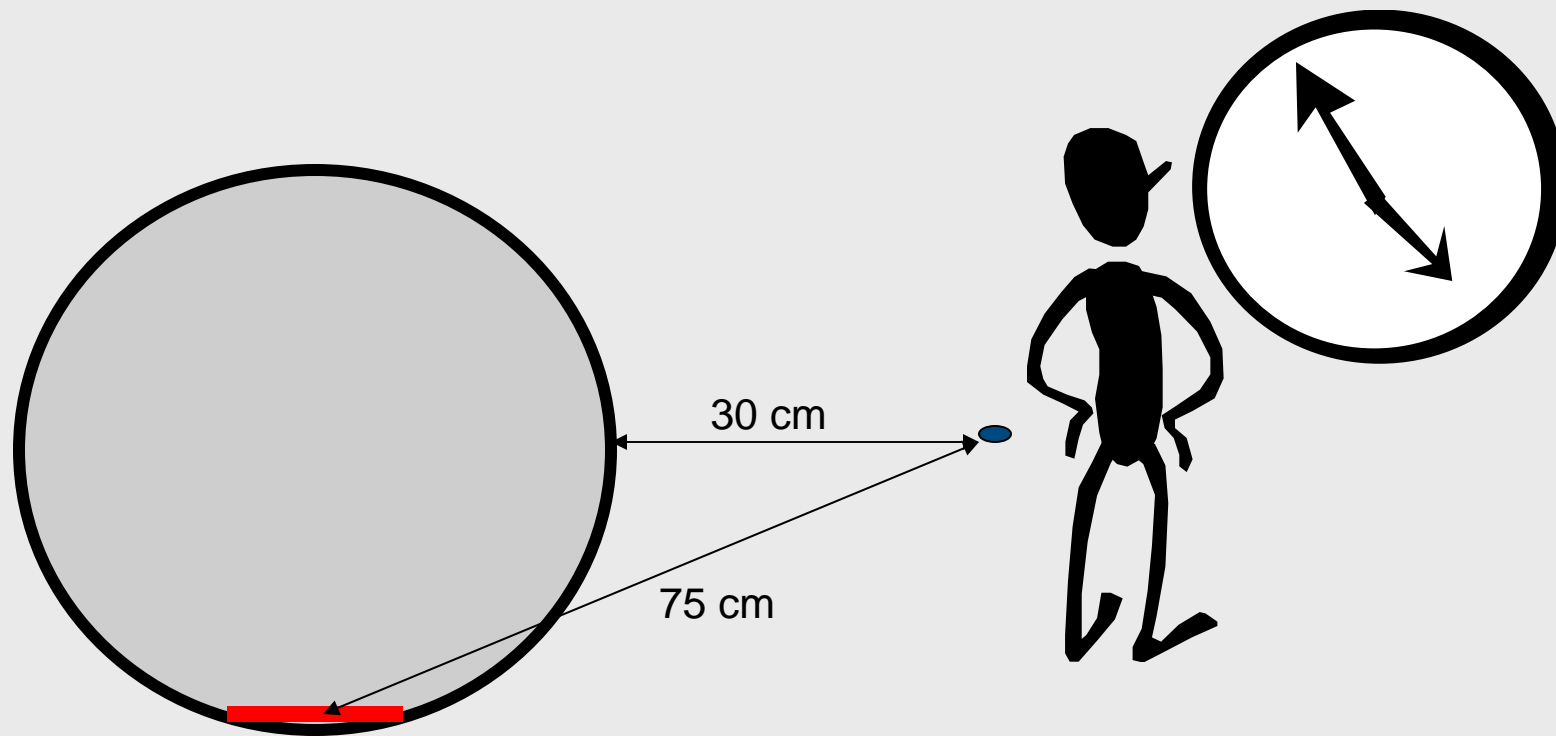
	Bottom Surface mrem/hr	Side Surface mrem/hr	Side 1 M mrem/hr
Max.	1,200	270	12
Min.	720	140	6.5
Avg.	953	180	9.3

- 8 “empty” RU cylinders
- 3-4 ppb ²³²U
- aged 48 months prior to emptying

Model 30B UF₆ cylinder

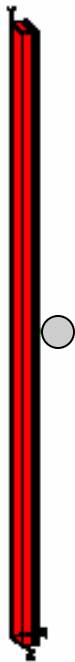


Source to detector geometry



MicroShield[®] case: contact

Case Title: Case 1
Description: Case 1
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	2.54 cm	1.0 in
Width	7.62 cm	3.0 in
Height	152.4 cm	5 ft 0.0 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	5.08 cm 2.0 in	76.2 cm 2 ft 6.0 in	3.81 cm 1.5 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	2949.672 cm ³	Uranium	5
Shield 1	1.27 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input

Grouping Method : Actual Photon Energies

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Tl-208	1.0000e-003	3.7000e+007	3.3902e-001	1.2544e+004

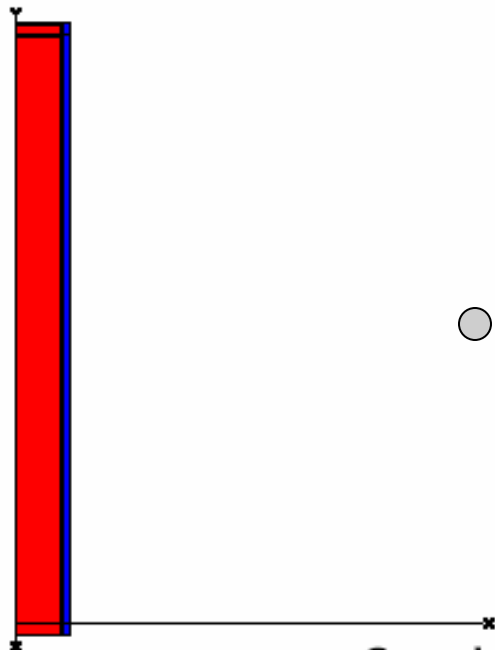


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MicroShield[®] case: 30 cm

Case Title: Case 1
Description: Case 1
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	7.62 cm	3.0 in
Width	2.54 cm	1.0 in
Height	152.4 cm	5 ft 0.0 in

Dose Points

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	75.184 cm 2 ft 5.6 in	76.2 cm 2 ft 6.0 in	1.27 cm 0.5 in

Shields

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	180.0 in ³	Uranium	5
Shield 1	.5 in	Iron	7.86
Air Gap		Air	0.00122

Source Input

Grouping Method : Actual Photon Energies

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm³</u>	<u>Bq/cm³</u>
Tl-208	1.0000e-003	3.7000e+007	3.3902e-001	1.2544e+004

Buildup

The material reference is : Shield 1



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MicroShield® case: 30 cm

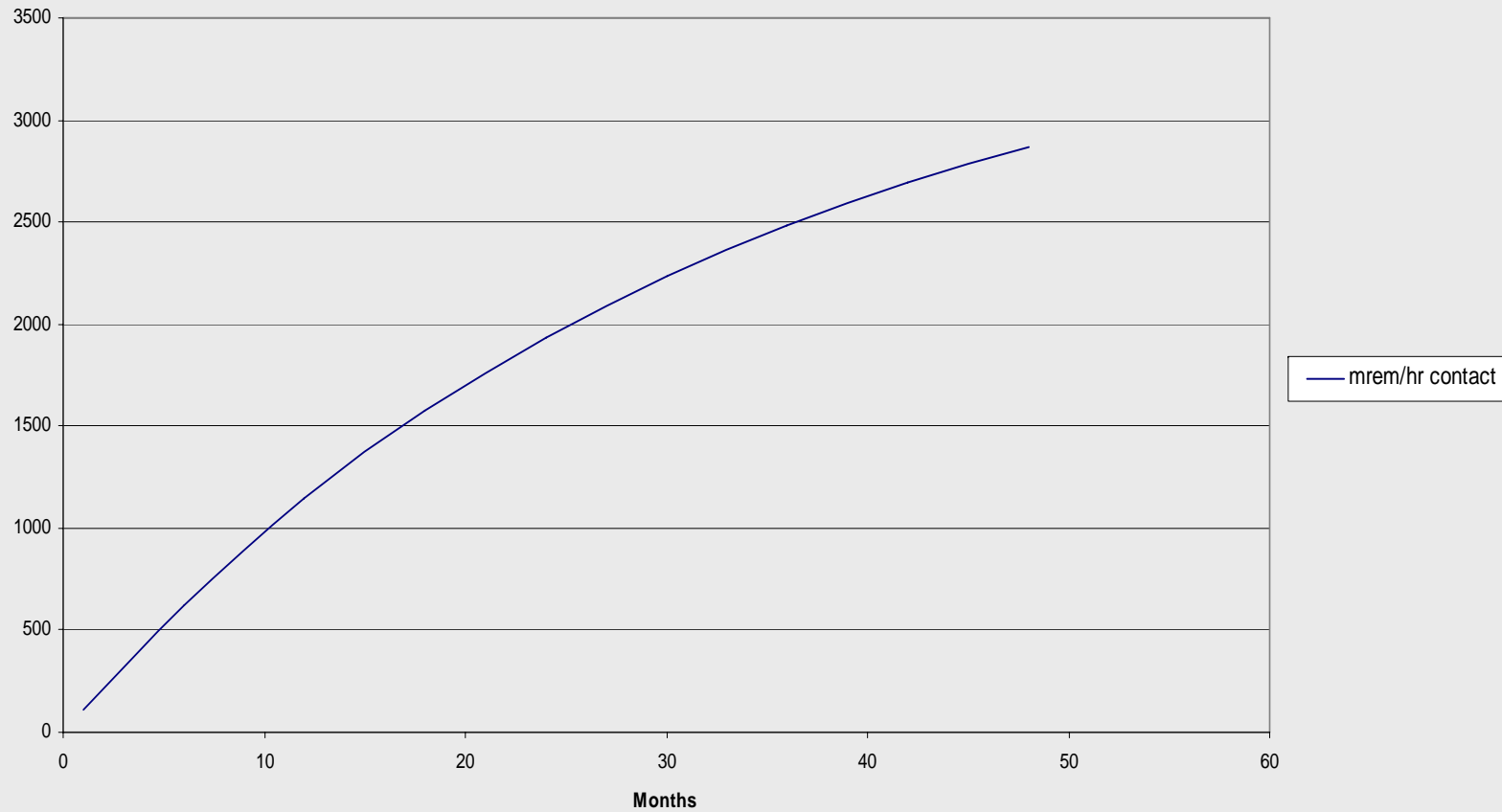
<u>Energy</u> MeV	<u>Activity</u> photons/sec	Results			
		<u>Fluence Rate</u> MeV/cm ² /sec <u>No Buildup</u>	<u>Fluence Rate</u> MeV/cm ² /sec <u>With Buildup</u>	<u>Exposure Rate</u> mR/hr <u>No Buildup</u>	<u>Exposure Rate</u> mR/hr <u>With Buildup</u>
0.0728	7.515e+05	1.610e-06	2.705e-06	2.669e-09	4.486e-09
0.075	1.269e+06	5.352e-06	9.170e-06	8.725e-09	1.495e-08
0.0849	5.638e+05	2.509e-05	4.634e-05	3.898e-08	7.200e-08
0.2114	6.277e+04	8.383e-04	2.564e-03	1.497e-06	4.581e-06
0.2334	1.145e+05	2.351e-03	7.387e-03	4.283e-06	1.346e-05
0.2526	2.954e+05	8.428e-03	2.692e-02	1.558e-05	4.976e-05
0.2773	2.511e+06	1.039e-01	3.361e-01	1.950e-04	6.307e-04
0.5108	7.976e+06	2.682e+00	8.282e+00	5.265e-03	1.625e-02
0.5831	3.117e+07	1.539e+01	4.573e+01	3.009e-02	8.940e-02
0.722	7.496e+04	6.553e-02	1.800e-01	1.260e-04	3.463e-04
0.7631	6.056e+05	6.082e-01	1.633e+00	1.163e-03	3.123e-03
0.8404	1.322e+05	1.677e-01	4.318e-01	3.170e-04	8.164e-04
0.8604	4.608e+06	6.178e+00	1.575e+01	1.165e-02	2.968e-02
0.9276	4.616e+04	7.358e-02	1.813e-01	1.373e-04	3.381e-04
0.9827	7.275e+04	1.319e-01	3.164e-01	2.438e-04	5.849e-04
1.0939	1.366e+05	3.115e-01	7.111e-01	5.648e-04	1.289e-03
2.6147	3.693e+07	3.426e+02	5.889e+02	4.859e-01	8.353e-01
TOTALS:	8.731e+07	3.683e+02	6.625e+02	5.357e-01	9.778e-01

Summary of results

Months	Tl-208 (mCi)	@ 30 cm	mrem/hr @ 1 m	mrem/hr contact
1	3	3	1	112
6	19	19	6	622
12	35	34	11	1141
18	49	47	15	1574
24	60	58	19	1935
30	69	67	22	2236
36	77	75	24	2487
42	83	81	26	2697
48	89	87	28	2871

Summary of results

Dose Rate Vs Age of Material
RU heel cylinder after vaporization of 1500kg U @ 10 ppb U232



Summary of results

DOSE RATE & ACTIVITY Vs AGE OF MATERIAL
RU heel cylinder after vaporization of 1500kg U @ 10 ppb U232

