

Determination of External Dose from Thorium Metal Machining - A TBD-6000 Approach

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Introduction

The basic methods used for the determination of external dose from handling and machining operations involving uranium metal developed in TBD-6000 were utilized to determine the external dose from thorium metal operations. The thorium metal was assumed to be in 100% equilibrium with its progeny at the time of handling. MCNP6 was used to determine the average dose per photon emission from the decay of ^{232}Th and its progeny; the average dose per electron emission from the decay of ^{232}Th and its progeny; and finally the bremsstrahlung dose per electron emission from the decay of ^{232}Th and its progeny. These values were scaled in accordance with data obtained from the Joslyn facility with regards to rod sizes that were handled. Dose rates were determined for the same periods as used in TBD-6000 and are to be scaled according to the specific operational details for a facility.

Files

- thor_rod_gamma_2014.i (MCNP6 input file for photon dose)
- thor_rod_gamma_2014.io (MCNP6 output file for photon dose)
- thor_rod_beta_2014.i (MCNP6 input for file for beta dose)
- thor_rod_beta_2014.io (MCNP6 output file for beta dose)
- thor_rod_brem_2014.i (MCNP6 input file for bremsstrahlung dose)
- thor_rod_brem_2014.i o (MCNP6 output file for bremsstrahlung dose)
- electron spectra 4-8-2014 for thorium chain.xls (summary of electron emissions spectra from ^{232}Th in equilibrium with all progeny)
- thorium dose summary .xls (summary of the dose from all sources and the beta and gamma emission lines used)

MCNP 6 Modeling

A thorium rod 50 in. long, with a radius of 1 7/8 in., a density of 11.7 g/cm³ was modeled using data included in the references files for ^{232}Th in equilibrium with its progeny. As described above, these were the dimensions of rods actually handled at Joslyn. Using the decay information from Thorium and the data provided in the files, it was determined that there are 4 betas and 3.465 photons per ^{232}Th decay (including from progeny). The 26.469 Kg of ^{232}Th was determined to have a decay rate of 1.08×10^8 Bq (based solely on the ^{232}Th) using the dose determined from the MCNP 6 runs, which converted the photon and beta spectra into units of dose per photon, and electron using the ICRP 74 Tables A.43 (for pGy/electron) and ICRP A.17 (for photons to pSv/photon). See worksheet Summary from file Thorium Dose Summary.XLS for complete calculation details that are included in part in Tables 1 and 2. Table 1 provides a summary of the individual dose components from beta dose and gamma dose from the Bremsstrahlung and photon emissions of thorium and its progeny. Table 2 summarizes the TBD-6000 equivalent doses from these emissions whole body photon dose, whole body beta dose, and beta dose to the hands and forearms.

Table 1: Summary of Dose rates from thorium metal rod

Beta Dose (thor_rod_beta_2014.io)	Doses from MCNP 6 Runs Bremsstrahlung (thor_rod_brem_2014.io)	Photon (thor_rod_gamma_2014.io)
1 cm	1 cm	1 cm
6.45E-05 pGy/electron	2.65E-06 pSv/electron	4.03E-04 pSv/photon
4.31E+08 electrons/sec	4.31E+08 electrons/sec	3.74E+08 photons/sec
2.78E+04 pGy/s	1.14E+03 pSv/s	1.51E+05 pSv/s
1.00E+01 mrad/hr beta	4.12E-01 mrem/hr	5.42E+01 mrem/hr
1 ft	1 ft	1 ft
8.80E-06 pGy/electron	2.16E-07 pSv/electron	3.20E-05 pSv/photon
4.31E+08 electrons/sec	4.31E+08 electrons/sec	3.74E+08 photons/sec
3.80E+03 pGy/s	9.30E+01 pSv/s	1.20E+04 pSv/s
1.37E+00 mrad/hr beta	3.35E-02 mrem/hr	4.30E+00 mrem/hr
1 m	1 m	1 m
1.10E-06 pGy/electron	4.06E-08 pSv/electron	5.85E-06 pSv/photon
4.31E+08 electrons/sec	4.31E+08 electrons/sec	3.74E+08 photons/sec
4.74E+02 pGy/s	1.75E+01 pSv/s	2.19E+03 pSv/s
1.71E-01 mrad/hr beta	6.31E-03 mrem/hr	7.87E-01 mrem/hr

These data were converted to units of dose to machining operations in an identical fashion as used for TBD-6000 including the categories of workers and assumptions (see worksheet Summary from file Thorium Dose Summary.XLS) for complete calculation details.

Table 2: Summary of doses using a TBD-6000 methodology for thorium metal handling

Summary of dose rates (per hour) for thorium metal handling				
Distance	1 cm	1 ft	1 m	
Photon dose	5.46E+01	4.34E+00	7.93E-01 mrem/hr	
Beta dose	1.00E+01	1.37E+00	1.71E-01 mrad/hr	
Thorium using TBD-6000 Approach- full year-based on 40 hour work week				
			operator	gen lab
Photon whole body (mrem/yr)			4335.734	7.93E+02
beta whole body (mrad/yr)			1366.28	683.1399
beta hands & forearms (mrad/yr)			10017.01	5008.507
			super	clerical
			396.5633	39.65633
			68.31399	0
			500.8507	0
Thorium using same technique - 24 hr dose rates				
			operator	gen lab
Photon whole body (mrem/24 hrs)			52.03	9.52
beta whole body (mrad/24 hours)			16.40	8.20
beta hands & foreams (mrad/24 hours)			120.20	60.10
			super	clerical
			4.76	0.48
			0.82	0.00
			6.01	0.00

Application for Dose at Joslyn

In accordance with records from Joslyn, thorium rods were handled on two occasions, all in very limited quantities. These included the following:

Operations in May 1946 included the Medart straightening and centerless grinding of 6 thorium rods (srdb 80029, pages 2 and 3 and 80171, page 3). In early 1947, Joslyn centerless ground and Medart straightened (three times each) 5 thorium rods (SRDB 81068, page 2). Because of the very limited amounts of thorium used in the experiments, a conservative estimate of 2.5 work days each for 1946 and 1947 operations has been assumed.

As described in the (thorium dose summary.xls) file, the thorium rod size was estimated as being 50 in. in length with a diameter of 1 7/8 in., a density of 11.7 g/cm³ for an estimated 26.469 Kg of thorium metal per rod.

Two and one-half work days during this time period corresponds to 24 hours of work (2400 hrs/250 work days*2.5 work days). Therefore the dose from thorium for both 1946 and 1947 at Joslyn was determined to be shown in Table 3.

Table 3: External dose per year for 1946 and 1947 at Joslyn from handling thorium metal

Thorium using same technique - 24 hr dose rates	
	operator
Photon whole body (mrem/24 hrs)	52.03
beta whole body (mrad/24 hours)	16.40
beta hands & foreams (mrad/24 hours)	120.20