Dose Reconstruction Methods for Joslyn Manufacturing and Supply Co.

NIOSH White Paper, Rev. 0

April 17, 2014

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Purpose

NIOSH found that it is not possible to completely reconstruct uranium and thorium internal radiation doses at Joslyn Manufacturing and Supply Co. (Joslyn), in Fort Wayne, Indiana, for the time period of March 1, 1943 through July 31, 1947. NIOSH finds that dose reconstruction is possible for the remaining covered time period of August 1, 1948 through December 31, 1952. This White Paper discusses the NIOSH-proposed dose reconstruction (DR) methods at the Joslyn facility for the workers not included in the Special Exposure Cohort, as well as for the partial DR methods for the SEC time period. The methods described in this document are intended to supplement (and in some cases replace) the methods provided in the Joslyn SEC ER and ER Addendum[1].

Internal Dose

There was no bioassay monitoring at Joslyn and a limited number of air samples taken during the entire covered period. In the ER, NIOSH compared the Joslyn-specific air sampling data to the air sampling data for the corresponding time periods in Battelle-TBD-6000, *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals*. Because the Joslyn dataset has limitations on its use for dose reconstruction, NIOSH chose to initiate this comparison to verify if the well-validated data set of Battelle-TBD-6000 was an appropriate upper bound for the available Joslyn data. NOSH compared the 1952 Joslyn un-weighted breathing zone (BZ) air concentration data for rolling operations to the Battelle-TBD-6000 Finishing Roll Operator and Rouging Roll Operator air concentration data, which are the two highest-exposure rolling jobs documented in Battelle TBD-6000. While the purpose and end uses of the uranium products coming out of Joslyn after 1948 changed, the basic product (rolled and finished rods) did not. While it is reasonable to presume that the Rolling Operator values would continue to represent the highest-exposure jobs at Joslyn following the production rolling period in 1948, NIOSH has included both the Rolling and Machining Operator categories. Table A-1 of Attachment A provides a listing of uranium rolling days. Table A-2 of Attachment A lists uranium machining days. Table A-3 of the same attachment provides a list of thorium rolling and machining days for the covered time period at Joslyn.

Tables A-4 and A-5 of Attachment A provide a comparison between the Joslyn rolling operation air concentration data and the Battelle-TBD-6000 air concentration data that was depicted in the ER. The 1952 study presented in Table A-4 is the only time-weighted-average (TWA) study located for Joslyn. As can be seen, each arithmetic mean (AM) of the distribution with the given geometric mean (GM) and a geometric standard deviation (GSD) of 5 is generally much higher than the 1952 TWA values obtained at Joslyn. In one location ("9-inch finishing roll east"), the Joslyn value was higher. A similar comparison was also made for the limited centerless grinding data in 1951. In this case, TWA values were not available, but the average and maximum values of the Joslyn data were compared to Battelle-TBD-6000. The results are provided in Table A-5. The conclusion is that results favorable to claimants at Joslyn would be obtained by using the machining and rolling operator categories from Battelle-TBD-6000. Only the operator category shall be used for dose reconstruction in order to insure that the data is bounding for internal dose beginning in August of 1948. These are reproductions of tables 7-8 [inhalation] and Table 7-9 [ingestion], which appeared in ER Rev. 1. The conclusion was that results favorable to claimants at Joslyn would be obtained by using Battelle-TBD-6000. The intake rates from Battelle-TBD-6000 (Table 7-8 [inhalation] and Table 7-9 [ingestion]) appeared in Rev. 1 of the Joslyn ER as Table 7-3; this table is reproduced as Table A-6.

[1] It should be noted that Tables 7-1 and 7-2 and Figures 7-1 and 7-2 from Rev. 1 of the Joslyn ER have been updated and corrected in this white paper as revised in the ER Addendum to address an uncertainty calculation correction and a TWA timeframe adjustment from 2,400 to 2,200 work hours per year for the purpose of converting Battelle-TBD-6000 intake rates to an estimated airborne concentration for comparison to the 1952 Joslyn air data.

Description of DR methods for internal dose:

- The uranium exposure rates in Table B-6 associated with rolling and machining operations are based on a single shift per workday. For situations where an employee may have worked multiple shifts, these intakes are to be adjusted to account for the longer exposures times. In addition, for situations where rolling and machining operations may have occurred on the same day, the larger of the two exposure rates (but not both) will be applied.

- For the worker's employment period, determine the number of days that uranium was rolled and machined in each year based on research summarized in Tables A-1 and A-2.

- For each operational day, assign intakes based on the intake rates in Battelle-TBD-6000, Table 7.8 (inhalation) and Table 7.9 (ingestion) also in ER Rev. 1 as Table 7-3 and here as Table A-6). Please note that since the intake rates in Battelle-TBD-6000 are based on 365 calendar days/year, it will be necessary to convert the intake rates to 250 workdays per year (i.e., to multiply the intake rates by 365/250). These daily intakes will then be multiplied by the number of rolling or machining days to arrive at a total annual intake per year.

- The operator category shall be assumed for all workers.

- For each non-operational day (i.e., no rolling or machining), assign inhalation intakes based on the method described Battelle-TBD-6000, Section 7.1.5, using the operator category for all workers. Intakes should be based on the following assumptions: operational air concentration of 2,491 pCi/m3; deposition velocity of 7.5E-04 m/s; deposition time of 30 days; and a re-suspension factor of 1E-5 m^{-1}. This results in an intake rate for inhalation of 558 pCi per non-operational workday.

- For each non-operational day (i.e., no rolling or machining), ingestion intakes are assigned to be equal to the ingestion intakes for machining during the operational period. This results in an ingestion intake rate of 588 pCi per non-operational workday prior to 1951, and 539 pCi per non-operational workday for 1951 forward.

- For each year of employment, sum the inhalation and ingestion intakes for both operational and non-operational days, as determined above, and assign assuming 100% uranium-234.

- For determining the probability of causation (POC), the doses determined above are treated as the geometric mean (GM) of a lognormal distribution with geometric standard deviation (GSD) of 5.

Thorium

Extruded thorium rods were centerless ground and medart straightened on two occasions at Joslyn Manufacturing. Although the centerless grinding operations could have created respirable particles, the work was performed under wet conditions for cooling purposes. Furthermore, these operations occurred during the SEC period for which NIOSH has determined it is not feasible to reconstruct internal exposures adequately. Consequently, no internal dose is assigned from thorium operations.

On-site Environmental

Environmental internal doses will not be assigned; only the occupational doses determined by using the above procedure, which accounts for any environmental internal exposures, will be employed for all claimants.

External Dose

The principal sources of external radiation doses for members of the evaluated class were exposure to gamma and beta radiation associated with handling and working in proximity to uranium and uranium compounds while involved in the hot rolling, quenching, straightening, grinding, and cutting of the materials. Some employees were also potentially externally exposed to the radiation from re-suspended contamination from uranium metal surfaces and the floor during the course of their work with these radioactive materials. The metal workers were assumed to have been provided annual medical chest X-rays examinations as part of the hazard and health monitoring of these workers.

Since no dosimetry information is available for Joslyn employees, NIOSH will bound the external exposures and reconstruct the doses to an employee by using the models, guidance, and default bounding values in Battelle-TBD-6000, ORAUT-OTIB-0006, and ORAUT-OTIB-0079. NIOSH will employ these resources to calculate external beta and gamma doses from working, as an Operator in the Joslyn plant for all covered years. In addition, occupational medical doses from annual X-ray examinations will be assigned for this period of employment.

NIOSH understands that exposure to the uranium metal was not a continuous exposure over the course of the year; thus, annualized exposure calculations would be a significant overestimate of the actual exposure potential. Specific rolling dates are provided in the example DR below.

DR methods for external dose:

- For each operational day, external doses are based on the exposure rate for the "long billet" at 30.48 cm provided in Battelle-TBD-6000, Table 6.1. For purposes of dose reconstruction, the numbers of rolling days-per-year in the Example DR, Attachment A, Table A-1 are assumed to apply to both rolling and machining operations. (See Table A-7 for dose values.)

- Use 10 times the gamma exposure rates at one foot for the beta (skin) exposure rate per guidance in Battelle-TBD-6000, Section 3.3.1. (See Table A-7 for dose values.)

- For each non-operational day, external doses are based on the exposure rate associated with contaminated air and surfaces provided in Battelle-TBD-6000, Tables 3.9 and 3.10. The non-operational days in Table B-1 represent the number of days that the workers were in the plant but not performing uranium rolling or machining operations. (See Table A-7 for dose values.)

- Occupational X-ray doses are extracted from ORAUT-OTIB-0006 Appendix A in Table A-7 for the Lung and Entrance Skin for the PA X-ray projection; each is multiplied by the number of years employed for a total dose for the two organs for the number of years worked.

- The dose from submersion in the contaminated plant air for the employment period is determined from Battelle-TBD-6000, Table 3.9, and is found to be trivial.

- For each year of employment, sum the annual dose for both rolling and non-operational days, as determined above, making sure that any annual dose rates from Battelle-TBD-6000 have been normalized to 250 days of exposure.

- For determining the probability of causation (POC), the doses determined above are treated as the geometric mean (GM) of a lognormal distribution with geometric standard deviation (GSD) of 5.

Thorium

The Battelle-TBD-6000 modeling for uranium metal was adjusted to thorium dose rates using a computer model MCNPX. The estimated dose rate is provided in Table B-8. These doses are applied in IREP as a lognormal distribution with a GSD of 5.

Thorium has a significant number of higher-energy photons in the Th-232 decay chain. Based on the half-lives of the progeny, only a partial equilibrium is possible; therefore, it is conservative to state that equilibrium would be reached in this decay chain. It has been assumed that Ra-228 and Th-228 progeny were in equilibrium with Th-232. Under this assumption, the progeny are the major source of both penetrating and non-penetrating external exposure.

Photon Dose

Photon dose at Joslyn would be primarily made up of Operator exposure to photons from the uranium metal being worked at the site, with exposure to contaminated surfaces being a lesser dose contributor. While the preferred indicators of external dose are dosimetry measurements, NIOSH has not identified any personnel external monitoring records or personal dosimetry data associated with the uranium processing conducted during the period under evaluation. Battelle-TBD-6000, Section 6.2, provides guidance on estimating external dose rates due to penetrating radiation emitted from the surface of uranium metal. Using the results of Monte Carlo N-Particle Transport Code (MCNP) calculations performed for a number of basic shapes, it provides calculated dose rates for distances of one centimeter, one foot, and one meter from the surface of the natural uranium metal. These dose rates are used to estimate the component of whole-body dose that a worker would receive while handling or near uranium metal, applying information that may be available about the specific conditions of a worker’s likely exposure. If no information is available about the specific conditions of exposure, Battelle-TBD-6000 provides for generic worst-case assumptions to be made about a worker’s exposure conditions.

Dose reconstruction at Jolsyn will use the operator category for all employees. The potential exposure accrued from the presence of contamination on work surfaces would be minor in comparison with the primary exposure to the uranium metal.

Beta Dose

Non-penetrating beta dose is primarily associated with the hands and forearms, and then other skin surfaces, of a worker who handles uranium metal in close proximity. Battelle-TBD-6000, Section 6.3, details a method to estimate skin doses for the hands and forearms of a worker who handles uranium metal as well as the other skin surfaces.

Medical X-ray Dose

Although NIOSH has not located specific parameters associated with occupational medical X-rays (i.e., specific information on the X-ray devices), default values of entrance kerma, developed for the most commonly-used occupational medical diagnostic procedures, are available in ORAUT-OTIB-0006. These values can be used to support bounding the medical X-ray dose for the time period under evaluation. These default values are maximum or upper limit values developed from: review of patient doses reported in the literature; machine characteristics; and knowledge of X-ray procedures used during different historical time periods. These default values can be used in lieu of actual measurement data, or entrance kerma derived from technique factors, to bound the occupational X-ray exposures for Joslyn uranium and thorium workers from March 1, 1943 through December 31, 1952. For dose reconstruction purposes, a pre-employment, post-employment, and annual examination is assumed during the operational period, per guidance in ORAUT-OTIB-0079.

Example DR:

Attachment B on the beginning provides an example dose reconstruction using the approach described in this white paper.

References

42 CFR 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule, Federal Register/Vol.67, No. 85/Thursday, May 2, 2002, p 22314, SRDB Ref ID: 19392

42 CFR 81, *Guidelines for Determining the Probability of Causation Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule, Federal Register/Vol.67, No. 85/Thursday, May 2, 2002, p 22296, SRDB Ref ID: 19391

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ORAUT (Oak Ridge Associated Universities Team), ORAUT-OTIB-0017, *Interpretation of Dosimetry Data for Assignment of Shallow Dose*, Rev 01, October 11, 2005, SRDB Ref ID: 19434

Rad Handbook, 1998, *Handbook of Health Physics and Radiological Health*, 3rd Edition; editors include Bernard Schleien, Lester Slaback, and Brian Kent; 1998; SRDB Ref ID: 22737

Attachment A

Table A-1: Uranium Rolling Days at Joslyn (pages 8 and 9)		
Time Period	**Rolling Days**	SRDB Ref ID
March 13, 1943	1	82362
June 29, 1943	1	11036, pdf p. 42; 33190, pdf p. 66; 33190, pdf p. 244
January 3 - 14, 1944	1	11036, pdf p. 53
May 3-6, 1944	4	11036, pdf p. 216
May 9 - June 24, 1944	7	33190, pdf p. 67
June 1 - 5, 1944	5	17594, pdf p. 4
June 19 - 20, 1944	2	118502, pdf p. 2
December 7, 1944	1	118144, pdf p.4
December 11 - 28, 1944	13	34028, pdf p. 42
March - May, 1945	54	31145, pdf p. 196
Unknown date, 1946	~10-20	90948, pdf p. 8
October 28,1946	~1-2	93775, pdf p. 6
November, 1946	~5-10	31145, pdf p. 16
January, 1947	~5-10	90948, pdf p. 2
August 5 – 6, 1947	2	37411, pdf p. 44; 126764, pdf p. 5; 37374, pdf p. 43; 16511, pdf pp. 3, 5; 37390, pdf p. 44
January 28 - March 4, 1948	16	37587, pdf p. 54; 36762, pdf p. 35; 36762, pdf p. 38; 37586, pdf p. 35; 129759, pdf p. 9; 85872, pdf p. 2; 11996, pdf p. 129; 37587, pdf p. 23
April 3 - 5, 1948	3	16288, pdf p. 5

Table A-1: Uranium Rolling Days at Joslyn (pages 8 and 9)		
Time Period	**Rolling Days**	SRDB Ref ID
May, 1948	26	59249, pdf p. 7; 129474; 11036, pdf p. 19
June 4 – 18, 1948	15	16509; 129748; pdf p. 10; 11036, pdf p. 177
July 9 – 11, 1948	3	118155, pdf p. 2
July 27 – 30, 1948	4	115156, pdf p. 2
1947 – 1950[a]	~10 days	112574, pdf p. 25 (see also 116843)
May 26 – 27, 1949	2	116843
February and July, 1950	2	36889, pdf p. 109; 36834, pdf p. 131
April 26 – 27, 1950	2	116844[b]
August 10 – 11, 1950	2	120484
August 4, 1950	1	118159
September 5, 1950	1	28071, pdf p. 2
October 24, 1951	1	11036, pdf p. 23
January 8 – 9, 1952	2	9664
January 16, 1952	1	9664

Table A-2 Uranium Machining Days (pages 9 and 10)		
Time Period	**Machining Days**	**SRDB Ref ID**
June 29, 1943	1	11036, pdf p. 42; 33190, pdf p. 66; 33190, pdf p. 244
September 7, 1943	1	11036, pdf p. 85
November 29 – December 15, 1943	15	11036, pdf pp. 59, 69, 222-3
Unknown date, 1944	1	33190, pdf p. 74
January 3 - 14, 1944	12	11036, pdf p. 53
January 7, 1944	1	11036, pdf p. 135
February 23 - 26, 1944	4	11036, pdf p. 130
May 3 - 6, 1944	4	11036, pdf p. 216
June 1 - 5, 1944	5	17594, pdf p. 4
March - May, 1945	54	31145, pdf p. 196
Unknown date, 1946	~10-20	90948, pdf p. 8
May, 1946	1	80171, pdf p. 3
October 28,1946	1-2	93775, pdf p. 6
November, 1946	~5-10	31145, pdf p. 16
January, 1947	~5-10	90948, pdf p. 2
August 5 – 6, 1947	2	37411, pdf p. 44; 126764, pdf p. 5; 37374, pdf p. 43; 16511, pdf p. 3, 5; 37390, pdf p. 44
January 28 – March 4, 1948	16	37587, pdf p.54; 36762, pdf p. 35; 36762, pdf p. 38; 37586, pdf p. 35; 129759, pdf p. 9; 85872, pdf p. 2; 11996, pdf p. 129; 37587, pdf p. 23
April 3 – 5, 1948	3	16288, pdf p. 5
April 10-17, 1948	8	37591, pdf p. 164
May, 1948	26	59249, pdf p. 7; 129474; 11036, pdf p. 19
June 4 – 18, 1948	15	16509; 129748; pdf p. 10; 11036, pdf p. 177
July 9 – 11, 1948	3	118155, pdf p. 2

Table A-2 Uranium Machining Days (pages 9 and 10)		
Time Period	**Machining Days**	**SRDB Ref ID**
July 27 – 30, 1948	4	115156, pdf p. 2
August 5, 1950	1	11036, pdf p. 15
August 10 – 11, 1950	2	120484
August 24, 1951	1	11036, pdf p. 23
July 16, 1952	1	91923, pdf p. 2

Table A-3 Thorium Rolling and Machining			
Time Period	**Rolling Days**	**Machining Days**	**SRDB Ref ID**
May, 1946	0	2.5	80171, pdf p. 3
January, 1947	0	2.5	81068, pdf p. 2

Table A-4 Comparison of 1952 Time-Weighted Average (TWA) Study with Battelle-TBD-6000 (Joslyn ER, Rev. 1, Table 7-1)					
Joslyn Work Area/Job Description	**TWA (pCi/m^3)**	**Battelle-TBD-6000 Equivalent Description**	**GM (pCi/m^3)**	**95% (pCi/m^3)**	**AM (pCi/m^3)**
18" rough roll east	1496	Rolling Operator	1606	22675	5864
18" rough roll west	169	Rolling Operator	1606	22675	5864
Roller Forman	327	Rolling Supervisor	148	2090	540
Asst Roller (Ass't Foreman)	327	Rolling Supervisor	148	2090	540
Furnace Heaters	7	Rolling General Labor	296	4179	1081
Recorder	7	Rolling General Labor	296	4179	1081
12" rough roll east	273	Rolling Operator	1606	22675	5864
12" rough roll west	257	Rolling Operator	1606	22675	5864
Drag Down (Billet)	140	Rolling General Labor	296	4179	1081

Table A-4 Comparison of 1952 Time-Weighted Average (TWA) Study with Battelle-TBD-6000 (Joslyn ER, Rev. 1, Table 7-1)					
Joslyn Work Area/Job Description	**TWA (pCi/m^3)**	**Battelle-TBD-6000 Equivalent Description**	**GM (pCi/m^3)**	**95% (pCi/m^3)**	**AM (pCi/m^3)**
9" finishing roll east	7451	Rolling Operator	1606	22675	5864
9" finishing roll west	2609	Rolling Operator	1606	22675	5864
Quench Tank	70	Rolling General Labor	296	4179	1081
Draggers	374	Rolling General Labor	296	4179	1081
Rod Stamper	109	Rolling General Labor	296	4179	1081
Rod Bundler	58	Rolling General Labor	296	4179	1081
Lathe Operation	5	Machining Operator	2491	35171	9096
Centerless Grinder	45	Machining Operator	2491	35171	9096
Grinder (portable)	125	Machining Operator	2491	35171	9096
Cutomatic	86	Machining Operator	2491	35171	9096

The 1952 study presented in Table 4 above is the only time-weighted-average (TWA) study located for Joslyn. As can be seen, each arithmetic mean (AM) of the distribution with the given geometric mean (GM) and a geometric standard deviation (GSD) of 5 is generally much higher than the 1952 TWA values obtained at Joslyn. In one location ("9-inch finishing roll east"), the Joslyn value is higher.

Table A- 5: Comparison of 1951 Air Concentrations to Battelle-TBD-6000 (Joslyn ER, Rev. 1, Table 7-2)						
Joslyn Work Area/Job Description	**Average (pCi/m^3)**	**Maximum (pCi/m^3)**	**Battelle-TBD-6000 Equivalent Description**	**GM (pCi/m^3)**	**95% (pCi/m^3)**	**AM (pCi/m^3)**
Centerless grinding, 1951 General Area	20	23	Machining Operator 1/1/1951 to 12/31/55	2491	35171	9096
Centerless grinding, 1951 Operator	486	811	Machining Operator 1/1/1951 to 12/31/55	2491	35171	9096

Table A-6: Daily Intake Rates for Joslyn from Battelle-TBD-6000 (Joslyn ER, Rev. 1, Table 7-3)

Job Description	Inhalation	Ingestion	Inhalation	Ingestion
	8/1/1948-12/31/1950		1/1/1951-12/31/1952	
	(pCi/cal. day)	(pCi/cal. day)	(pCi/cal. day)	(pCi/cal. day)
Rolling Operator	12671	260	11615	238
Machining Operator	19654	403	18016	369

Table A-7: External Dose from Uranium

Rolling or Machining Workday?	Penetrating Dose Rate (mrad/workday)	Non-Penetrating Dose Rate (mrad/workday)
No (1943-1950)	0.041	3.942
No (1951-1952)	0.037	3.614

Table A-8: External Dose from Thorium

Work Area/Job Description	Penetrating Dose (mremd/workday)	Non-Penetrating Dose (mrad/workday)
Operator	20.812	6.56

Attachment B

Joslyn Example Dose Reconstruction for the Post-SEC Period (August 1948 on)

Employee Information

Cancer Description:	Lung (ICD-9: 162); diagnosed 12/31/1977
	Prostate diagnosed (ICD9 185); diagnosed 12/31/1977
	BCC of the back (ICD-9: 173); diagnosed 12/31/1977
	SCC of the back (ICD-9: 173); diagnosed 12/31/1977
	Kidney; diagnosed 12/31/1977
	Liver; diagnosed 12/31/1977
Year of birth:	1923
Gender:	Male
Smoking:	Former Smoker
Ethnicity:	"White, non-Hispanic"

Employment Information

Employer:	Joslyn
Start date:	03/01/1943
End date:	12/31/1952
Occupation:	Operator
Dosimetry Data:	None

Organ Dose Assessed [3]

The organs evaluated in the Example DR are shown in Table B-1.

Table B-1: Example DR Evaluated Organs

Cancer	External Organ Used	Internal Organ Used
Lung	]Lung	Lung
Prostate	Urinary Bladder	Non-Metabolic Organ with Highest Dose (Adrenals/Brain)
Skin	Skin	Skin
Kidney	Liver	Kidney
Liver	Liver	Liver

Internal Dose

Internal dose during the residual period was assigned in accordance with methodology presented in the SEC-00200 Joslyn SEC Evaluation Report.[4] Intake values tabulated in Battelle-TBD-6000 were used as a basis for the assigned inhalation and ingestion intakes[6]. Inhalation and ingestion intake rates from Battelle-TBD-6000, Tables 7.8 and 7.9, were used to assign intakes during rolling days. Inhalation and ingestion intake rates used to assign intakes during non-operational days were based on guidance in Battelle-TBD-6000, Sections 7.1.5 and 7.1.6. The number of operational and non-operational days was based on research summarized in the Joslyn ER, as indicated in the external dose section above. The resultant intake rates are presented in Table B-2 on the next page.

Table B-2: Estimated Annual Uranium Inhalation and Ingestion Intake Quantity for Joslyn						
Year	**Rolling Days**	**Machining Days**	**Rolling and Machining Days**	**Non-Operational Days**	**Inhalation Intake Rate (pCi/year)**	**Ingestion Intake Rate (pCi/year)**
1943[a,c]	1	16	1	190	0	0
1944[c]	23	10	6	207	0	0
1945[c]	0	0	54	196	0	0
1946[c]	0	1	32	217	0	0
1947[c]	0	0	12	238	0	0
1/7/1948[c]	0	8	67	71	0	0
8-12/1948	10[b]	0	0	94	237,435	59,104
1949	2	0	0	248	175,348	146,677
1950	8	3	0	239	367,409	145,425
1951	1	1	0	248	170,081	134,494
1952	3	1	0	246	202,974	134,111

a. 1943 is a partial year (March through December); therefore, the 250 workdays were prorated by 10/12 to account for this.
b. SRDB 112574 indicates a rolling operation occurred sometime between 1947 and 1050 for 10 days. Therefore it was assumed to have all occurred in 1948 to be claimant favorable, since 1947 is covered under the SEC.
c. During the SEC, internal dose assessment is considered infeasible. Therefore, no intakes are assessed during this period.

Thorium

Thorium operations occurred during the SEC period for which NIOSH has determined it is not feasible to reconstruct internal exposures adequately. Consequently, no internal dose is assigned from thorium operations.

External Dose

External Dose (deep and shallow) was assigned in accordance with the SEC-00200 Joslyn SEC Evaluation Report.[4] A photon dose of 7.03 mrem per uranium rolling/machining day and 1.08 mrem per non-operational day was assigned. An electron dose of 70.3 mrem per uranium rolling/machining day was assigned. External exposure during uranium rolling/machining days was based on the dose rate calculated at a distance of one foot from a Long Billet[6], assuming a 10-hr working day. External exposure during non-operational days was based on the dose rate calculated at a distance of one meter from a Long Billet[6], assuming a 10-hr working day. The number of operational and non-operational days was determined based on site research data[4] and is summarized in Table B-3 on the next page.

Table B-3: Estimated Annual Uranium External Exposures for Joslyn				
Year	**Operational Days**	**Non-Operational Days**	**Annual Deep (mrem)**	**Annual Shallow (mrem)**
1943[a]	18	190	134	2014
1944	43	207	311	3839
1945	54	196	388	4569
1946	33	217	241	3175
1947	12	238	94	1782
1948	85[b]	165	604	6626
1949	2	248	24	1118
1950	11	239	87	1716
1951	2	248	23	1037
1952	4	246	37	1170

a. 1943 is a partial year (March through December); therefore, the 250 workdays were prorated by 10/12 to account for this.
b. SRDB 112574 indicates a rolling operation occurred sometime between 1947 and 1050 for 10 days. Therefore it was assumed to have all occurred in 1948 to be claimant favorable, since 1947 is covered under the SEC.

A photon dose of 20.9 mrem per thorium rolling/machining day was assigned. A shallow dose of 6.3 mrem per thorium rolling/machining day was assigned. External exposure during thorium rolling/machining days was based on the BattelleTBD-6000 modeling for uranium metal and adjusted to thorium dose rates using a computer model MCNPX. The number of rolling and non-operational days was determined based on site research data and is summarized in Table B-4 below.

Table B-4: Estimated Annual Thorium External Exposures for Joslyn			
Year	**Operational Days**	**Annual Deep (mrem)**	**Annual Shallow (mrem)**
1946	2.5	52	16
1947	2.5	52	16

Penetrating Dose

For the purpose of estimating probability of causation, all photon doses are assumed to be acute.[2] Photon doses were determined by applying a 100% 30–250 keV energy distribution to the reported photon doses[2]. The dose rate was multiplied by the deep dose mode organ dose conversion factor. An organ dose conversion factor value of 1 was used for the skin in conjunction with guidance in ORAUT-OTIB-0017. The organ dose conversion factors are shown in Table B-5 on this page.

Non-Penetrating Dose

For the determination of non-penetrating dose, an energy distribution of 100% > 15 keV electrons has been assumed for all non-penetrating doses. The electron radiation was only considered in the dose reconstruction of the skin because it would not have added dose to the other cancer sites.

For skin cancer claims, ethnicity is necessary to determine the probability of causation.[1,5] The hypothetical covered employee was assumed to be "white, non-Hispanic" for the purposes of this example dose reconstruction.

Table B-5: Organ Dose Conversion Factors

Organ	30-250 keV (mode)	Electron>15 keV
Lung	0.695	n/a
Prostate	0.873	n/a
Skin	1.000	1.000
Kidney	0.748	n/a
Liver	0.748	n/a

The total doses for photon and beta dose (skin only) are given in Table B-6 below.

Table B-6: Total Assigned External Dose

Organ	Photons (rem)	Electrons (rem)
Lung	1.422	n/a
Prostate	1.788	n/a
Skin	2.080	27.047
Kidney	1.531	n/a
Liver	1.531	n/a

Medical Dose

Table B-7 presents the estimated annual medical dose for Joslyn.

Table B-7: Estimated Annual Medical Dose for Joslyn

Year	Lung	Prostate	Skin	Kidney	Liver
1943	0.084	0.025	0.270	0.090	0.090
1944	0.084	0.025	0.270	0.090	0.090
1945	0.084	0.025	0.270	0.090	0.090
1946	0.084	0.025	0.270	0.090	0.090
1947	0.084	0.025	0.270	0.090	0.090
1948	0.084	0.025	0.270	0.090	0.090
1949	0.084	0.025	0.270	0.090	0.090
1950	0.084	0.025	0.270	0.090	0.090
1951	0.084	0.025	0.270	0.090	0.090
1952	0.084	0.025	0.270	0.090	0.090
TOTAL	0.838	0.250	2.700	0.902	0.902

Uncertainty

External photon dose for uranium was applied as a lognormal distribution with a GSD of 5. Internal dose was applied as a lognormal distribution with a GSD of 5. Occupational medical X-ray doses were assigned as a normal distribution with an uncertainty of 30%.

Summary

The assessment methods presented in this report define the methods by which a dose estimate can be determined for employees of Joslyn during the covered period. These methods support NIOSH's conclusion that the operationally-related internal dose for the evaluated worker class can be bounded. A summary of the doses and probability of causations are provided in Table B-8 on the next page.

<table>
<tr><th colspan="6">Table B-8: Summary of the Doses and Probability of Causations</th></tr>
<tr><th>Cancer</th><th>External (rem)</th><th>Internal (rem)</th><th>Medical (rem)</th><th>Total (rem)</th><th>Probability of Causation</th></tr>
<tr><td>Lung</td><td>1.422</td><td>170.658</td><td>0.838</td><td>172.918</td><td>97.67%</td></tr>
<tr><td>Prostate</td><td>1.788</td><td>1.057</td><td>0.250</td><td>3.094</td><td>29.21%</td></tr>
<tr><td>Skin BCC</td><td rowspan="2">29.127</td><td rowspan="2">1.057</td><td rowspan="2">2.700</td><td rowspan="2">32.884</td><td>94.04%</td></tr>
<tr><td>Skin SCC</td><td>29.75%</td></tr>
<tr><td>Kidney</td><td>1.531</td><td>17.787</td><td>0.902</td><td>20.219</td><td>74.27%</td></tr>
<tr><td>Liver</td><td>1.531</td><td>5.952</td><td>0.902</td><td>8.384</td><td>80.22%</td></tr>
</table>