
Draft

**REVIEW OF “SITE PROFILES FOR ATOMIC WEAPONS
EMPLOYERS THAT WORKED URANIUM METALS:
APPENDIX J–JOSLYN”**

Contract Number 211-2014-58081
SCA-TR-SP2015-0050, Revision 0

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May 12, 2015

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S. Cohen & Associates: <i>Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program</i>	Document Description: SCA-TR-SP2015-0050
	Effective Date: Draft – May 12, 2015
REVIEW OF “SITE PROFILES FOR ATOMIC WEAPONS EMPLOYERS THAT WORKED URANIUM METALS: APPENDIX J–JOSLYN”	Page 2 of 33
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Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	5/12/15	Initial issue

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ABBREVIATIONS AND ACRONYMS

Advisory Board	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
ANL	Argonne National Laboratory
AP	anteroposterior
AWE	Atomic Weapons Employer
CLG	centerless grinding
cm	centimeter
d	day
DCAS	Division of Compensation Analysis and Support
dpm	disintegrations per minute
DR	dose reconstruction
DWA	daily weighted average
ElectroMet	(or Eletromet) Electro Metallurgical Company
ft	foot
GSI	General Steel Industries
h	hour
in	inch
keV	kiloelectronvolt
kg	kilogram
m	meter
mm	millimeter
MED	Manhattan Engineer District
MeV	million electron volts
M.I.T.	Massachusetts Institute of Technology
mrad	millirad
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
NRC	National Research Council (Canada)
OCAS	Office of Compensation Analysis and Support
pCi	picocurie
P.O.	purchase order

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SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	Technical Basis Document
U of C	University of Chicago
U ₃ O ₈	uranium oxide
WAPD	Westinghouse Atomic Power Division
wk	week

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Review of “Site Profiles for Atomic Weapons Employers that Worked Uranium Metals: Appendix J–Joslyn”

On October 7, 2014, David Allen (NIOSH/DCAS) issued Appendix J to TBD-6000 (Allen 2014a). In an e-mail message on March 24, 2015, Ted Katz, Designated Federal Official to the Advisory Board, asked SC&A to review this report. On the following day, Paul Ziemer, Chair of the Work Group on TBD-6000, concurred with this request.

In our review, we confine the discussion to observations and issues in areas in which we and NIOSH are not in agreement. Our comments include issues that affect the dose reconstruction methods prescribed in the appendix, as well as observations on statements in the appendix that, while they do not affect dose reconstructions, fail to accurately describe the site of the Joslyn Manufacturing and Supply Company in Fort Wayne, Indiana, and its operations.

1.0 REVIEW COMMENTS

This review follows the sequence of topics presented by Allen (2014a). Section and table numbers beginning with the letter “J” are from Allen (2014a).

1.1 Site Description

In Section J.2, Allen (2014a) refers to “Joslyn Manufacturing and Supply Company, also known as Joslyn Stainless Steel Company, Fort Wayne Steel Corporation, and Slater Steel.” This could give the erroneous impression that all four names referred to this facility during the period of covered operations. The company was known as “Joslyn Manufacturing and Supply Co.” throughout the covered period. Furthermore, Allen states: “These activities were conducted in support of the Manhattan Engineer District (MED) from March 1, 1943 through December 31, 1952.” In fact, the Manhattan District, as it was commonly called, turned over its control of nuclear-related activities to the Atomic Energy Commission (AEC) on December 31, 1946, and was officially abolished on August 15, 1947 (“Manhattan District History . . .” n/d). It would be more appropriate to refer to both MED and AEC in discussing activities that continued after 1946.

1.2 Uranium Processing

In Section J.2.1, “Site Activities,” under the subheading “Uranium Processing,” Allen (2014a) describes several uranium processing campaigns at Joslyn during 1943–1944 and 1947–1948. In Section J.2.3, “Production Rate,” Allen refers to the detailed listings of uranium rolling and machining days at Joslyn in Tables J.5/6. The number of days during which each operation (or both operations simultaneously) occurred in a given year is summarized in Table J.1. These data are used in Section J.4 to determine the intakes of uranium dust by Joslyn workers, and in Section J.5 to determine doses from external exposures. In the next section of the present review, we perform an independent estimate of the number of days spent on uranium operations during each year of the covered period. Following the detailed discussion of our analysis, we compare our results with the uranium workdays listed by Allen.

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1.2.1 Independent Evaluation of Uranium Processing Days

Table J.5 lists the dates on which uranium billets were rolled into fuel rods at Joslyn during the period of covered operations: 1943–1952. Table J.6 presents a similar listing of uranium machining at Joslyn during this period. Each entry in Tables J.5/6 is accompanied by one or more references to documents in the Division of Compensation Analysis and Support (DCAS) Site Research Data Base (SRDB). In order to perform an independent evaluation of the number of rolling and machining days, we reviewed each of these documents, as well as references listed in the Special Exposure Cohort (SEC) petition evaluation report (Harrison-Maples et al. 2012), which was cited by Allen (2014a), and other references in the SRDB, comprising a total of about 100 documents. We did not confine our review to the specific pages cited in the NIOSH reports, but either visually scanned each document or performed a computer-enabled text search to find all relevant references to Joslyn.

Allen (2014a) separately evaluated the days devoted to rolling uranium billets into fuel rods, and days spent machining such rods, which may have been rolled at another facility. This distinction is needed for the assignment of daily intakes of uranium dust from rolling and machining on the basis of data for these operations listed in TBD-6000 (Allen 2011, Tables 7.8 and 7.9). However, since NIOSH has concluded that it cannot estimate internal doses at Joslyn with sufficient accuracy prior to August 1, 1948, there was no need to separate the rolling and machining operations that occurred prior to that date, nor did we do so in the present review. The total days of uranium handling are used to assign external doses during the entire period of MED/AEC operations, so these days need to be estimated for each year during this period.

In the following discussion, we attempt to determine the maximum likely days of uranium processing during each year. We note that Allen (2014a) based his analysis on a normal workyear comprising 250 workdays. However, Joslyn at times operated up to 20 h/d, 7 d/wk. We took these factors into account in determining the workdays of uranium activities for use in dose reconstruction.

1943

The earliest reference to uranium processing at Joslyn is by Chipman (1943), who cited the rolling on March 13, 1943, of three ingots cast at “M.I.T.” (Massachusetts Institute of Technology). The next reference is a memo by Chipman and Greninger (1943) who described the rolling of six billets on June 29, 1943. Both Chipman and Greninger were on the staff of the University of Chicago (U of C) Metallurgical Laboratory, which later became the Metallurgy Division of Argonne National Laboratory (ANL). DeBlois (1946, Part 2) stated that Joslyn used 32.3 tons of uranium to produce 23.5 tons of rods, the work being completed on June 25, 1943. Since ingots or billets (the terms appear to be used interchangeably) typically weighed 100–200 lb each, there was clearly more production than can be inferred from Chipman’s memo. Later documents indicate that Joslyn could roll 3–10 tons of uranium per day. Since this was one of the first uranium rolling campaigns, we assume that the productivity was at the low end of the scale due to lack of experience. We therefore assume that Joslyn spent 11 days rolling the 32.3 tons of uranium cited in DeBlois’ memo prior to June 25, plus 1 day on June 29.

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On August 15, 1943, U of C issued a subcontract (Service Contract No. 7401-37-9) to Joslyn to perform a variety of tasks connected with the production of uranium fuel rods. The initial contract, issued on August 15, 1943, with a termination date of December 31, 1943, was:

to perform centerless grinding operations on rods and tubes to be furnished by the Contractor, together with those operations that may be preliminary and supplementary thereto, such as straightening, centerless turning, pickling, etc., at the rate of twelve dollars (\$12.00) per hour which rate is all inclusive of facilities, supplies, labor and supervision supplied by the Subcontractor. (University of Chicago 1943)

This initial contract did not cite a total price, nor are there any invoices or other documentation that would allow us to estimate the total amount of work actually performed during this period. We are limited to individual reports and memos that pertain to work during this time. The first of these is a report by Greninger and Van Echo (1943a), dated September 1, 1943, which described centerless grinding (CLG) of extruded uranium rods at Joslyn, but did not specify the dates, duration, or quantity. The operations were said to be described in three tables, but we could not identify these in the SRDB. Since the operation most likely took place between the issuance of the contract on August 15 and the date of the memo, the duration could have been between 1 and 17 days. The next reference is a September 7, 1943, report by the same authors (Greninger and Van Echo 1943b), which described the CLG of 14 extruded uranium rods. Because time-saving procedures were used, the rods were ground in 8 hours. This suggests that the previous grinding campaign could have taken longer. We thus make the claimant-favorable assumption that the first grinding took 2 days, the experience gained allowing Joslyn to perform the second operation more quickly. The next period of activity was November 29–December 15, a span of 17 days, comprising 16 days of CLG that ended at 11 PM on December 14, and preparation for shipping on December 15 (Simmons 1944a). We note that our analysis assumes that a single worker worked continuously for 17 days. Although he would have been entitled to overtime pay, we are not aware of any regulations that would have prohibited such work, nor is it implausible for a person to work such an extended schedule for a limited time.

The uranium workdays in 1943 are summarized as follows:

- 32.3 tons rolled prior to June 25 11 d
- 6 billets rolled on June 29 1 d
- Rolling prior to September 1 2 d
- Rolling prior to September 7 1 d
- November 29–December 15 17 d
- Total 32 d

We thus conclude that there were 32 days of documented or inferred uranium handling at Joslyn during 1943. Since the covered period began on March 1, there were 44 weeks during the

remainder of the year. Assuming 2 weeks of vacation leaves 210 workdays.¹ Since the 17-day span included two weekends, we expanded the total number of workdays in 1943 to 214.

1944

There were five subsequent agreements following the initial U of C contract. Agreement 1 was “to continue to perform centerless grinding operations on rods and tubes to be furnished by the Contractor, plus preliminary and supplementary operations thereto.” Each of the subsequent agreements specified: Work (No Change). Each agreement listed a cumulative cost ceiling for the current and all prior agreements; however, no mention was made of expenditures during the initial contract. Given the rate of \$12/h, we estimated the maximum hours worked at Joslyn during each contract period, based on the cost ceiling for that period. We then estimated the number of workdays based on the assumed length of the workday for the given time period, which we obtained from the Excel file *Joslyn Example DR Rolling and Machining Workdays Calcs 2014-04-15.xlsx*, which is on the DCAS restricted website, and which was used to calculate doses reported by Allen (2014a). Prior to 1951, the workday was assumed to be 9.6 h long. These five agreements and the estimated maximum number of uranium machining days in each period are summarized in Table 1.

Table 1. Agreements Modifying Joslyn’s Subcontract with the University of Chicago

Agreement No.	Dates		Cost Limit (cumulative)	Workdays ^a
	From	To		
1	1/1/44	6/30/44	\$5,000	87
2	1/1/44	6/30/44	\$10,000	
3	7/1/44	12/31/44	\$20,000	87
4	1/1/45	6/30/45	\$30,000	87
5	7/1/45	6/30/46	\$35,000	43

^a Estimated on the basis of \$12/h, 9.6 h/d.

As shown in the table, Agreements 1 and 2 both spanned the first 6 months of 1944; Agreement 2 increased the allowed cost specified in Agreement 1. The other three agreements extended both the period of performance and the cost. The last column shows the estimated uranium machining days during the period covered by each agreement. These are the maximum machining days during the respective periods, exclusive of any machining that might have been performed at the request of other organizations not covered by the U of C contract.

“Subcontract Monthly . . .” (1945) refers to a subcontract to Joslyn for “rolling mills” that was “cancelled in favor of P.O. [purchase order].” This confirms that the contract discussed above was only for CLG and other machining on rods that had been produced elsewhere, most likely by extrusion, and did not cover the rolling of billets into rods. Such activity was therefore in

¹ Our analysis follows the self-consistent methodology of TBD-6000 as well as the NIOSH methodology of estimating radiation exposures of Joslyn. In the NIOSH scheme, the workweek is assumed to comprise 5 workdays, with the length of the workday adjusted to account for the total hours in the workweek.

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addition to the machining under the contract. Further confirmation is furnished by Greninger (1945):

The type of work carried out by Joslyn for us has involved the hot rolling of uranium and uranium alloy billets from about 4½” diameter billets to about 1½” diameter rod (they also carry out miscellaneous straightening, grinding, etc, for us under a Service and Supply Subcontract).

Greninger (1945) further stated that Joslyn provided a cost estimate for each rolling job, confirming that this work was outside the machining contract. One day of rolling—on May 4, 1944—was ordered by Greninger (1944).

As stated previously, the workdays listed in Table 1 are maxima: this estimate assumes that the full value of the contract was realized by Joslyn during the period covered by each agreement, and that each day’s work was performed during a single shift. Given that Agreement 2, dated April 17, 1944, provided an additional \$5,000 for the period January 1–June 30, 1944, it is reasonable to conclude that the workload was such that the original allocation of \$5,000 for this period was likely to be exceeded. Although we cannot rule out the possibility that each day’s work was performed during more than one shift, we note that the work—a maximum of 87 workdays in a 6-month period—could have been easily accomplished by using single shifts.

“Subcontracts—Chicago Area . . .” (1946), dated May 31, 1946, stated that Joslyn held a service contract issued August 15, 1943, with a termination date of June 30, 1946; the estimated cost was \$35,000. These terms are consistent with the terms of Service Contract No. 7401-37-9 and its subsequent agreements, discussed previously. However, the “Subcontract” document lists an amount of \$13,388 under “payments made by contractor” and the same amount under “reimbursed.” Since the subcontracts status report was prepared one month before the termination of the Joslyn subcontract, it is difficult to determine how much work Joslyn actually performed under the U of C contract—it is possible that some work had not yet been invoiced and paid for, or more work was done during the final month of the contract, in which case such work would not have been included in the amount of the payment.

At a minimum, Joslyn performed machining for U of C during the term of the contract for which it was paid \$13,388. Given the rate of \$12/h, we can infer that the work took ≈1,116 h, or ≈116 d. Given the \$20,000 ceiling under the U of C subcontract during 1944, we assume, for the purpose of the present analysis, that all of this work was performed during that year.

We also note specific documentation for rolling and machining that was performed by Joslyn during 1944. Simmons (1944a) reported CLG was performed between January 3 and 14. Fuqua (1944) reported rollings on May 8–9. Simmons (1944b) reported rolling and grinding on June 1–5. Some of these were done on behalf of duPont (see below), the rest for U of C. Simmons (1944c) reported rolling on June 19–20.

Joslyn had a contract with duPont, the wartime manager of the Hanford site, to roll uranium fuel rods for Hanford. According to duPont (1945), Joslyn rolled uranium rods under this contract on May 9–11, June 2, and June 22–24. King (1945) reported rollings performed on December 11–12 and December 20–28 under the duPont contract.

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According to duPont (1945),

Several experimental and small-scale production rolling runs had been made during 1943 and 1944, initially under Metallurgical Laboratory [U of C] orders and supervision, but later (May - September 1944) arranged and followed by Construction and TNX. Most of these rolling trials were made at Joslyn Mfg. & Supply Co.

Harrel (1944) cited a separate U of C subcontract with Joslyn, effective October 2, 1944. He cited total charges of \$11,801.83 up to the date of his letter—December 4, 1944.² Since Joslyn most likely invoiced U of C on a monthly basis, these are probably the charges through November 30. The type of work performed was not cited. Since Joslyn is referred to as the seller, presumably U of C was purchasing rolled or finished rods. Assuming that Joslyn incurred similar operating costs for rolling as for CLG, we can estimate the workdays by assuming a cost of \$12/h, which results in 983 h. Given the 60 d period during which this work was performed, Joslyn is assumed to have worked ≈ 16 h/d, or two shifts/day, 7 d/wk, which is consistent with their schedule during other periods of uranium metal production. It is unlikely that any one worker would have worked continuously during this period. However, based on interviews with workers at another steel plant (General Steel Industries [GSI]), working 65 h/wk during periods of high production was not unusual (Allen 2014b). Since the period in question spanned 9 weeks, we will assign 61 days for this period ($9 \text{ weeks} \times 65 \text{ h/wk} \div 9.6 \text{ h/d} \approx 61 \text{ d}$).

The specifically documented uranium workdays in 1944, excluding machining performed under the U of C subcontract, are summarized as follows:

- May 8–11 4 d
- June 1–5 5 d
- June 19–24 6 d
- October 2–November 30..... 61 d
- December 11–12, 20–28 11 d
- Total documented..... 87 d

Simmons (1944a) reported CLG and other machining being performed from 1 PM, January 3, to 3 PM, January 8, 16 h/d, with a 6 h lapse, and again from 8 AM January 11 until midnight, January 13, 20 h/d, which constitutes a total of 132 h during 9 calendar days. Given a maximum of 1,116 h under the U of C machining subcontract, this leaves a balance of 984 h. Assuming 9.6 h/d, this constitutes an additional 103 d. We thus estimate a maximum of $103 + 11 + 87 = 201$ d of uranium exposure during 1944. Since December 20–28 spanned a weekend, we increase the total workdays during this year to 252.

² It is likely that this was the subcontract that was cancelled prior to July 30, 1945 (“Subcontract Monthly . . .” 1945).

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1945

Koenig (1945) reported that an order for 12 tons of rolled rods had been received from the District Office, and that “the possibility of having this work performed at . . . [Joslyn] is now being investigated.” Presumably, the order was awarded to Joslyn, since Belmore (1945a) reported that 25 out of a special order of 220 threaded rods were expected to be shipped by Joslyn during the week ending March 5 (which fell on a Monday), while Bassett and Belmore (1945b) reported that this order was completed on May 16. Monthly updates on the production of these rods provided by Belmore (1945b) and by Bassett and Belmore (1945a) indicated incremental progress each month. Assuming that the production of the remaining 195 rods began on March 1, the elapsed time would have been 11 weeks. Given the slow rate of production, we assume the work was performed only on weekdays, which results in a total of 55 workdays during this period. Based on this rate of production, the entire order of 220 rods could have taken 62 workdays. No explanation is given for the relatively slow rate of production compared to later orders for similar items.

According to a report from the NRX Reactor at Chalk River, Ontario, Joslyn supplied 222 rods to this Canadian reactor in 1945 (Garrow 1961, Table 1). There is no specific mention of the production of these rods in any other document that we examined in the SRDB. Based on the preceding rolling experience, it is possible that the Canadian order took ≈ 63 d to complete. However, it is also possible that, despite the slight discrepancy in the number of rods, the two orders are one and the same. We note that in both cases, the diameter of the rods is specified to be 1.360 in. Alternatively, given the slow rate of production of the first order, both orders might have been filled simultaneously. We thus estimate a total of 63 d of uranium exposure in 1945.

1946

An internal ANL memo dated July 18, 1946, requested that Joslyn be awarded another MED contract (Schumar 1946a). However, we have found no record of such a contract in the SRDB. Consequently, we have to estimate the uranium workdays during 1946 on the basis of records of uranium metal shipments to and from Joslyn.

Belmore (1946) reported that 50.9 tons of uranium billets were shipped to Joslyn during August 1946. Beeler (1947) referred to the production of 15 tons of rods by Joslyn for Great Britain. These rods were made from billets produced at “Electromet” (the Electro Metallurgical Company, also known as ElectroMet) during the final 6 weeks of operation before the plant went on standby on September 1, 1946.³ According to Schumar (1946b), the billets for producing these rods arrived at Joslyn on August 13; the production of the rods was scheduled to begin September 3. It is likely, but not certain, that the billets cited by Belmore are the same ones referred to by Beeler and by Schumar. Since the Beeler memo, which dealt primarily with shipments of uranium oxide during 1946, is dated January 14, 1947, the rods were almost certainly produced in 1946. Other documented shipments from Joslyn during the latter part of that year comprise 4,407 lb (shipping weight) of rods shipped to Hanford in October (Hanford 1946) and 11 tons of rods shipped to Hanford during November (“Monthly Report . . .” 1946), for a total production of 28.2 tons. We previously estimated that the production of 12 tons of

³ Date of standby period is from Glover (2012).

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rods required 62 d. Based on this rate, Joslyn would have required \approx 146 workdays to produce 28.2 tons of rods in 1946.

We do not know exactly when Joslyn started to produce rods for Hanford, nor when the production of rods for Great Britain ended. We make the claimant-favorable assumption that production started on September 3 and that the final rods for Great Britain were shipped on December 31, a span of 17 weeks plus 1 weekday. Assuming a worker worked 5 d/wk, there would thus have been 86 uranium workdays during 1946, rather than the 204 days estimated above.

In order to account for the 50.9 tons of billets received in August, we note that Beeler (1947, Appendix B) stated that in producing 1,000 lb of rods, Joslyn also produced 500 lb of uranium metal scrap and 500 lb of oxide. If we assume the oxide to be U_3O_8 , 500 lb would have contained 424 lb of uranium. Therefore, producing 28.2 tons of rods would have created \approx 26 tons of uranium waste. The total mass of uranium in the rods and the waste would more than account for the mass of the billets. Since Beeler aimed to set a price on the rods, his estimate of waste may have been overly conservative.

We note that Garrow (1961, Table 1) listed 166 rods at the NRX Reactor that were rolled by Joslyn in 1946. We assume that these are the same as the 15 tons of rods produced for Great Britain reported by Beeler (1947), inasmuch as Schumar (1946b) referred to the contemporaneous “fabrication of special uranium rods for the British and Canadian Governments.”

1947

Smith (1947) reported that 10 tons of uranium billets were received by Joslyn on July 28, 1947. The billets were stored until August 4, when they were weighed; they were rolled into rods on August 5–6. There is no mention of machining the rods after they were rolled, which explains the fast production rate. Cleanup was completed on August 7 and shipment was scheduled for August 8.

Based on this account, we estimate that the uranium was handled during 6 days: July 28, when the billets were received at Joslyn; August 4 when they were weighed; August 5–6 when they were rolled into rods; August 7 when cleanup took place; and August 8, when the rods were scheduled to be shipped. It is plausible and claimant favorable to assume 6 days of external exposure during this operation—the billets were presumably stored in a warehouse under armed guard July 29–August 3, so there was little potential for exposure during this time. This is the only uranium operation during 1947 for which we found any records in the SRDB, nor is there any information that Joslyn had a contract with AEC or one of its contractors during that year.

1948

Rolling of uranium billets into rods resumed in 1948. On February 6, Greninger (1948) wrote:

We understand that the A·E·C· [sic] will arrange for the alpha-rolling of all Hanford billets at Joslyn Mfg. & Supply Co, Fort Wayne, Indiana, this operation

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to continue until such time as we are equipped either to alpha-roll or alpha-extrude in the 300 Area.

Taussig (1948) wrote that Joslyn can roll 35 tons of billets in 5 days, beginning March 1. Contract AT-30-1-GEN 281 (1948) specified that Joslyn will roll 170 tons of uranium, starting on March 1 and ending no later than April 30. However, according to “Hanford Works Monthly Report: March, 1948” (PDF p. 54), rolling began on February 28. Supplemental Agreement No. 1 (1948) increased the amount to 225 tons, with the same period of performance. Supplemental Agreement No. 2 (1948) increased the amount to 345 tons, with the period of performance extended to May 31. Supplemental Agreement No. 3 (1948) increased the amount to 520 tons, with the period of performance extended to June 30. Supplemental Agreement No. 4 (1948) specified the rolling of an additional 110 tons, starting on July 2 and ending no later than July 31. Finally, Macherey (1948) requested Joslyn to roll seven billets in early August. Based on the previous production rates, this would most likely have been done in one day.

We make the plausible and claimant-favorable assumption that uranium was being continuously handled at Joslyn from February 28 to June 30, and again from July 2 to July 31, a period that spans 22 weeks, or a total of 110 weekdays. Adding 1 day in August results in 111 workdays. This total includes 110 days during the SEC period, when NIOSH performs only partial dose reconstructions (DRs) based on external exposure, as well as 1 day of rolling in the post-SEC period, when both external and internal doses are reconstructed.

1949

Garrow (1959a) reported the fabrication of 244 uranium rods at Joslyn in 1949 for use in the NRX reactor. Two hundred and seventy-five billets were rolled into rods on May 26–27.

After rolling the rods were numbered, cooled partially in air (presumably through the recrystallization temperature), and then finally cooled in water. The ends of the rods were then cropped to sound metal, and 2-1/2 inch sample lengths were cut from each end if the rods were long enough. Before machining the rods were straightened in a Medart straightener. They were then rough turned to 1.42 inches, centreless ground to 1.375 inches, and cut to length. Both ends of the rod were then threaded and they were finished by centreless grinding to 1.360 inches +/- 0.002 inches. After this the rods were wiped with a wet rag and inspected by an NRC inspector according to Specification NRX-100-4. The rods were then weighed, packed in individual aluminum tubes and crated for shipment. (Garrow 1959a)

Although the rolling only took 2 days, the other operations described by Garrow (1959a) required the uranium to be on site and in process for a considerably longer time. There is no documentation of the total time for the production of these rods. However, Klevin (1952, Appendix B) presented job analysis sheets for processing uranium rods at Joslyn based on his site visit in January 1952. These sheets present the only detailed data on the duration of each operation at Joslyn and on the throughput of the uranium for each work station. We therefore used these data to estimate the duration of the production of fuel rods in 1949, 2½ years prior to the operations observed by Klevin.

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The limiting operation is CLG. This operation was staffed by one man per shift, who processed 18 rods per shift. Since there were two shifts per day, grinding 275 rods would have required ≈ 8 days. Allowing time for the other processes mentioned by Garrow (1959a), including weighing and packing, we estimate 9 days of uranium handling at Joslyn, since machining of each batch of rods could begin shortly after their rolling. Given the short duration of this work, a single worker could have been exposed during this whole time.

1950

There is incomplete information on uranium processing at Joslyn during 1950. On July 31, Freitag (1950) requested that 5,500 lb of rolled uranium rods be shipped to Joslyn as soon as possible. Depending on their size, this could have constituted 30–50 rods. We assume that these rods were machined and finished at Joslyn during the month of August. Belmore (1950) requested that Joslyn furnish a quote for the production of 305 fuel rods for the National Research Council of Canada. Stroke (1950a) observed the rolling of uranium rods for the National Research Council on August 10 and 11. These presumably became the 280 rods furnished to the NRX Reactor at Chalk River, Ontario, reported by Garrow (1959b).⁴ Stroke (1950b) discussed uranium rolling experiments at Joslyn, but did not cite the dates, duration, nor amount of metal processed. The date had to be prior to August 9, the date of the letter to which Stroke was responding. Harris (1950) cited three uranium jobs in August, which included rolling and machining—he provided no information on the duration or amounts of material processed. Braiden and Gustavsen (1951) reported that 6,621 kg of uranium rods were shipped from Joslyn to the AEC Lake Ontario Office between January 1 and October 31.

We estimate that the rolling and finishing of 305 rods, 280 of which were accepted by the NRX Reactor, took about 10 days, based on the production of 275 in 1949. Each of these rods was produced from a billet weighing 185–200 lb (84–91 kg). Assuming that a rod constituted $\approx 75\%$ of the mass of the billet, the rods would have had a total mass of $\approx 18,000$ kg. These rods were most likely separate from the 6,621 kg of rods mentioned above. Therefore, the production of these latter rods constitutes another period of uranium activity. Based on their mass, we estimate their production took about 3 days. Still another activity was the experimental rollings cited by Stroke (1950b), which we conservatively assume to have taken 3 days, since each of the jobs mentioned by Harris was of short duration. We therefore estimate there were 16 days of machining and rolling during 1950. Since these activities were not continuous, any one worker could have been exposed for this entire period. This total number of days subsumes any activities for which precise documentation is lacking.

1951

“Hanford Works Monthly Report for July 1951” mentioned orientation studies on four rods rolled at Joslyn. Although there is no other mention of such a rolling during 1951 prior to the time of this report, we make the claimant-favorable assumption that these rods were produced in 1951, and that the production included machining as well as rolling. In addition, the National Lead Company of Ohio, operator of the Fernald Feed Materials Production Center, conducted a

⁴ The difference in the number of rods could have been due to the rejection of some rods that did not meet specifications, or to a change in the order after the request for a quote.

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uranium dust survey during machining operations at Joslyn on October 24 (AEC 1951). Absent other documentation, we assign 2 days of exposure to uranium machining during 1951. We note that there is no order for or report of this machining operation in the SRDB, which leads us to believe that the records are not complete, and that there may have been other activities involving uranium during that year. However, absent other documentation, we have no basis for assigning additional uranium exposure days in 1951.

1952

Klevin (1952) reported a survey of uranium air dust concentrations during various operations at Joslyn. In the introduction to the report, Klevin stated that the survey was conducted on January 8–9 and January 16, 1952. However, the nine sample sheets at the back of the report, which are not numbered consecutively, are dated January 8, 16, and 18. A review of the sheets indicates that the sample numbers and dates are consecutive and there do not appear to be any intermediate missing sheets. We conclude that the dates on the sheets are most likely the correct dates for the survey, and that the introductory statement is erroneous. In either case, it appears that uranium processing took place during 3 days in January.

On January 23, Malone (1952) requested the shipping of three rods to Joslyn. These rods would have most likely been machined sometime after that date; we therefore assign one additional day of machining in 1952. In a memo dated July 16, Dunlap (1952) reported planned experiments requiring fuel rods of three sizes. The preparation of these rods required Medart straightening followed by CLG at Joslyn, followed by tests at Brookhaven and “WAPD” (acronym for Westinghouse Atomic Power Division). The next step, presumably on the same rods, was drawing to a smaller diameter, further Medart straightening and CLG (presumably at Joslyn) further tests at Brookhaven and WAPD, Medart straightening, and cutting and deburring. Based on our understanding of this protocol, the rods would be sent to Joslyn three times, on three different days. We therefore assign 3 additional days of machining, for a total of 7 days of machining in 1952.

1.2.2 Comparison of SC&A and NIOSH Workday Estimates

Table 2 presents the results of the workday analysis discussed above. The NIOSH values are from Allen (2014a, Table J.1). We have combined Allen’s values for “Rolling only,” “Machining only,” and “Rolling + Machining” for the SEC period (March 1, 1943–July 31, 1948) in the “Machining” column, since only external doses from uranium are calculated during this period, and these do not depend on the type of operation. For the later period, we combined “Machining” with “Rolling + Machining,” since the daily external and internal doses from these two scenarios are the same. Workdays when there were no uranium production or handling activities are listed under the heading “Inactive.”

We observe that for every year except 1947 and the last 5 months of 1948, the SC&A workday estimates are significantly higher than those made by NIOSH. The reason for the difference in 1947 is that NIOSH assumed that the uranium rods sold to the British and Canadian Governments, as described by Beeler (1947), were produced during that year, while we concluded that they were produced in 1946, since Schumar (1946b) stated that production was to have started on September 3 of that year. The reason for the difference in 1948 is that NIOSH

based the production of rods for the Canadian NRX Reactor on the statement by Garrow (1961, p. 7) that “the original batches of uranium rods were rolled between 1947 and 1950” and assigned the entire production to the latter part of 1948, after the SEC period. However, we noted the listing of the number of rods delivered each year in Table 1 of the same document and utilized these data to apportion the production to the years in which the rods were delivered.

Table 2. Comparison of SC&A and NIOSH Uranium Workdays

Year	Total workdays	SC&A			NIOSH		
		Machining ^a	Rolling	Inactive	Machining ^a	Rolling	Inactive
1943	214	32		182	18		190
1944	252	201		51	43		207
1945	250	63		187	54		196
1946	250	86		164	33		217
1947	250	6		244	12		238
Jan-Jul 1948	146	110		36	75		71
Aug-Dec 1948	104		1	103	0	10	94
1949	250	5	2	243	0	2	248
1950	250	10	6	234	3	8	239
1951	250	2		248	1	1	248
1952	250	7		243	1	3	246

^a Sum of machining and rolling days during SEC period (March 1, 1943–July 31, 1948)

1.3 Occupational Internal Dose

1.3.1 Intakes of Uranium Dust During Rolling and Machining Operations

Allen (2014a) calculated intakes of uranium dust from rolling and machining during the post-SEC period (August 1, 1948–December 31, 1952) in the following manner:

- Rolling
 - Inhaled intake
 - Calculate the inhaled intake of the rolling operator per workday by multiplying the inhaled intake per calendar day listed in TBD-6000, Table 7.8, by 1.46 ($365 \text{ d/y} \div 250 \text{ workday/y} = 1.46 \text{ d/workday}$).
 - Multiply result by number of rolling days in a given year to obtain annual inhaled intake from rolling uranium.
 - Ingested intake
 - Calculate the ingested intake in the same manner as the inhaled intake, but use the ingested intake per calendar day listed TBD-6000, Table 7.9.

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We note that the method of calculating ingestion intakes described in TBD-6000, Section 7.1.6, is based on a misinterpretation of the methodology described by Neton (2004). Neton described a method for calculating the intake of uranium aerosols that settled on the surface of a coffee cup, and derived a multiplier of 0.0985 to be applied to the airborne activity concentration to derive the intake via this pathway during an 8 h day. This factor needs to be scaled linearly to be applied to a longer workday. He also described a method for estimating the hand-to-mouth transfer of activity on a contaminated surface, and derived a multiplier of 0.1 (the exact value is 0.010044), which is based on the ingestion continuing during a 24 h day. This factor is independent of the actual length of the workday. In TBD-6000, however, both ingestion factors are scaled to the length of the workday. Consequently, all ingestion intakes listed in Table 7.9 for time periods prior to 1956, when the workday was assumed to be longer than 8 h, are greater than the values obtained by correctly applying Neton’s methodology.

- Machining
 - Calculate the inhaled and ingested intakes from machining in the same manner as from rolling, but use the intakes of the machining operator listed in TBD-6000, Tables 7.8 and 7.9.

We note that the daily inhaled intakes of the rolling and machining operators listed in TBD-6000, Table 7.8, were computed using the imprecise conversion factor of 2.2 dpm/pCi, rather than the exact value of 2.22. However, the ingested intakes listed in Table 7.9 did use the correct conversion factor.

1.3.2 Intakes of Uranium Dust in Between Rolling and Machining Operations

Allen (2014a) lists the intakes of uranium dust on days when no uranium rolling or machining operations were performed, which are based on the resuspension of uranium aerosols deposited on the floor. Allen states that the contamination level was calculated according to the procedure in TBD-6000. This procedure is described in greater detail by Sharfi et al. (2014), who state that they used the method described in TBD-6000, Section 7.1.5. The latter document assumed a uranium airborne activity concentration of 7,000 dpm/m³, which is equal to 3,153 pCi/m³. (We note in passing that shifting between activities expressed in disintegrations per minute and picocuries in various NIOSH documents leads to needless confusion, as well as occasional errors and inaccuracies, as noted previously. We recommend that NIOSH adopts SI units and expresses activities in units of becquerels.) However, Sharfi et al. adopted an activity concentration of 2,491 pCi/m³, which is listed in these authors’ Table A-5, which is reproduced from Harrison-Maples (2014, Table 7-2). The value is identified as the geometric mean of the machining operator in TBD-6000. It appears to have been derived from the geometric mean of the operator’s daily weighted average (DWA) concentration, 5,480 dpm, as listed in TBD-6000, Table 7.5, “Air sampling data for facilities machining uranium.” However, this value (as well as other values listed by Harrison-Maples, 2014, Table 7-1, Cols. 4–6) appears to have been derived by using the imprecise conversion factor of 2.2 dpm/pCi, rather than the exact value of 2.22. The correct value, based on TBD-6000, Table 7.5, is 2,468 pCi/m³.

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The airborne activity concentration used by Sharfi et al. (2014) and adopted by Allen (2014a) is claimant favorable but inaccurate. More important, neither Allen nor Sharfi et al. explain the use of a uranium air concentration of 2,491 pCi/m³ rather than the value of 7,000 dpm/m³ (3,153 pCi/m³) cited in TBD-6000, Section 7.1.5, to calculate the surface contamination level.

According to Allen (2014a), “Ingestion is proportional to contamination level and it is assumed those levels do not change between days of uranium work. Therefore, the operational ingestion values were also assigned for non-uranium work days.” The rates of ingestion during such days are specified by Sharfi et al. (2014), who state:

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.

The ingested annual intakes listed by Sharfi et al. (2014, Table B-2) utilize this methodology—the daily ingested intakes listed by Allen (2014a, Table J.2) are based on these values. Since the uranium aerosol concentrations, and hence the ingestion rates, are higher during machining operations than during rolling, this leads to the illogical result that the uranium ingestion rate is higher on days when no uranium was handled than on days when uranium billets were rolled into rods. A consistent and claimant-favorable assumption is to assign the highest ingestion rates—i.e., those during machining operations—during each workday, regardless of whether machining, rolling, or no uranium operations were taking place.

1.3.3 Total Annual Intakes of Uranium Dust

Sharfi et al. (2014, Table B-2) list annual intakes of uranium dust by inhalation and ingestion (in units of picocuries) during the post-SEC period of AEC operations. We confirmed that these values are consistent with the methodology described above, including the number of days devoted to rolling and/or machining listed in their Table B-2 that are reproduced by Allen (2014a, Table J.1). We have independently calculated uranium intakes during this period, using our estimates of machining and rolling days listed in Table 2, and the values of airborne uranium activity concentrations based on the operator’s DWA concentrations during rolling and machining operations listed in TBD-6000, Tables 7.3 and 7.5. We calculated ingestion intake rates based on the machining operator’s DWA concentration, using the formulas presented by Neton (2004) for Modes 2 and 3. The results of these analyses are listed in Table 3, along with the corresponding values presented by Allen (2014a, Table J.2).

As shown in Table 3, the inhaled intakes for each period except August–December 1948 are higher in the SC&A analysis, primarily due to higher estimates of machining days during these periods. Our ingested intakes are consistently lower, being based on Neton’s (2004) methodology rather than on the values listed in TBD-6000, Table 7.9.

1.4 Occupational External Dose

1.4.1 External Exposure to Penetrating Radiation from Uranium

Allen (2014a, Section J.5) describes the calculation of doses from external exposure to uranium metal and to surfaces contaminated with uranium dust. He assumed workers were 1 ft from a long uranium metal billet for 10 h during every day that uranium was rolled or machined. On nonoperational days, he stated that “the estimated contamination levels from section J.4 were combined with the photon dose conversion factors from table 3.9 of TBD-6000.” The annual external dose rates are listed in Table J.3. We observe that TBD-6000, Table 3.9, lists exposure (in milliroentgens) not dose rates from submersion in uranium aerosols. Table 3.10 lists exposure rates from a contaminated surface. Although the calculations are explained in somewhat greater detail by Sharfi et al. (2014), we were able to reproduce Allen’s results only by examining the Excel file *Joslyn Example DR Rolling and Machining Workdays Calcs 2014-04-15.xlsx*, which is on the DCAS restricted website.

Table 3. Comparison of SC&A and NIOSH Intakes (dpm per calendar day)

Year	SC&A		NIOSH ^a	
	Inhaled	Ingested	Inhaled	Ingested
Aug-Dec 1948	1,092	814	3,445	858
1949	1,905	821	1,066	892
1950	3,185	821	2,235	885
1951	1,081	784	1,034	818
1952	1,859	784	1,235	816

^a Source: Allen (2014a, Table J.2)

Examining this Excel file, we observe that NIOSH calculated the surface contamination level, in dpm/m^2 , by converting the air concentration from machining operations listed by Harrison-Maples (2014, Table 7-2) in units of pCi/m^3 to units of dpm/m^3 . The conversion utilized the factor 2.22 dpm/pCi . However, since Harrison-Maples had used the incorrect factor of 2.2 dpm/pCi , the original concentration of 5,480 dpm/m^3 listed in TBD-6000, Table 7.5, became 5,530 dpm/m^3 . While not a significant difference, it leads to potential confusion and undermines confidence in the accuracy of the analysis.

We further note that the exposure durations are inconsistent. On rolling or machining days, workers are assumed to have been exposed for 10 h/d, while on nonoperational days, they were exposed for 9.6 h/d prior to 1951 and 8.8 h/d in later years. The latter two exposure durations are consistent with TBD-6000, which incorporated these exposure durations in the external dose calculations for the various time periods (but failed to explicitly state these assumptions, much less justify their rationale). We recommend that NIOSH uses consistent exposure durations for exposures to uranium metal and to contaminated surfaces.

Finally, we note that Allen (2014a, Table J.3) added the exposures to contaminated surfaces, which are expressed in milliroentgens, to doses from uranium metal, which are expressed as

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personal dose equivalents, $H_p(10)$, in units of millirem. This is of more than just academic interest: an examination of OCAS-IG-001 (OCAS 2007) shows that for every organ listed, the exposure-to-organ-dose factors for photons of energies 30–250 keV in the anteroposterior (AP) orientations are up to 50% higher than the corresponding $H_p(10)$ dose factors.

A larger problem stems from the fact that the uranium dust that was deposited on the floor came primarily from the surface of the uranium metal. The surface of billets cast from natural uranium often has enhanced concentrations of short-lived progenies. As discussed by SC&A (2008),

Putzier (1982) reported measurements of increased beta activities on the surface of freshly cast uranium. He attributed this to the tendency of ^{234}Th , in equilibrium with its $^{234\text{m}}\text{Pa}$ daughter, to migrate to the surface as well as to the interface between the molten metal and the mold. Whereas the beta radiation at the surface of uranium metal in secular equilibrium with its short-lived progeny produced dose rates of about 200 mrad/h, the fresh castings had rates of 2,000–3,000 mrad/h.

Allen (2014b) cited this phenomenon in assigning doses to the skin of workers at GSI: “This effect is accounted for by assuming the Th-234 and Pa-234m activity is 15 times higher than what would be present at equilibrium.” There is no reason that the same assumption should not be used in the present assessment, especially since uranium billets rolled at Joslyn were produced by the Mallinckrodt Chemical Works (the source of the uranium handled at GSI) and by ElectroMet. The above phenomenon, which we have called the “Putzier effect,” was observed at both facilities. As cited by Thurber (2011),

A similar separation occurs in the processes at Mallinckrodt Chemical Works Plant 4 and Electro Metallurgical Company. In these plants, uranium metal, with UX1-UX2 [^{234}Th and $^{234\text{m}}\text{Pa}$] in approximate equilibrium, is purified by vacuum recasting at a temperature which volatilizes various impurities in the metal, including the UX1-UX2. These impurities condense on the cooler surfaces of the furnace interior and this deposit is the source of intense beta exposure during charging, discharging, cleaning and repair of the furnaces. [AEC 1949]

To evaluate the magnitude of this effect on external dose calculations for Joslyn, we performed independent MCNPX simulations of doses from photons emitted by uranium dust uniformly distributed over the floor of the room housing a rolling mill at Joslyn. As shown in a drawing by Piccot (1949), this room measured 96×300 ft and was the largest single area depicted in this floor plan. The photons comprised gamma and x radiation—and bremsstrahlung x rays from β emissions—from natural uranium isotopes and the short-lived radioactive progenies of ^{235}U and ^{238}U , assumed to be at 15 times their secular equilibrium concentrations. We note that TBD-6000, Table 3.10, assumed ingrowth of uranium progenies for 100 d after chemical separation. The ^{238}U progeny would be at $\approx 94\%$ of their equilibrium activities while ^{231}Th , the daughter of ^{235}U , which has a 25.5 h half-life, would be at essentially 100%. Because the time since separation of the uranium handled at Joslyn was variable and/or unknown, we performed a simplified, claimant-favorable analysis, assuming that the short-lived progenies were in secular equilibrium with their parent isotopes prior to remelting of the metal. Photon doses were

expressed in terms of $H_p(10)$ and were assessed in the center of the room at a height of 1 m above the floor.

We also performed MCNPX simulations of the dose to the skin from β rays emitted by the short-lived uranium progenies. We averaged the dose over a circular area with a radius of 25 cm in a horizontal plane at an elevation of 1 m above the center of the floor, using an F2-type fluence tally. The maximum energy of the β rays from the uranium progenies is 2.27 MeV—their maximum range in air is ≈ 1.025 m. We restricted the radiation source to a circular area of the floor with a radius of 1.05 m to avoid needlessly simulating the transport of β rays that would be absorbed in the air before reaching the target.

The results of our analyses are shown in Table 4. As shown in the table, our calculated $H_p(10)$ dose rate is 4 times larger than the exposure rates listed in TBD-6000, while the electron skin dose rate is 8 times larger than the TBD-6000 dose rate.

Table 4. Comparison of NIOSH and SC&A Dose Rates from Uranium-Contaminated Floor

Data	Photons– per dpm(α)/m ²		Electron skin dose
	Value	Quantity (units)	mrad/h per dpm(α)/m ²
NIOSH ^a	3.94e-10	Exposure (mR/h)	3.82e-08
SC&A	1.73e-09	$H_p(10)$ (mrem/h)	3.08e-07
Difference ^b	-77%		-88%

^a Source: Allen (2011, Table 3.10)

^b NIOSH \div SC&A – 1

1.4.2 Skin Doses from Electrons Emitted by Uranium Metal

Allen (2014a) based doses to skin from nonpenetrating radiation from uranium metal on TBD-6000, Section 6.3. The dose to the skin on the hands and forearms of an operator, assumed to be in contact with the metal during 50% of the workday, was assigned a value of 230 mrem/h. The dose to the skin on the rest of the body was based on the dose rate at a distance of 1 ft from the surface of the metal, which was assumed to be 10 times the dose rate from penetrating photon radiation from a large uranium billet. The skin doses assigned by Allen to workers at Joslyn do not adequately account for the Putzier effect, as discussed above.

In order to evaluate the impact of this effect, we performed independent MCNPX analyses of electrons emitted from such a billet to derive a realistic but bounding estimate of skin doses from uranium billets handled at Joslyn. We modeled the billet as a cylinder, 4.75 in (12.065 cm) in diameter and 28 in (71.12 cm) long, in a vertical orientation in the center of a stylized concrete room, represented by a hollow cylinder, 3 m high and 10 m in diameter, with 1 ft thick walls, floor, and ceiling. The center of the billet was 100 cm above the floor. This geometry provided a reasonable approximation of scatter in an actual industrial setting, while providing an axially symmetric geometry which enables greater computational efficiency.

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The radiation source was a billet composed of natural uranium and the short-lived radioactive progenies of ^{235}U and ^{238}U . Only the β rays emitted by nuclides inside a 1 mm thick surface layer can exit the metal and thus contribute to the external electron dose. In order to account for the Putzier effect, we assumed that the short-lived progeny of ^{238}U — ^{234}Th , $^{234\text{m}}\text{Pa}$, ^{234}Pa —and ^{231}Th , the short-lived progeny of ^{235}U , were at concentrations equal to 15 times their secular equilibrium concentrations inside this surface layer.

The first simulation calculated external doses from the continuous β ray spectra of the natural uranium progenies, assumed to be at 15 times their secular equilibrium concentrations. We used F2-type fluence tallies to calculate the electron skin doses over cylindrical surfaces concentric with the metal rod at distances of 0.007 cm (the depth of the epithelial layer of the skin) and 1 ft (30.48 cm) from the metal. Each surface extended 5 cm in each direction from the center of the rod. The second simulation was the same as the first one, except that the source term was the discrete electrons emitted during the decay of the natural uranium isotopes and their short-lived progenies, again at 15 times their secular equilibrium concentrations. We added the MCNPX results from the two simulations for each distance to estimate the total dose to the skin at each distance from the metal. The results, along with a comparison to the electron skin doses assumed by NIOSH, are presented in Table 5.

Table 5. Comparison of NIOSH and SC&A Electron Skin Dose Rates from Uranium Billet (mrad/h)

Data	Distance	
	Contact	1 ft
NIOSH	230	7.03
SC&A	1,147	93.5
Difference ^a	-80%	-92%

^a NIOSH \div SC&A – 1

1.4.3 Annual External Doses from Uranium

We have combined our estimate of workdays devoted to handling uranium at Joslyn during each year of covered operations listed in Table 2 with the results of our analyses of external exposure to penetrating and nonpenetrating radiation discussed in Sections 1.4.1 and 1.4.2 to derive $H_p(10)$ and electron skin doses. The $H_p(10)$ doses were derived using the following equations:

$$\begin{aligned}
 D_b &= d_{b1} f t_w T_U \\
 D_f &= d_\sigma T_w \sigma_U \\
 D_t &= D_b + D_f
 \end{aligned}$$

- D_b = $H_p(10)$ dose rate from external exposure to uranium billet (mrem/y)
- d_{b1} = $H_p(10)$ dose rate from external exposure at 1 ft from uranium billet
= 0.703 mrem/h (Allen 2011, Table 6.1)
- f = fraction of workday spent in vicinity of uranium metal
= 0.5 (Allen 2011, Section 6.2)

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- t_w = length of workday (*Joslyn Example DR Rolling and Machining Workdays Calcs 2014-04-15.xlsx*)
 = 9.6 h/d (prior to 1951)
 = 8.8 h/d (1951–1952)
- T_U = uranium machining + rolling days in each year (see Table 2) (d/y)
- D_f = $H_p(10)$ dose rate from external exposure to contaminated floor (mrem/y)
- d_σ = $H_p(10)$ dose rate from external exposure to contaminated floor
 = 1.73×10^{-9} mrem/h per dpm(α)/m²
- T_w = length of workyear (*Joslyn Example DR Rolling and Machining Workdays Calcs 2014-04-15.xlsx*)
 = 2,400 h/y (prior to 1951)
 = 2,200 h/y (1951–1952)
- σ_U = uranium contamination level (*Joslyn Example DR Rolling and Machining Workdays Calcs 2014-04-15.xlsx*)
 = 1.075×10^7 dpm(α)/m²
- D_t = total $H_p(10)$ dose rate from external exposure (mrem/y)

The resulting doses for each year are listed in Table 6, along with the corresponding values presented by Allen (2014a, Table J.3).

Table 6. Comparison of SC&A and NIOSH External Doses from Uranium

Year	SC&A			NIOSH ^a		
	$H_p(10)$	Electron skin dose (rad/y)		$H_p(10)$	Electron skin dose (rem/y)	
	mrem/y	Other skin	Hands & forearms	mrem/y	Other skin	Hands & forearms
1943	146	21.16	182.5	134	2.01	21.45
1944	723	98.23	1,111.4	311	3.84	50.27
1945	257	36.22	353.8	388	4.57	62.87
1946	335	46.55	480.0	241	3.18	38.80
1947	65	10.64	40.9	94	1.78	14.74
1948	419	57.77	617.3	604	6.63	98.40
1949	68	11.09	46.4	24	1.12	3.28
1950	99	15.13	95.8	87	1.72	13.59
1951	47	8.10	17.3	23	1.04	3.28
1952	63	10.16	42.5	37	1.17	5.57

^a Source: Allen (2014a, Table J.3)

Our estimates of $H_p(10)$ doses are significantly higher than those presented by Allen (2014a) in all but two years. Several differences account for the disparity in the results:

- Estimates of uranium workdays listed in Table 2

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- Assumptions regarding the length of the workday
 - Allen (2014a) assumed full-time exposure at a distance of 1 ft from a uranium billet during a 10 h workday
 - SC&A assumed 9.6 h/d and 8.8 h/d, respectively, for the two periods: prior to 1951 and 1951–1952
 - SC&A assumed the operator was 1 ft from the billets during 50% of the workday
- Assumptions regarding external exposure to the contaminated floor
 - Allen (2014a) assumed exposure to the contaminated floor only on nonuranium workdays
 - SC&A assumed exposure to the contaminated floor during every workday
- SC&A dose rates from the contaminated floor incorporate the Putzier effect

We calculated the annual electron skin dose in an analogous, self-evident manner. The dose to the skin, other than the skin on the hands and forearms, was calculated assuming that the worker spent 50% of each uranium workday at a distance of 1 ft from a uranium billet, utilizing the dose rate listed in Table 5. His skin was assumed to be exposed to β radiation from the contaminated floor during every workday of the year. The skin on the hands and forearms was assumed to be in contact with the uranium metal during 50% of the workday. Otherwise, the dose was calculated in the same manner as the dose to the other skin, except that we assumed that the skin was shielded from the floor when it was in contact with the uranium.

The resulting electron skin doses for each year are listed in Table 6, along with the corresponding values presented by Allen (2014a, Table J.3). The primary cause of the significant differences between the doses resulting from our analysis and that of Allen (2014a) is our incorporation of the Putzier effect in the dose rates from the uranium billet and the contaminated floor. These differences also reflect the factors listed in the discussion of the dose rates from penetrating (photon) radiation discussed previously.

1.4.4 External Exposure to Thorium Metal

Allen (2014a, Table J.4) listed annual external doses to Joslyn workers from exposure to thorium metal rods. These doses were taken from an earlier NIOSH report (Glover and Allen 2014); however, that reference is not cited by Allen (2014a). Our review of the earlier report (Anigstein 2014) produced several findings regarding the accuracy of the MCNP simulations. We also found that the assessment of photon exposures in terms of effective doses was incompatible with OCAS-001 (OCAS 2007), which makes no provision for converting such doses to the organ dose equivalents that are required for dose reconstruction. We had therefore performed an independent assessment to determine the $H_p(10)$ and air kerma dose rates, as well as electron dose rates to the skin.

There were two occasions on which thorium rods were Medart-straightened and centerless ground at Joslyn: in June 1946 and in January 1947. In addition, Schumar (1947) wrote: “We have a tentative schedule with the Joslyn Manufacturing Company to roll the 3" diameter billets

some time during the week of July 21 [1947].” Harrison-Maples et al. (2012) concluded that this last rolling never took place. We believe that, in the absence of conclusive evidence that the rolling was canceled, NIOSH should make the claimant-favorable assumption that it did occur. However, since NIOSH assumed that the thorium exposures lasted 24 h during each of the two years, whereas, based on reports on the processing of uranium fuel rods, each instance of thorium handling probably lasted 1–2 days, we agree that the exposure duration assigned by NIOSH is plausible and claimant favorable.

To determine the impact of our revised dose assessment on DRs performed for Joslyn, we calculated $H_p(10)$ doses, as well as external doses to the skin on the hands and forearms and to the skin on the rest of the body, using the results of our previous analysis (Anigstein 2014) combined with the NIOSH assumptions about exposure duration. These results, together with the NIOSH assessments, are shown in Table 7.

Table 7. Comparison of SC&A and NIOSH Annual External Doses from Thorium

Year	SC&A				NIOSH ^a		
	$H_p(10)$	Other skin (mrad)	Hands & forearms (mrad)		Eff. dose	Electron skin dose (mrem)	
	(mrem)	Electrons	Electrons	Air kerma	mrem	Other skin	Hands & forearms
1946	66	27	648	1,229	52	16	120
1947	66	27	648	1,229	52	16	120

^a Source: Allen (2014a, Table J.4)

As shown in Table 7, our external doses to the whole body are expressed in terms of $H_p(10)$, while NIOSH reported effective doses, which, as stated earlier, are incompatible with OCAS-IG-001 (OCAS 2007). The two quantities cannot be compared directly. The doses to skin from electrons are higher in our analysis, due to differences in the MCNP models. We also assessed the air kerma in contact with the metal. Unlike the case of uranium, the intense photon radiation from ^{232}Th and its radioactive progeny makes a significant contribution to skin dose.

Comparing these doses to the external doses from uranium listed in Table 6, we observe that the $H_p(10)$ doses from thorium are comparable to those from uranium during the same years. The doses to the skin are far smaller and thus would not make a major contribution to DR assessments.

2.0 CONCLUSIONS

In Appendix J, Allen (2014a) presents a prescription for dose reconstruction assessments of Joslyn workers that incorporates without citation the results of two NIOSH white papers—Sharfi et al. (2014) and Glover and Allen (2014). Anigstein (2014) previously reviewed the latter report, so we only cite the highlights of our findings in the present review. However, the present review includes an implicit review of Sharfi et al. to the extent that their results are utilized by Allen. Allen makes references to TBD-6000 and to the two Joslyn SEC Petition Evaluation Reports: Harrison-Maples et al. (2012) and Harrison-Maples (2014).

Allen (2014a) precisely utilizes the results from the two NIOSH white papers. However, we disagree with the several of the results from both papers. We also find that some assumptions

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used by Allen in deriving limiting doses are internally inconsistent and also inconsistent with the DR methods prescribed in TBD-6000.

2.1 Summary of Findings

Finding 1: Uranium Workdays

In all but 2 years of the 10-y period of MED/AEC operations at Joslyn, Allen (2014a), using (without citation) data tabulated by Sharfi et al. (2014), underestimated the number of days that uranium was processed or handled at Joslyn. The discrepancies result from a very narrow evaluation of the data available in the SRDB: rolling and/or machining were assumed to take place only on dates specifically cited in correspondence or reports. Some additional workdays were assumed if there was a reference to quantities or masses of uranium billets or rods. However, except for a passing reference by Harrison-Maples et al. (2012), no attention was paid to Joslyn's contracts with the U of C. The billings under those contracts represent work that is not specifically cited in reports of rolling and machining. It is not surprising that the records of uranium-handling activities at Joslyn are not complete—this has been our experience reviewing other Atomic Weapons Employer (AWE) facilities. It is therefore incumbent on NIOSH to use all available information to make claimant-favorable assumptions about the duration and number of uranium operations. In the present case, we find that NIOSH did not do so.

Finding 2: Inhaled Intakes

In all but one year of the post-SEC period, Allen (2014a) underestimated the inhaled intakes of uranium dust. These results stem directly from the estimates of uranium workdays, discussed in Finding 1.

Finding 3: Photon and Electron Dose Rates from Contaminated Floor

Allen (2014a) failed to account for the enhanced concentrations of short-lived uranium progenies on the surface of freshly cast uranium billets supplied to Joslyn from Mallinckrodt and ElectroMet, which we have called the Putzier effect. This effect would have resulted in much higher photon and electron dose rates, since the dust that accumulated on the contaminated floor during rolling operations would have come primarily from the surface of the billets.

Finding 4: Doses from External Exposure to Penetrating Radiation from Uranium

Allen (2014a) underestimated the doses from external exposure to penetrating radiation from uranium in 7 years of the 10-year period of MED/AEC operations. This underestimate is due to underestimated dose rates from the contaminated floor and to the underestimated uranium workdays. It is partly offset by the assumption that the worker was exposed to penetrating radiation from the uranium billet during his entire workday, which was assumed to have a duration of 10 h during the entire period. Both these assumptions are contrary to the methodology of calculating external doses from uranium metal prescribed in TBD-6000.

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Finding 5: Exposures Improperly Combined with Personal Dose Equivalents $H_p(10)$

Allen (2014a), in determining doses from external exposure, added the calculated exposures from contaminated surfaces, which are expressed in milliroentgens, to doses from uranium metal, which are expressed as personal dose equivalents, $H_p(10)$, in units of millirem. This mixed quantity cannot be used for calculating organ doses, since there are significant differences between the exposure-to-organ dose and personal-dose-equivalent-to-organ dose conversion factors.

Finding 6: Doses to Skin from Nonpenetrating Radiation from Uranium

Allen (2014a) underestimated the doses to the skin from external exposure to nonpenetrating radiation from uranium in each year of MED/AEC operations. The main factors are failure to incorporate the Putzier effect in estimating the dose rates from electrons emitted from uranium metal and uranium dust on contaminated floors and an underestimate of uranium workdays.

Finding 7: External Exposure to Thorium

Allen (2014a) underestimated the doses to the skin from external exposure to thorium rods. The major difference is in the contact dose to the skin on the hands and forearms, which is due to an incorrect geometry in the NIOSH MCNP analysis (Anigstein 2014).

2.2 Observations

We have made a number of observations and comments throughout the present review on the presentation of the Joslyn dose assessments, as well as on assumptions used in these analysis which, although they do not have a major impact on the results, are in some cases inaccurate and/or inconsistent with other, similar NIOSH dose assessments. These are discussed in the body of the report.

One general observation is that Appendix J was issued as a self-contained document that makes no reference to NIOSH white papers—Sharfi et al. (2014) and Glove and Allen (2014)—nor to the Excel file *Joslyn Example DR Rolling and Machining Workdays Calcs 2014-04-15.xlsx*, which is on the DCAS restricted website. It would not have been possible to review the appendix had we not had access to these documents. Allen (2014a) should include sufficient detail to enable an independent audit of his results without referring to other sources that are not cited nor publicly available.

We also observed inconsistencies in exposure durations for the various exposure scenarios. For example, a worker is assumed to be 1 ft from a uranium billet during 100% of the workday, but only 50% of the time in the case of a thorium rod. As another example, external exposure to the uranium billet is assumed to take place during a 10 h workday, but the exposure duration to a contaminated floor is 9.6 h/d before 1951 and 8.8 h/d in 1951–1952. Although these examples result in claimant-favorable assessments, Allen (2014a) should either explicitly explain the rationale for the inconsistencies or achieve consistency, both internally and with TBD-6000.

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