DOE Review Release 10/27/2014

Site Profile for Simonds Saw and Steel

ORAUT-TKBS-0032 Rev. 02
Effective Date: 10/21/2014
Supersedes: Revision 01

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☐ New ☒ Total Rewrite ☐ Revision ☐ Page Change

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
05/31/2005	00	New Technical Basis Document: Basis for the Development of an Exposure Matrix for Simonds Saw and Steel, Lockport, New York. First approved issue. Incorporated formal internal and NIOSH review comments. No training required. Initiated by Cindy W. Bloom.
07/08/2005	00 PC-1	Approved page change revision corrects Table 15 on page 27. No changes were needed as a result of NIOSH formal review. Retraining is not required. Initiated by Cindy W. Bloom. Approval: Signature on File 06/21/2005 Cindy W. Bloom, TBD Team Leader Signature on File 06/21/2005 Judson L. Kenoyer, Task 3 Manager Signature on File 06/21/2005 Richard E. Toohey, Project Director Signature on File 07/08/2005 James W. Neton, Associate Director for Science
04/18/2011	01	Revision initiated to incorporate SEC-00157 information as directed by NIOSH. Includes information on the SEC class. Section 3.4 was revised to reflect the inability to reconstruct thorium exposure during the operational period and the associated tabulation of internal exposure values (Table 20). The description of the derivation of the external exposure dose estimates along with the associated dose tabulation (Table 20) was revised to remove consideration of external exposure from thorium during the operational period. Additional changes include the following: The calculation of intake quantities from plutonium (Table 20) was revised to maintain consistency between trace radionuclides and those in which they are mixed. Deleted options of associating class S plutonium with class M uranium and vice versa. The site description and the associated dose calculations tabulated in Sections 3 and 4 (Tables 12 and 15) were revised to reflect the change in the end of the operational period and the concurrent change to the start of the residual period. The medical X-ray examinations section was revised. The tabulation in Table 20 was updated. Revised the methodology for assessment of internal exposure which includes the reconstruction exposure from thoron. Table 3 was added to show the number of rolling days for each year. Tables 8, 9, 10, and 11 were modified to include 1957 in the assessment of internal intake using air monitoring data. Information was added to section 3.1.2 detailing air sampling results for rolling activities on the 10 inch mill and for uranium forging activities (Tables 12, 13, 14 and 15 added). Intake rates in Table 17 were revised to account for the reduced use of engineering controls during the post 1952 time period (i.e., intake rates calculated for the initial operations period, 1948, were assigned from 1953 through 1957). Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Joseph S. Guido.

10/21/2014	02	Revision initiated to incorporate Advisory Board comments as directed by NIOSH. Intake rates in Table 3-13 (formerly Table 17) of Section 3.3 were recalculated, and intake rates for the 95th percentile were added. Dose rates in Table 4-3 (formerly Table 20) of Section 4.4 were recalculated for 1948, and dose rates for the 95th percentile were added. Residual approach in Section 5.0 for internal and external was completely revised. Updated table and figure numbering to current format. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Mutty M. Sharfi.

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ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
AWE	Atomic Weapons Employer
cm	centimeter
d	day
DOE	U.S. Department of Energy
dpm	disintegrations per minute (also d/m)
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ft	foot
FMPC	Feed Materials Production Center
FUSRAP	Formerly Utilized Sites Remedial Action Program
GM	geometric mean
GSD	geometric standard deviation
hr	hour
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
in.	inch
IREP	Interactive RadioEpidemiological Program
keV	kilovolt electron, 1,000 electron volts
L	liter
lb	pound
m	meter
MAC	maximum allowable concentration
MCNP	Monte Carlo *n*-particle
mg	milligram
mL	milliliter
mo	month
mR	milliroentgen
mrad	millirad
mrem	millirem
mrep	millirep
NIOSH	National Institute for Occupational Safety and Health
NLO	National Lead Company of Ohio
NYOO	New York Operations Office
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
pCi	picocurie
R	roentgen

s	second
SEC	Special Exposure Cohort
SRDB Ref ID	Site Research Database Reference Identification (number)
t	ton
U.S.C.	United States Code
USACE	U.S. Army Corps of Engineers
yr	year
µg	microgram
µm	micrometer
§	section or sections

1.0 INTRODUCTION

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH staff in the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer [AWE] facility" or a "Department of Energy [DOE] facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA, as amended, provides for employees who worked at an AWE facility during the contract period and/or during the residual period.

Under EEOICPA, employment at an AWE facility is categorized as either (1) during the DOE contract period (i.e., when the AWE was processing or producing material that emitted radiation and was used in the production of an atomic weapon), or (2) during the residual contamination period (i.e., periods that NIOSH has determined there is the potential for significant residual contamination after the period in which weapons-related production occurred). For contract period employment, all occupationally derived radiation exposures at covered facilities must be included in dose reconstructions. This includes radiation exposure related to the Naval Nuclear Propulsion Program and any radiation exposure received from the production of commercial radioactive products that were concurrently manufactured by the AWE facility during the covered period. NIOSH does not consider the following exposures to be occupationally derived (NIOSH 2010a):

- Background radiation, including radiation from naturally occurring radon present in conventional structures

- Radiation from X-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons

For employment during the residual contamination period, only the radiation exposures defined in 42 U.S.C. § 7384n(c)(4) [i.e., radiation doses received from DOE-related work] must be included in dose reconstructions. Doses from medical X-rays are not reconstructed during the residual contamination period (NIOSH 2010a). It should be noted that under subparagraph A of 42 U.S.C. § 7384n(c)(4), radiation associated with the Naval Nuclear Propulsion Program is specifically excluded from the employee's radiation dose. This exclusion only applies to those AWE employees who worked during the residual contamination period. Also, under subparagraph B of 42 U.S.C. § 7384n(c)(4), radiation from a source not covered by subparagraph A that is not distinguishable through reliable documentation from radiation that is covered by subparagraph A is considered part of the employee's radiation dose. This site profile covers only exposures resulting from nuclear weapons-related work. Exposures resulting from non-weapons-related work, if applicable, will be covered elsewhere.

1.1 PURPOSE

This document provides an exposure matrix for workers at the facility listed as Simonds Saw and Steel Company in Lockport, New York. Simonds was involved primarily with the rolling of natural uranium rods as well as the rolling of some depleted and enriched uranium and thorium rods. After the U.S. Atomic Energy Commission (AEC) contract operations, Simonds became known as Guterl Specialty Steel. Part of the facility is now owned by Allegheny Ludlum Corporation.

1.2 SCOPE

Section 2.0 describes the Simonds site and operations that pertain to possible radiation exposures and discusses radiation source terms. Section 3.0 provides guidance for the determination of internal exposure. Section 4.0 provides guidance for the determination of external doses from measured doses or for periods for which records of measured doses are missing. Section 5.0 discusses doses from residual exposure.

1.3 SPECIAL EXPOSURE COHORT

Through December 31, 1957, NIOSH has determined, and the Secretary, Health and Human Services has concurred, that it is not feasible to reconstruct internal and external radiation dose received as a result of operations involving the use of thorium (Sebelius 2011). Accordingly, a special exposure cohort class has been designated:

> *All Atomic Weapons Employer employees who worked at Simonds Saw and Steel Co. from January 1, 1948 through December 31, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort"* (Sebelius 2011)

For any claim referred to NIOSH regarding an employee,

- Who was employed during the Special Exposure Cohort (SEC) period but because of limited employment during this period is not a member of the SEC, or

- Who is a member of the SEC and whose cancer is not defined as a specified cancer under EEOICPA (and so is not eligible for compensation under EEOICPA without a dose reconstruction),

NIOSH will continue to attempt to complete dose reconstructions using whatever information is available about an energy employee's work history and available bioassay and monitoring data along with the guidance in this site profile document.

2.0 SITE DESCRIPTION AND OPERATIONAL HISTORY

The information that follows applies to a period of U.S. Atomic Energy Commission (AEC) operations at Simonds Saw and Steel from February 24, 1948, to December 31, 1957 (Leiton 2010), involving AEC-contracted uranium and thorium work. Although the buildings were closed and the contaminated areas were isolated as of May 1, 1983, this analysis assumed that the residual contamination period was from January 1, 1958, through the present.

The Simonds radiological source term consisted primarily of natural uranium metal, uranium oxides, and uranium's short-lived progeny. Long-lived progeny in the uranium series prevent significant ingrowth past ^{234}U in the ^{238}U decay series and beyond ^{231}Th in the ^{235}U decay series. The source term included smaller amounts of thorium metal and thorium oxides.

The first known rolling of uranium at Simonds occurred on February 24, 1948, before its contractual agreement with the AEC. The first contract with the AEC New York Operations Office (NYOO), AT-30-1-Gen 339, was initiated in May 1948 and was renewed annually through February 1952. The contract was officially closed on July 21, 1952. Simonds continued work under subcontract S-4 (effective March 1, 1952, through December 31, 1956) to the National Lead Company of Ohio (NLO)

at the Feed Materials Production Center (FMPC) in Fernald, Ohio, which had contract AT (30-1)-1156 with NYOO (Author unknown undated).

While a majority of documents state that no uranium or thorium was processed for the AEC at Simonds after 1956, some documents indicate that approximately 13 t of uranium slabs were produced in April 1957. NLO Production Order Request # A-60 in April 1957 states that the work was not to be billed because it was applied to research and development (NLO 1957a). In reference to Production Order # A-60, a subsequent June 1957 memorandum states that 26,860 lb of normal uranium forged slabs had been shipped via truck from Simonds to Superior Steel Corporation on April 29, 1957 (McCreery 1957). This signifies that the work under the production order request had been completed. Subsequent documents indicate final contract closure occurred sometime in late 1957; the exact date is unknown (Ericson 1957a, 1957b; NLO 1957b).

In 1956, Simonds reportedly requested that NLO survey the thorium work that consisted of drop forging, rolling on the 16-in. bar mill, and finishing on the strip mill (Wunder 1956). This was reportedly commercial work for Babcock & Wilcox that was to occur in June 1956, but might not have occurred until July 1956 (NLO 1956).

2.1 SITE DESCRIPTION

The Simonds buildings most associated with AEC operations were referred to as Building A (also known as Buildings 6 and 8) with the 16-in. and 10-in. rolling mills, and Building B (also known as Building 3) with the hammer forge shop (FBDU 1981). Wallace-Murray Corporation purchased the Simonds facility in 1966 and operated it until 1978. Guterl Specialty Steel purchased the site in 1978 and, upon bankruptcy in 1982, transferred a portion of the site to Allegheny Ludlum Corporation, which continued operations in the transferred areas. The area that was excluded from the transfer (called the “excised area”) remains under the ownership of Guterl Specialty Steel Corporation (a Chapter 7 bankrupt corporation). As of March 31, 2011, the remainder of the site is owned by Phersas.

Vitkus (1999) described the former Simonds site as a 28-hectare (1 hectare equals 2.47 acres) area bordered by Ohio Street to the east, residential and commercial properties to the north, U.S. Highway 95 to the west, and the New York State Barge Canal to the south. As of 1999, the property was grouped into three areas:

- The Allegheny Ludlum Corporation, which includes four buildings that were constructed after the termination of AEC activities;
- The 3.5-hectare landfill area in the northwest corner of the site; and
- The 3.6-hectare excised area in the southeast corner of the site, which includes nine buildings that existed during the AEC activities (Vitkus 1999).

Table 2-1 lists the buildings that probably existed at the time of AEC operations.

Figure 2-1 shows the Simonds site and the boundaries of the Allegheny Ludlum (black border) and excised area (blue border) (USACE ca. 2010).

Table 2-1. Simonds buildings where contamination has been found.

Building number	Building letter[a]	Use
1		Manufacturing
2		Manufacturing
3	B	Grinding and rolling, hammer forge shop
4		Manufacturing
5		25-cycle heat exchanger
6	A	16-in. rolling mill
8	A	10-in. rolling mill
9		Manufacturing
35		Grinding and roll staging

a. Nomenclature used in 1981 report (FBDU 1981).

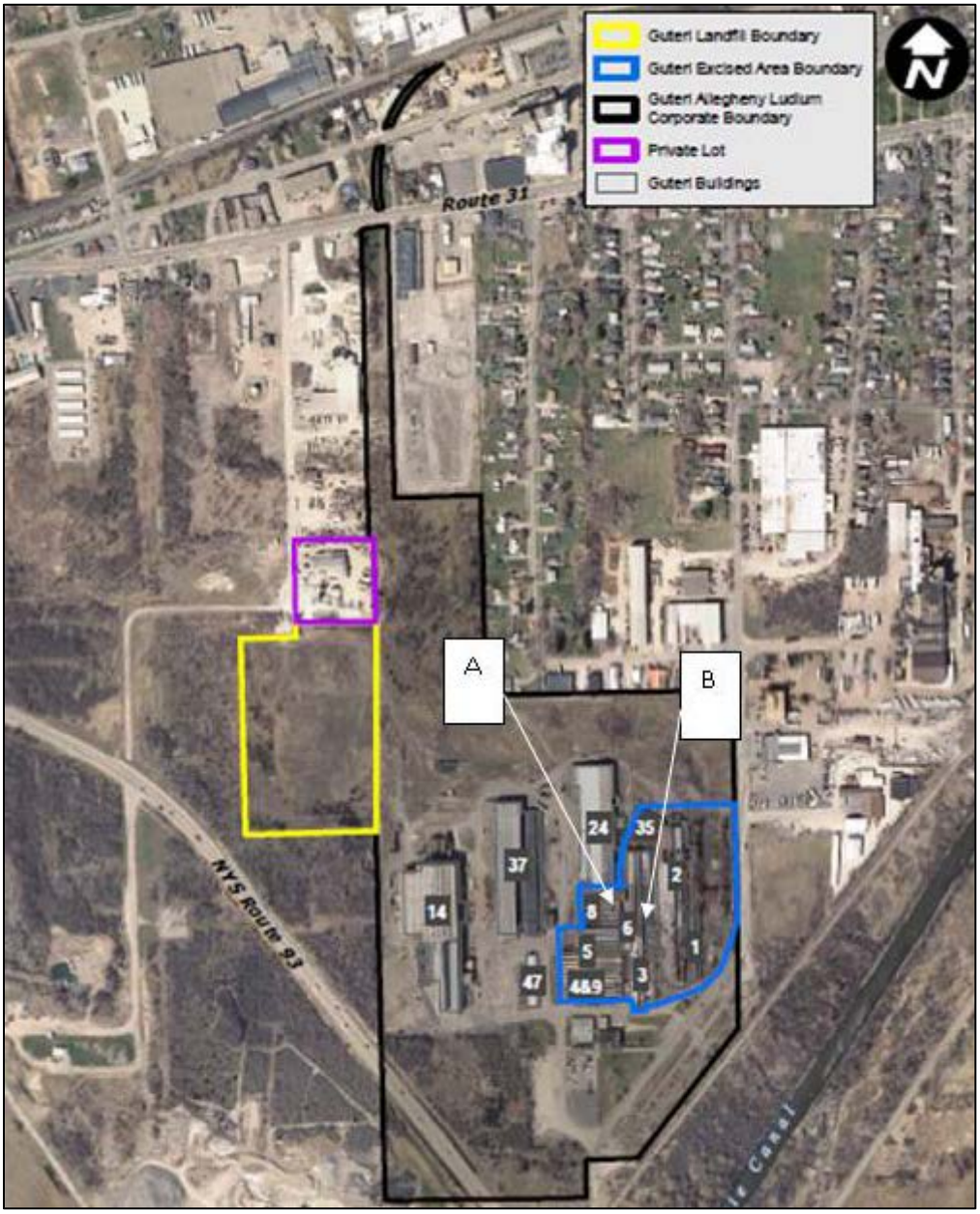

Figure 2-1. Aerial view of Simonds Saw and Steel (modified from USACE ca. 2010).

2.2 PROCESS DESCRIPTION

"An experimental [uranium] run was made at Simonds Saw & Steel on February 24" (AEC 1948a). Massachusetts Institute of Technology studies showed satisfactory results and arrangements were made to roll a carload of uranium metal beginning on March 29, 1948 (AEC 1948b).

Materials for processing arrived, at least in the early years, in boxcars. Crated or palleted ingots or billets were placed in a temporary storage area. Just before rolling, workers uncrated the ingots or billets and rigged them for transfer by crane to the weigh station. According to a 1951 report on rolling procedures, the billets were initially either 5.125 in. diameter and 15 to 20 in. long, or 4.25 in. diameter and 20 to 22 in. long (Smith 1951). The rolling reduced them to rods of 0.875-in. diameter, each weighing approximately 200 lb. Therefore, each turning was approximately 75 to 100 billets.

After weighing, the ingots or billets were transferred into a furnace. A gas combustion furnace was used in the early years and occasionally thereafter. About January 1950, a heated lead bath furnace was installed to reduce the airborne radioactivity. The ingots or billets were loaded into the lead furnace, which was of a "Ferris wheel" type design for submerging and carrying the charge through the heated lead bath. It is not known how many billets the furnaces could handle at once, but it is known that each billet was in the furnace for about 40 minutes. The heated billets were transferred with tongs and a roller table (a table with rollers on top to reduce friction and ease heavy material transfers) to the 16-in. mill and rolled in two of its four stands. Depending on size, the bar could have been cut at the shears midway in the rolling operation. After rolling, the rods were quenched (either pressure quenched or dipped in a tank) and transferred in bundles by crane to the shipping area. There they were placed in tared H-beams, weighed, and loaded into railcars from the shipping dock (DOE 1979; Keller 1979). AEC noted that trucks rather than railcars were being used as of August 1950, which eliminated daily handling and shoring of the load by shippers (Heatherton 1950a).

The majority of the AEC work involved the task of rolling uranium, but occasional tests were run to determine if different coatings or methods would either produce a better product or reduce worker exposure. AEC reported on the rolling of copper-clad uranium on March 7 or 8, 1951 (Heatherton 1951a), which was deemed unsuccessful due to increased product problems and increased air concentrations.

Simonds performed hot forging of uranium and thorium metal – uranium on an experimental basis, and thorium mostly on a production basis. The metals were usually forged and then rolled into rods (Huke 1951). This was apparently the primary method for processing thorium at Simonds (ORAUT 2010).

Information on Simonds uranium forging is limited, but records indicate that "some 15 of [or?] 20 ingots were processed in the hammer forge shop" (Keller 1979). The AEC concluded that forging was a very dusty operation and, based on health considerations, recommended not using the process for uranium (Heatherton 1950b). A 1957 document refers to the production of 26,860 lb of forged uranium slabs that had been shipped by truck to Superior Steel Corporation (McCreery 1957).

In 1956, Simonds reportedly requested that NLO survey the thorium work that consisted of drop forging, rolling on the 16-in. bar mill, and finishing on the strip mill (Wunder 1956). This thorium work was reportedly commercial work for Babcock & Wilcox and was to occur in June 1956, but the work was reportedly completed in July 1956 (Heatherton 1956).

In 1952, FMPC became the primary AEC site for processing uranium, and the Simonds uranium processing activities were significantly reduced. Simonds received odd lots that could not be easily processed at FMPC. "A few of the later lots of material were depleted uranium and several were enriched to the extent of about 2.5% [by mass]" (Keller 1979).

2.3 SOURCE TERM

Several documents provide summaries of Simonds operational history, including the estimated total quantities of uranium and thorium metals that were processed. The documents typically state that between 25 and 35 million lb of uranium and approximately 30,000 to 40,000 lb of thorium were rolled from February 24, 1948, until operations ceased sometime in 1957 (Vitkus 1999). Information on material processing was compiled from all available Simonds-related documents and places the total quantities of uranium and thorium processed at 23 million and 114,000 lb (11,500 and 57 t), respectively (NIOSH 2010b).

"Over 99 percent of all Simonds uranium work consisted of rolling on the 16-inch bar mill" (Keller 1979) in Building A (Building 6). Before the NLO subcontract, as much as 500,000 or 600,000 lb of uranium were processed per month (Keller 1979). Several small lots of uranium bars and thorium ingots were run through the 10-in. rolling mill in Building A (Building 8), and approximately 15 to 20 ingots were processed in the hammer forge shop in Building B (Building 3). Figures 2-2, 2-3, and 2-4 show the layouts.

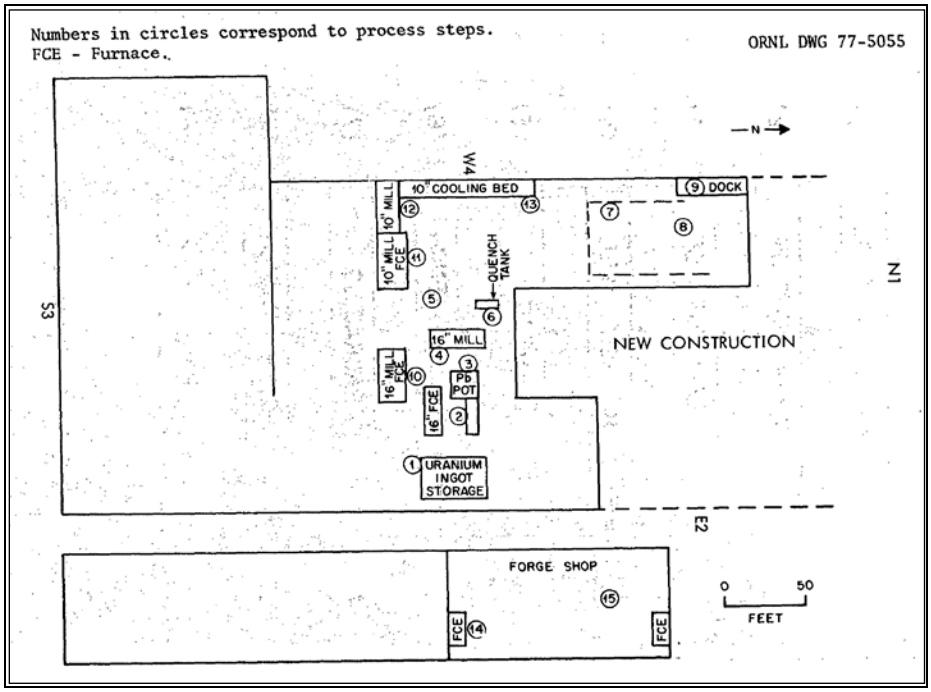

Figure 2-2. Simonds rolling mills and hammer forge areas. Buildings 6 (16-in. mill), 8 (10-in. mill) and 3 (forge shop) (DOE 1979).

Processing occurred in turnings of about 15,000 to 20,000 lb each. There were approximately 312 turnings per year from 1948 to 1952. At the end of the initial AEC contract, turnings reportedly decreased to 29 turnings in 1953, 56 in 1954, 58 in 1955, and 22 in 1956 (Keller 1979). It appears that a rolling turn required an entire shift (Schumann 1953), so there were about 156 days per year, two shifts each day, that were devoted to AEC work from 1948 to 1952. This translates into 31 of 52 weeks or approximately 60% of the time was spent on AEC work. Documentation of specific rolling dates was available only for those periods AEC included in the reports of its visits. Based on the number of turnings in Keller (1979), the number of uranium rolling days can be estimated as 15, 28, 29, and 11 rolling days for 1953, 1954, 1955, and 1956, respectively. Although it was not reported by Keller, rolling of uranium has been confirmed during at least one period in 1957 (Ericson 1957a, 1957b; NLO 1957b). The total quantity reported to be rolled in 1957 was approximately 26,860 lb. Based on what is known about uranium processing rates at Simonds, the number of days associated with this operation would be less than 2.

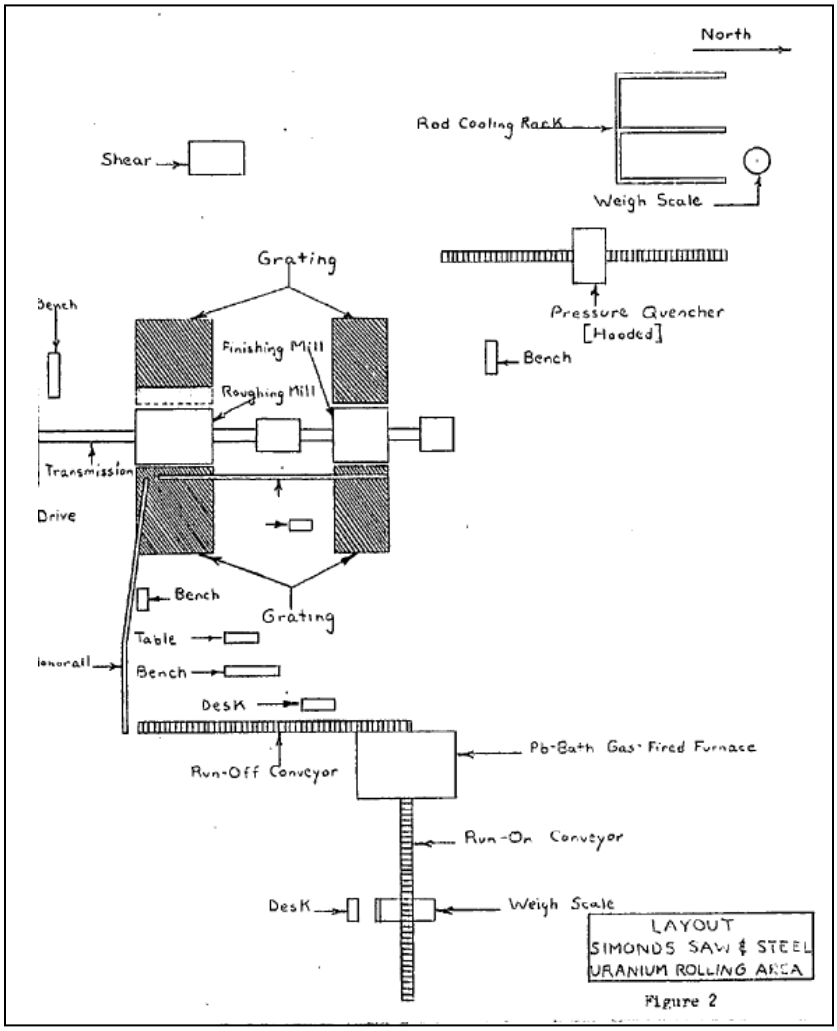

Figure 2-3. Simonds 16-in. rolling mill area, Building 6 (Klevin and Weinstein 1953a).

For fiscal year 1950, Simonds agreed to meet the AEC rolling requirements, as high as 170 t/mo, so AEC consolidated most of its rolling operations at Simonds (AEC 1949a).

A national steelworkers' strike began in October 1949. "A short-term agreement between the steelworkers' union and company officials at Simonds Saw & Steel Company was reached," which allowed the October uranium rolling to continue as scheduled (AEC 1949b). Simonds planned to roll 160 t of uranium in November because it had negotiated a short-term contract through December 1, 1949. No uranium was to be rolled in December 1949, but rolling was to resume in January 1950 (AEC 1949b).

The earliest known document about thorium rolling at Simonds is correspondence dated August 1951 (Huke 1951). In relation to thorium, it states:

> *Approximately two tons of thorium metal were rolled at Simonds Steel Co., Lockport, New York on August 16, 1951, …. We believe that this is the first time that thorium billets have been rolled directly to rods on what might be termed production scale. Previously, billets were forged to 2" squares and then rolled. … Most of the material received consisted of 3 in. diameter round billets in the range of 15-in. long.*

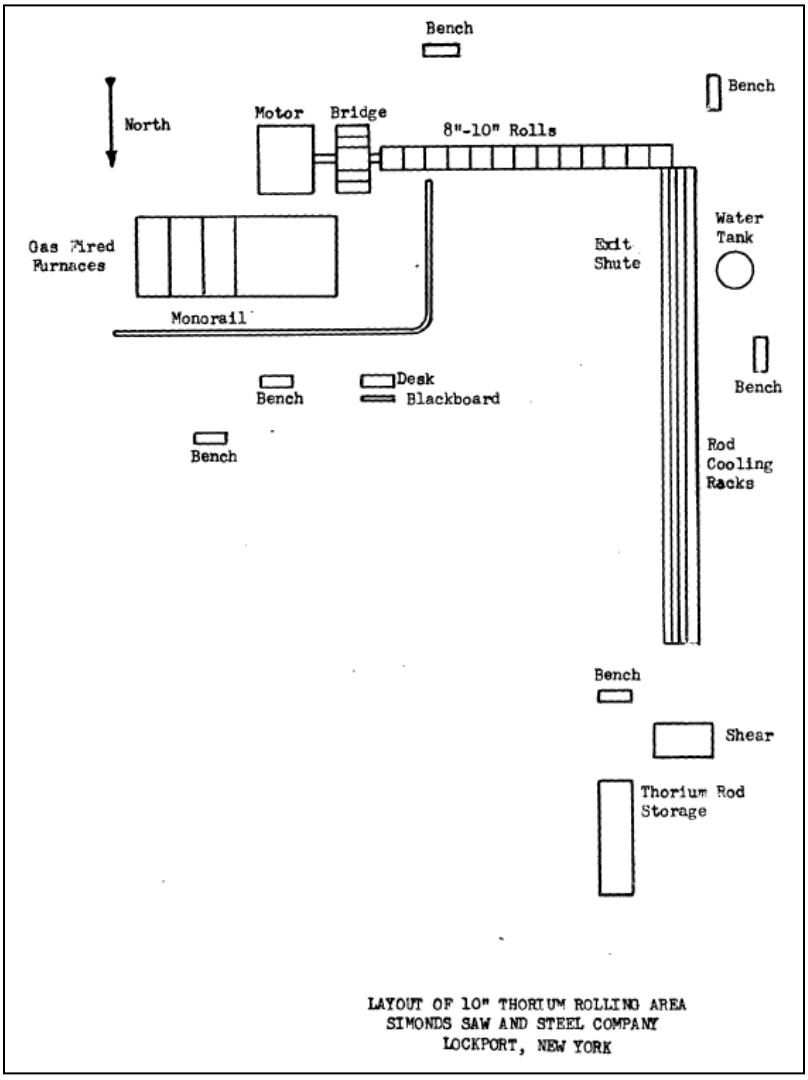

Figure 2-4. Simonds 10-in. thorium rolling area, Building 8 (Klevin and Weinstein 1953b).

The statement, "Previously, billets were forged … and then rolled …," indicates that thorium forging and rolling were performed before August 16, 1951. However, because there is not sufficient information to determine an accurate thorium-processing start date, NIOSH assumes that thorium processing began coincident with the start of AEC-contracted work at Simonds in February 1948.

The AEC Tonawanda Area Office reported that 36 thorium billets were shipped to Simonds for rolling on November 19, 1951 (AEC 1951), that no thorium metal was rolled in January 1952, and that there were no plans to roll thorium at Simonds for the next few months (AEC 1952). Inventory amounts of thorium were shown for May, September, and November 1952 (AEC 1953). In November 1952, 8,500 lb of thorium were to be rolled (Belmore 1952). An additional thorium rolling took place in August 1954 (Harris 1954). Documents indicate that thorium-forging work was performed in May and July 1956 (Magoun and Yocco 1956; NLO 1954–1956). The largest known thorium rolling was performed in December 1953 (Wunder 1953, p. 6), in which 21 t (455 ingots) of thorium were rolled in a 3-day period.

In December 1948, Tabershaw (1948) mentioned a group of 150 Simonds workers. In February 1949, Tabershaw (1949) mentioned that there were 180 Simonds workers who had been examined and that 57 were exposed to uranium at close quarters. Air-sampling data indicated that there were

13 to 28 rolling mill workers who were considered in the airborne uranium exposure studies on any one shift. Simonds worked two shifts, the maximum number of workers in any of the studies was 45 (one study reported 48 workers but only 45 were identified in the job categories). A film badge record includes 21 workers in October 1949 (AEC 1949c).

Table 2-2 lists the job categories AEC and NLO included in the exposure studies, but the AEC reports indicated that workers switched categories. In addition, it was noted that workers could have worked on both the 16- and 10-in. bar mills. No specific worker data were found in relation to the limited forging of uranium.

Table 2-2. Some job titles involved in uranium rolling.

Assistant foreman	Rod stamper
Billet loader	Roller #1 (rougher)
Dippers	Roller #2 (finisher)
Drag down man	Run-out
Foreman	Shear man
Furnace man (heater)	Shippers
Heater helper	Straightener
Hook man	Stranner
Poke-in	Weighers (rod)
(Pressure) quencher	Weigh in (weigh up)

The documents that relate to Simonds do not mention area access controls, so it is not clear who had access to the areas where the AEC rolling occurred.

As noted above, Simonds worked two shifts. AEC reports indicate that a shift lasted from 8 to 11 hours, with the typical shift lasting about 10 hours. These work hours included at least 45 minutes for locker room and lunchtime.

2.4 SAFETY

Early in the contract, the AEC provided safety recommendations for the uranium rolling operations at Simonds, including exhaust ventilation, a central vacuum cleaner, floor grating, and high-pressure water nozzles for descaling (Wolf 1948; page 3 of the 4 pages of recommendations was missing). AEC air-sampling and radiation surveys were recommended to ensure that the engineering controls were adequate.

2.4.1 Workplace Contamination Controls

The main AEC safety recommendations for Simonds involved workplace contamination controls, which consisted primarily of ventilation controls and cleaning to minimize uranium dust in the workplace. There was little mention of external radiation safety practices. AEC reports documented incremental improvements in Simonds contamination control programs (AEC 1948c, 1948d, 1949d, 1949e, 1950; Heatherton 1950a, 1950b, 1951b; Klevin 1951). Over time, Simonds went from no ventilation controls to local ventilation exhausts over the 16-in. rolls and a central vacuum cleaner to replace broom sweeping by December 1948. In January 1949, a local exhaust was installed over the descaler. No local ventilation was described for the 10-in. rolling mill or the limited forging work. As of January 1950, a lead bath furnace was being used to reduce airborne contamination. Plexiglas shields were installed at some point to help contain contaminants and to direct airflow to the exhaust system. Dust collectors were added to the exhaust system to reduce uranium releases. Grating was used on the floor to minimize contact with the settling radioactive dust that could become airborne again. A partially legible AEC memorandum from August 5, 1948, indicates that the “mill crew” had two sets of clothing. The November 1948 AEC production report states that uniforms and gloves were provided to workers (AEC 1948e).

As of January 10, 1949, "complete ventilation had been installed, vacuum exhaust vented outside the mill area and exhaust fan from pressure quencher exhausted through roof" (AEC 1949d), but the floor gratings had not been obtained. AEC noted inexplicably large air concentrations near the pressure-quenching and rod-stamping areas, which were within a few feet of each other. AEC thought that perhaps the descaling machine was throwing off large chunks of uranium, which were being caught on the air sampler. "It was noted that occasional stinging particles were caught on the face and hands of the man doing the [air] sampling." In addition, the time to quench rods had been increased from 75 to 200 minutes per shift to improve scale removal, which factored into air concentration exposure estimates.

By April 5, 1949, a large pedestal fan was used to blow air across the pressure-quenching and rod-stamping areas, which reduced worker exposure in these areas but caused a general increase of uranium air concentration in other mill areas.

By June 13, 1949, a stack ventilation dust collector was in use, although it appeared to be collecting only about one-tenth of the expected emissions (Reichard 1949). By September 7, 1949, the air velocity was increased with the expectation that the collection efficiency of the Aerodyne Concentrator would increase by 70% to 90% (Hershman 1949).

On July 12, 1949, AEC requested funding to install a lead bath furnace at Simonds. Uranium billets were being heated in a combustion gas atmosphere where about 0.5% (by weight) of the billet was converted to an oxide, "most of which is eventually reprocessed to metal" (Reichard 1949). AEC noted that the lead bath would eliminate the need for brushing of uranium from the furnace, which reduced exposures. December 1949 was dedicated to thoroughly cleaning areas most likely to be contaminated. Airborne radioactivity was expected to be at its lowest level during the January rolling (AEC 1949a, 1950), which involved a trial run of 10 t of uranium (AEC 1949f, 1950) and the initial use of the lead bath. AEC noted that the lead bath was removed by September 1954 (Klevin 1954).

By January 1950, rods were cold stamped to reduce airborne materials (AEC 1950).

AEC reports discuss the effectiveness of the recommended contamination controls but noted inconsistency in their implementation. Available documentation indicates that after 1953 the engineering controls that were previously installed were not consistently used. The AEC and NLO constantly reminded Simonds to use the vacuum cleaner instead of broom sweeping the uranium dust areas. Simonds' use of the Plexiglas shields, floor grating, and ventilation system dust collectors appears to have been intermittent. Throughout AEC's periodic air monitoring reports, there are frequent accounts of the failure of Simonds to either implement the recommended exposure control practices or to continue to adhere to such practices. The concerns that were conveyed by the AEC are best summarized in a November 1954 memorandum that stated (Polson 1954):

> *On the rolling of October 9-11, 1954, a NLO Health and Safety representative was present. In his report, reference 5, mention was made of some of the "doubtful practices" noted.*
>
> *This included:*
>
> 1. *Dropping of billets on floor prior to rolling*
> 2. *Wire brushing billets to observe temperature*
> 3. *Sweeping of floor instead of vacuum cleaning*
> 4. *Use of cloth gloves*
> 5. *Eating in vicinity during rolling*

> *These practices have been going on for as long as anyone connected with the operations can remember. … Rolling has continued with the thought that as soon as other facilities become more fully developed future fabrication at Simonds will be almost nil. It is planned to extrude the depleted uranium orders at Wolverine Tube and extrude the thorium material at Bridgeport Brass in Adrian Michigan. Both of these facilities should be satisfactory from a health and safety standpoint*.

In late 1953, Heatherton (1953a) stated that to decontaminate Simonds the ventilation over the bar mill would be removed rather than left for future rollings. He pointed out that cleaning up from a single thorium rolling would result in less overall cost than maintaining the ventilation and that workers would be provided with respirators.

The wearing of dedicated anti-contamination clothing at Simonds appears to have been sporadic. AEC and NLO reports mention dedicated work clothes, but actual use is not clear. Cotton gloves appear to have been donned intermittently. In later years, there is mention of dust masks and respirators, especially in conjunction with the enriched uranium and the thorium processing, but it was noted that respirator use was intermittent, if not rare, during processing of AEC materials.

An NLO memorandum (Polson 1954) states that during the next several rollings:

> *… all operators have worn coveralls and caps supplied by NLO. Shoe covers are available but the men do not care to wear them. We have supplied respirators in the past but very few are worn continuously.*
>
> *Recently, we rolled enriched materials there (P.O. 296) and the men were concerned about its increased toxicity. Almost everyone wore coveralls, hats, shoecovers and respirators. Some, however, wore no protective equipment.*
>
> *For these past rollings, the two dust hoods over the 16-inch mill were used. There are no hoods over the 10-inch mill. The mill area has been cleaned after each rolling as well as possible considering the type of floor (steel plates).*

NLO concluded that as soon as other rolling facilities became available, they would be used rather than Simonds.

2.4.2 Air Concentrations

During World War II, permissible levels for uranium dust in air were set at 500 µg/m^3 for insoluble uranium compounds and 150 µg/m^3 for soluble uranium compounds. After the war, the University of Rochester lowered its recommendation for soluble uranium compounds to 50 µg/m^3 based on the chemical toxicity, which is equivalent to 70 dpm/m^3 of natural uranium. This level was based primarily on animal studies. The Medical Division of NYOO felt that a "maximum permissible level" was unknown and should be based on human data. Therefore, the 50 µg/m^3 level was referred to as the "preferred level" (AEC 1949g). Some reports refer to a maximum allowable concentration (MAC), which was the same as the preferred level.

From 1948 to 1951, the NYOO made several site visits to survey air quality. As better radiological controls were put in place, the air concentrations were lowered by a factor of 10 or more (AEC 1948c, 1948d, 1949d, 1949e, 1950; Heatherton 1950a, 1950b, 1951b; Klevin 1951).

In response to the January 1950 survey results, AEC (1950) reported:

> *The fact that a residual air contamination of the order of 25 µg/m^3 [35 dpm/m^3] exists, even after a thorough cleaning and a full month of no rolling indicates two things:*
>
> 1. *The entire mill has a low level of uranium contamination.*
> 2. *It will probably be impractical to reduce the airborne uranium level consistently below 15 µg/m^3.*

Heatherton (1950b) reported that air sampling results from forge-hammering operations ranged from 76 to 260 times the preferred level in the general air and from 220 to 400 times the preferred level in the breathing zones of some of the men handling the billets.

In January 1951, Simonds workers dip-quenched rather than pressure-quenched the rods, leaving more scale, which was evident as oxide dust on the floor of the rod-stamping area and resulted in increased air concentrations (AEC 1949–1954, p. 118). AEC also reported that the Simonds Plexiglas shields were not in place due to an oversight.

Schumann (1953) mentions the rolling of enriched uranium in January 1953. Heatherton (1953b) describes the radiological conditions:

> *On January 17, 1953, rolling of special "E" material was done at Simonds Saw & Steel Company. Rolling operations were done on the 16-inch bar mill and the 10-inch bar mill. Ventilation on the 16-inch mill was the same as normally used in uranium rolling operation at the Simonds plant. No ventilation was provided for the work on the 10 inch mill ….*
>
> *… Air dust levels measured in the survey would not be noticeably different if normal or depleted material were rolled ….*
>
> *… weighted exposures ranged from 5.4 to 130 times the MAC.*
>
> *Air dust respirators were worn by all mill workers at the time of rolling …. The actual operation time was only about 80 minutes.*
>
> *General air results indicate an overall contamination of the building as a result of performing the operation without ventilating.*

In November 1953, Heatherton (1953a) implied that no enriched uranium was rolled between January and November 1953. In October 1954, Yoder (1954) reported the rolling of 36 t of depleted uranium billets. Air samples that were collected during this visit could have been compromised because of missing air sampling heads. Makeshift sample heads were made by taping the filter paper to the female adapter for the regular sampling heads and leaving about the same open area on the paper as for the normal heads. Two operations measured slightly above the MAC, and the rest were less than the MAC (Yoder 1954).

Thorium air concentration results from July 1956 are probably measurements in relation to the commercial thorium work process arranged by Babcock & Wilcox. These results appear lower than the November 25, 1952, results (NLO 1956).

2.4.3 Contamination and Radiation Levels

While visiting Simonds on or before October 18, 1948, to survey a broken roller for disposition determination, AEC measured ambient radiation levels from a few milliroentgen per hour to greater than 25 mR/hr about 6 ft in front of the furnace. Further investigation was recommended (Heatherton1948).

The summary report notes that alpha contamination measured from 2,500 to 40,000 dpm/100 cm^2 in the mill area from October 1948 to January 1949. Most of the mill area beta-gamma readings were less than 2 mR/hr. The highest reading (15 mR/hr beta-gamma) was an area on the floor near the furnace, and elevated readings were found near East Roller #1 and the Shear (AEC 1949h).

"A radiation survey was made of the entire area surrounding the plant and all the other buildings with a Zeuto. Alpha readings were negligible" (AEC 1949h). A Zeuto was a portable ionization chamber. The early models were used to measure alpha contamination; some models also measured beta and gamma radiation.

2.5 INCIDENTS

There were four incidents reported:

1. An AEC employee noted that, while sampling air in January 1949, his face and hands were occasionally stung by particles that could have come from the descaling machine (AEC 1949d).

2. A flying chip embedded itself in the flesh of the inner thigh of a rod stamper (Heatherton 1951a). This could have been a chip from the die head or the hammer rather than a chip of uranium.

3. A rod stamper had a chip of material taken from his wrist. Klevin (1951) reported the uranium mass of the chip as 1.5 µg (in the data reports, the Greek γ was used to mean micrograms).

4. In March 1952, there was a concern about an "allergic" reaction by a doctor and a nurse at a local hospital who were treating a Simonds 10-in. bar mill worker (Tabershaw 1952). The rumor was enhanced by reports of several other Simonds workers who complained of dermatitis. The dermatitis was limited to the day shift and cleared up within a week or so. The dermatitis was unlikely to be a result of radiation or uranium exposure.

2.6 PHYSICAL EXAMINATIONS: X-RAYS

NIOSH is required to account for dose from medical X-rays that were performed on an EEOICPA-covered site (either the covered site where the AWE work was being performed or a covered site where medical X-rays were performed as a service). Simonds X-rays were performed off site at a noncovered commercial facility (Tabershaw 1948). Therefore, the dose from medical X-rays does not need to be accounted for in the overall estimated dose calculation (ORAUT 2011).

2.7 SUMMARY ASSUMPTIONS: OPERATIONAL PERIOD, WORKDAYS, WORK HOURS, WORK CATEGORIES

Section 2.3 of this analysis assumes there were 156 days of uranium rolling per calendar year before 1954, which decreased substantially beginning January 1, 1954. Considering the uncertainty in the determination of the number of rolling days, the value for the remainder of this analysis for the period beginning on January 1, 1954, is assumed to be 20% of the period year's values (i.e., 31 per year). A

summary of the number of rolling days per year is contained in Table 2-3. Table 2-4 lists the number of uranium rolling days and the number of nonrolling days for certain periods, which are based on the needs of subsequent analyses that are presented later in this document. It was assumed that there were two work shifts of 10 hours each. Although the available records indicate significant curtailment at the end of 1953, it was assumed that operations in 1953 continued at the same level as those in 1952.

Table 2-3. Number of assumed uranium workdays per year.

Start	End	Number of rolling days	Start	End	Number of rolling days
02/24/1948	12/31/1948	133	01/01/1953	12/31/1953	156
01/01/1949	12/31/1949	156	01/01/1954	12/31/1954	31
01/01/1950	12/31/1950	156	01/01/1955	12/31/1955	31
01/01/1951	12/31/1951	156	01/01/1956	12/31/1956	31
01/01/1952	12/31/1952	156	01/01/1957	12/31/1957	31

Table 2-4. Number of assumed uranium workdays and uranium-rolling days.

Start	End	Rolling workdays	Non-rolling workdays	Workdays
02/24/1948	12/01/1948	120	82	202
12/01/1948	04/05/1949	52	38	90
04/05/1949	04/13/1950	156	112	268
04/13/1950	01/01/1954	585	387	972
01/01/1954	12/31/1957	125	919	1044

Mill workers whose duties involved or put them near the 10- and 16-in. bar rollers were likely to have the largest internal and external radiation exposures. Workers who were involved in experimental radioactive material forging were likely to have had large exposures for much shorter durations, and so it is reasonable to group them with the mill workers. The records made no mention of restricted access in any of the milling work areas, so although it is likely that workers who were not involved in uranium or thorium production processes had much lower exposures, the mill worker exposures were used to bound exposures for these other workers.

Simonds workers are divided into two categories of exposure based on exposure potential. The lower exposure category is for those workers who typically work in administrative offices and the higher category is for all other workers. Administrative area workers are assumed to have the potential only for intermittent exposure while other workers are assumed to have continuous exposure.

2.8 CLEANUP AND THE RESIDUAL CONTAMINATION PERIOD

In November 1953, Blythe (1953) requested that arrangements be made for NLO to oversee the decontamination of Simonds. NLO raised a concern that additional thorium work could be requested within the next 6 months, but it appears that some cleanup could have taken place in late 1953 or early 1954. AEC-related work was performed at Simonds in April 1957 and final contract closure occurred sometime in late 1957. Therefore, the operational year was extended by 1 year to the end of 1957 (Leiton 2010).

The Formerly Utilized Sites Remedial Action Program (FUSRAP) began in 1976, and Simonds was revisited to determine if there was residual activity. DOE (1979) reported on a radiological survey in October 1976 to characterize the property for FUSRAP. At the time of the survey, about 50 of the 450 people employed at the Simonds site worked in Buildings A (6 and 8) and B (Building 3).

A radiological survey in October 1976 identified contamination (primarily ^{238}U) in and around site buildings. Uranium-238 is the predominant isotope by mass in natural uranium and is more easily identified than the other isotopes, so some records could refer to it as ^{238}U rather than natural

uranium, which consists of approximately equal activities of ^{234}U and ^{238}U plus a smaller amount of ^{235}U. Reported ^{238}U quantities could include all the uranium activity or just part, depending on actual analysis techniques and reporting procedures.

Guterl Specialty Steel, which bought Simonds in 1978, filed for bankruptcy in 1982 and closed its doors on May 1, 1983. Allegheny Ludlum purchased the site in 1984. The buildings Simonds used for uranium and thorium rolling, and some others, were in a fenced-off area referred to in a survey by the Oak Ridge Institute for Science and Education as the excised area (Vitkus 1999), and no work was done there. Buildings 1 through 6, 8, 9, and 35 are in the excised area. The building walls are brick and sheet-metal paneling, and the floors consist primarily of compacted dirt with some areas of concrete or brick. In 1999, the horizontal surfaces were found to contain excessive amounts of dust and debris. Buildings 6 and 8, where the rolling took place, had steel plates on the floor with dirt and cinders beneath. The majority of the equipment Simonds used during AEC work was still present in 1999. The buildings were isolated at the time of closing and exhibited leaking roofs, broken windows, and similar conditions. Although it is likely that the contaminated buildings and surrounding areas have remained inaccessible to Simonds site employees since May 1, 1983, this site profile assumes that residual contamination exposures could have occurred through the present.

A site remedial investigation was conducted under the direction of the U.S. Army Corp of Engineers (USACE) from 2007 to 2010 (USACE ca. 2010).

3.0 ESTIMATION OF INTERNAL EXPOSURE

The primary sources of internal radiation exposure at Simonds were uranium and thorium dust produced from the manipulation and oxidation of the metals during rolling and related processes. In the early years, natural uranium was rolled. There is reference to some use of uranium enriched to 2.5% or less and to depleted uranium in the later years of AEC work.

The AEC measured particle sizes at Simonds using a “modified cascade impactor” (Spiegl et al. undated). The sampler was 3.5 ft from the floor and 4 ft from the uranium billet during roughing and finishing. The four mass median diameter distribution measurements ranged from 1.22 to 1.80 µm with indication that the values increased over time. The reported geometric standard deviation (GSD) of each measurement was about 2.5. When adjusted for density, these results are consistent with International Commission on Radiological Protection (ICRP) Publication 66 default parameters for particle deposition (ICRP 1994), so dose reconstructions should assume ICRP Publication 66 defaults (including a 5-µm activity median aerodynamic diameter).

3.1 URANIUM

Human and animal studies have indicated that oxides of uranium can be very insoluble (ICRP 1995), which indicates absorption type S (0.1% and 99.9% with clearance half-times on the order of 10 minutes and 7,000 days, respectively). Other in vitro dissolution studies of compounds at uranium facilities have shown that oxides of uranium exhibit moderate solubility (Eidson 1994; Heffernan et al. 2001), which suggests absorption type M (10% and 90% with clearance half-times on the order of 10 minutes and 140 days, respectively). In vitro dissolution tests on oxides that were produced from uranium metal during depleted uranium armor penetrator tests have indicated multicomponent dissolution rates, with 25% of uranium dissolving with a half-time of less than or equal to 0.14 days and 75% dissolving with a half-time of 180 days. Because there was no specific information on the solubility of aerosols during operations, this analysis assumed that both types M and S were available. The selection of absorption type should depend on the organ of interest.

3.1.1 Uranium Bioassay

Individual uranium urinalysis data are available for some Simonds workers. Urine samples were not collected from all uranium workers at Simonds, so the lack of bioassay for an individual should not result in a conclusion of no internal exposure. The uranium urinalyses for Simonds workers range from 0 to 0.272 mg/L. AEC assumed that the 0.272-mg/L value from November 4, 1949, was obviously contaminated (1950, Table 4, footnote), but the only basis for this appears to be that the result was large. This analysis assumes that the 0.272-mg/L result was valid. The next largest result was 0.164 mg/L.

Many of the early samples were collected for understanding the relationship between exposures and urinalyses results. AEC (1949h) stated:

> *In order that some correlation could be obtained between uranium exposure of individuals in this area and the amount of uranium found in their urine, urine samples were obtained from 10 different individuals for 3 days before a rolling period, each day during the rolling period, and 4 samples taken twice weekly after the rolling had ceased.* [Urinalysis data that completely matched this quote have not been located.]

Although the AEC quote above indicates that multiple acute or short chronic intakes could best describe the exposures, the contamination of the workplace likely caused continual, albeit lower, intakes. Chronic exposure assumptions are used to fit the multiple intakes at Simonds.

Uranium urinalyses were performed by the University of Rochester in 1948. The AEC NYOO performed uranium urinalyses from 1949 through 1952. The uranium fusion photofluorimetry urinalyses at the University of Rochester and the AEC NYOO were similar to those at other AEC facilities. The default detection threshold for uranium urinalysis is assumed to be 10 µg/L based on a reported sensitivity of 5 to 10 µg/L for uranium fluorimetry urinalysis in the early years (Wilson 1959). The 1948 Simonds bioassay reports noted that the results of less than 0.01 mg/L were insufficient for reliable detection (Author unknown 1948), and the lowest non-zero result is recorded as 0.01 mg/L. The bioassay reports from the NYOO have non-zero results recorded as low as 0.001 mg/L.

For unmonitored workers or unmonitored periods, this site profile analyzes the bioassay results to provide estimates of coworker uranium intakes.

The first available bioassay samples for Simonds were dated November 1, 1948. Urinalyses were reported fairly regularly through December 15, 1950. The last available set of sample results was reported for December 20 and 22, 1952. No specific incidents were associated with any of the samples. One worker, who reportedly had two embedded metal chips removed from his skin, had no bioassay results that were dated after the two incidents. Results for two people, who were listed on data sheets where the plant was listed as NYOO, were not included in the analysis. One result was listed as zero, the other results were associated with an NYOO employee who visited multiple AEC facilities. Results dated December 14 and 15, 1950, appeared to be parts of the same set, so were combined and assumed to all be dated December 14, 1950. The bioassay data for the coworker exposure analysis are summarized in Attachment A. For each bioassay date, geometric means (GMs) were estimated by ranking the data, determining the *z*-scores, and plotting the respective *z*-score versus the natural logarithm of the data. A line was fit to the data; e raised to the line's *y*-intercept value was assumed to be the GM, and e raised to the slope value was assumed to be the GSD. Results reported as zero were ranked, but used only indirectly in the fitting of the line. The 84th percentile was estimated as the GM multiplied by the GSD. Before November 17, 1949, the number of results for a given date ranged from 10 to 16. The statistical fit parameter (R^2) results averaged 0.86 and ranged from 0.65 to 0.96, and were considered adequate for this set of data.

The daily uranium excretion in urine was calculated by multiplying the results in milligrams per liter by Reference Man's daily urine output (1.4 L/d) (ICRP 1975). Attachment A shows the bioassay results for the intake analyses. Table 3-1 summarizes the estimated geometric median, 84th-percentile, and maximum uranium urinalyses that were used to derive intake rates from three chronic inhalation intake regimes: February 24, 1948, to December 1, 1948; December 1, 1948, to December 15, 1950; and December 15, 1950, to December 31, 1952. Intake rates for after 1952 were set to those for the initial 1948 period to account for the reduced use of engineering controls and lack of bioassay data for this later period. Graphs of the fits of these intake regimes are shown in Attachment B. Additional intakes and alternate periods were tried, but fits were not more satisfactory than those chosen. When intakes are estimated from bioassay data, the mode of intake is usually assumed to be inhalation, unless there is information that indicates that other modes of intake are more likely. When using bioassay data, the inhalation intake model assumes that some of the intake behaves as ingested material. In general, intakes from bioassay will be larger when an inhalation rather than an ingestion intake is assumed.

The intake rates were calculated with the Integrated Modules for Bioassay Analysis (IMBA) program assuming an absolute uniform error of 1 and normal error distributions for each bioassay result. The GSDs for the intake rates were calculated by dividing the intake from the 84th-percentile regime by the intake from the GM regime. Table 3-2 lists the inhalation intake distributions from the analyses of the Simonds uranium urinalysis data, which assumes that either a type M or a type S (but not both) intake occurred. Intake rates are adjusted from milligrams per day to picocuries per day by multiplying by 682.91 pCi/mg.

Table 3-1. Bioassay results from coworker data[a].

Bioassay date	GM bioassay (mg/L)	84th-percentile bioassay (mg/L)	Maximum bioassay (mg/L)
11/01/1948	0.021	0.045	0.140
11/03/1948	0.022	0.042	0.090
11/04/1948	0.022	0.043	0.070
11/08/1948	0.011	0.018	0.030
11/11/1948	0.016	0.031	0.050
11/15/1948	0.016	0.035	0.050
01/06/1949	0.006	0.016	0.018
04/27/1949	0.017	0.028	0.036
11/04/1949	0.016	0.036	0.272
11/17/1949	0.001	0.010	0.164
01/06/1950	0.002	0.009	0.026
01/19/1950	0.010	0.024	0.035
05/15/1950	0.005	0.014	0.022
05/23/1950	0.008	0.019	0.034
08/14/1950	0.027	0.041	0.102
08/28/1950	0.016	0.022	0.033
09/23/1950	0.002	0.009	0.020
09/25/1950	0.011	0.018	0.024
10/20/1950	0.006	0.026	0.067
10/25/1950	0.005	0.016	0.043
11/09/1950	0.003	0.010	0.030
11/16/1950	0.005	0.014	0.028
12/14/1950	0.006	0.015	0.080
12/20/1952	0.016	0.035	0.066
12/22/1952	0.015	0.033	0.054

a. Multiply results in mg/L by 1.4 L/d to obtain results in milligrams/day.

Table 3-2. Inhalation intake rates (mg/d) based on coworker data[a].

Start	End	Type	Intake rate	GSD (type M)	Type	Intake rate	GSD (type S)
02/24/1948	12/01/1948	M	0.422	1.98	S	12.6	1.99
12/01/1948	12/15/1950	M	0.173	2.25	S	1.76	2.58
12/15/1950	12/31/1952	M	0.329	2.16	S	5.32	2.15
01/01/1953[b]	12/31/1957	M	0.422	1.98	S	12.6	1.99

a. Section 3.3 and Table 3-13 provide details on the implementation of these calculated intake rates.
b. Intake rates for after 1952 were set to those calculated for the initial 1948 period to account for the reduced use of engineering controls and lack of bioassay data for this later period.

3.1.2 Uranium Air Sampling

Air sampling was performed at Simonds during some of the uranium rolling campaigns (AEC 1948c, 1948d, 1949d, 1949e, 1950; Heatherton 1950a, 1950b, 1951b; Klevin 1951; Klevin and Weinstein 1953a; Schumann 1953). The air samples consisted of collection of radioactive particulate on filters from breathing zones, general areas, processes, and effluents. AEC (1948c) states the general method of air sample collection and analysis:

> *The [airborne] radioactive dust samples were collected on 1-1/8-in. diameter Whatman #41 filter discs, using a standard Fischer pump employed by the Medical Division, NYOO, a Wilson pump, and a small, light, air compressor with a Universal motor. The rate of flow found to be most suitable for collection purposes at the concentration sampled was 0.0175 cubic meters per minute. The collection period varied from 30 seconds to 45 minutes, depending upon conditions of operation and dust loading. All dust samples collected were counted on a flat plate alpha counter at the New York Health Instrument Laboratory. Attached to this report are the dust sample records, containing both general air and breathing zone samples which have been used in all calculations to evaluate the employees' exposure to radioactive dust.*

The measured alpha activity on the filter was used to determine airborne alpha activity concentrations. The AEC matched these air concentration determinations with information about worker categories, locations, tasks, and time at each location or task. For some tasks and locations, multiple samples were collected. The mean count rate was calculated and used to calculate an average air concentration.

AEC used the information on work tasks with the measured air concentrations to determine an average air concentration weighted by the exposure time and summed these average air concentrations to determine a daily time-weighted average air concentration for specified job categories. These air concentration results are further analyzed here to determine GMs for each workgroup. The workgroups are defined by the dates of air sample collection. The daily time-weighted average air concentrations were weighted further by the number of workers AEC reported as exposed at a given concentration. The GMs for each workgroups' daily time-weighted average air concentrations were calculated and used to derive the intake rates. The GSDs of the job category concentrations and the workgroup concentrations were determined to provide an indication of the distribution of the data (the latter GSD includes consideration of the number of workers included in each category in the AEC study). This analysis assumed that, because the data are limited and rigorous analyses to determine distribution type are not likely to be meaningful, a lognormal distribution should represent the time-weighted exposures.

Table 3-3 lists the GMs and GSDs, the number of job categories, and the workgroups' daily time-weighted average air concentrations. In addition, the simplified estimated intake rates assumed from review of the air exposures over time are presented.

Table 3-3. Daily time-weighted average uranium air concentrations.

	Air sample collection dates (workgroups)				
	10/27/1948	**12/01/1948**	**01/10/1949**	**04/05/1949**	**05/02/1949**
Number of job categories	9	9	9	9	10
GM (dpm/m^3)	1,977	860	523	263	226
GSD	3.0	1.9	2.9	1.8	1.8
Number of workers	32	30	28	30	40
GM (dpm/m^3)	1,842	853	455	266	256
GSD	3.0	1.9	3.2	1.8	1.9
Estimated air concentration (dpm/m^3)	2,000	1,000	1,000	250	250
	01/09/1950	**01/10/1950**	**04/13, 04/14, or 04/18/1950**	**05/17, 05/18, or 05/22/1950**	**08/14/1950–08/16/1950**
Number of job categories	10	10	13	13	11
GM (dpm/m^3)	190	180	90	75	96
GSD	1.8	1.9	1.9	2.7	1.5
Number of workers	40	40	45	45	38
GM (dpm/m^3)	205	199	88	82	89
GSD	1.9	1.9	1.9	2.7	1.5
Estimated air concentration (dpm/m^3)	250	250	150	150	150
	01/09/1951–01/10/1951	**08/20/1950–08/21/1951**	**01/01/1952–31/1952**	**09/12/1952**	**01/04/1953–01/21/1953**
Number of job categories	10	13	13	13	11
GM (dpm/m^3)	161	97	96	129	141
GSD	2.8	1.4	1.5	1.6	2.4
Number of workers	38	42	42	43	34
GM (dpm/m^3)	161	100	94	125	138
GSD	2.8	1.4	1.6	1.7	2.7
Estimated air concentration (dpm/m^3)	150	150	150	150	150

The air sampling reports show time-weighted air concentrations at the plant during rolling operations before and after improvements in processes, ventilation systems, and safety practices. As discussed in Section 2.4.2, exposure conditions were constantly changing but had a downward trend in the early years.

A simplified but representative set of intake rates was determined by a graphing and estimating technique because there were 15 sets of natural uranium air concentration data and the workgroups' daily time-weighted average air concentration results were changing over time.

Figure 3-1 shows the GMs, maximums, and minimums of the workgroups daily time-weighted average air concentrations for the 15 air sampling periods. The numerical results and the graph were used to estimate periodic intake rates, which are summarized in Table 3-4 and shown on the graph as estimated weighted exposures. A GSD of 3.0 (the largest calculated GSD associated with the data) was assumed to calculate the 95th-percentile estimated air concentrations in Figure 3-1.

This analysis of intake rates based on air concentrations assumed that uranium rolling took place between February 24, 1948, and December 31, 1957. Rolling was assumed to occur for 13 days of every month from February 24, 1948, to December 31, 1953, based on 312 turnings per year and double shifts. The time assumption for the later period (January 1, 1954, to December 31, 1957) was reduced to 20% as discussed in Section 2.7.

The breathing rate is based on the default for light work in ICRP Publication 66 (ICRP 1994, Table 6, p. 23). Intake rates in picocuries were calculated by dividing the estimated air concentration by

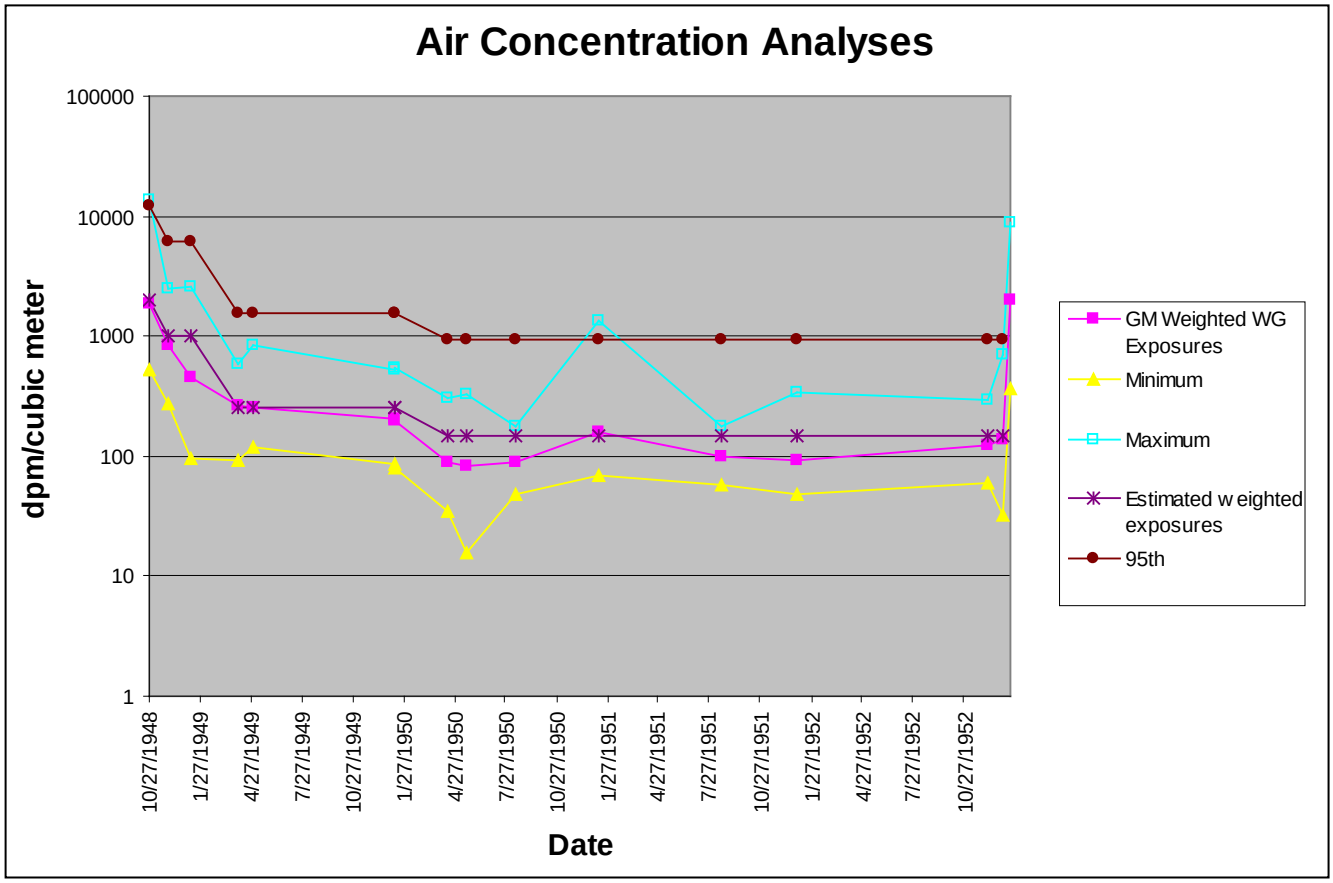

Figure 3-1. Workgroups daily time-weighted average uranium air concentrations and estimated weighted exposures.

2.22 dpm/pCi and multiplying this result by the breathing rate and the assumed number of exposure hours at the given concentration. Table 3-4 lists estimated annual uranium inhalation intake rates during rolling based on air concentrations.

Table 3-4. Uranium inhalation intake rates during rolling operations.

Work period		Number of potential AEC workdays	Air concentration (pCi/m^3)	Breathing rate (m^3/hr)	Hr/workday	Intake (pCi)
02/24/1948	12/01/1948	120	9.01E+02	1.2	10	1.30E+06
12/01/1948	04/05/1949	52	4.50E+02	1.2	10	2.81E+05
04/05/1949	04/13/1950	156	1.13E+02	1.2	10	2.11E+05
04/13/1950	01/01/1954	585	6.76E+01	1.2	10	4.74E+05
01/01/1954	12/31/1957	125	6.76E+01	1.2	10	1.02E+05
Total						**2.37E+06**

There was a potential for internal exposure to resuspended material from the AEC work during non-AEC operations. To estimate exposure from resuspended materials, this analysis assumed that surfaces in the building became contaminated by deposition of uranium dust during rolling operations.

The level of contamination was determined by multiplying the air concentrations in Table 3-4 by the indoor deposition velocity and the assumed deposition time, which for uranium was 20 hours per rolling day. The indoor deposition velocity is dependent on the physical properties of the room (e.g., air viscosity and density, turbulence, thermal gradients, surface geometry, etc.). It is also dependent on the physical properties of the aerosol particles (e.g., diameter, shape, and density).

These characteristics are not known, so the terminal settling velocity was calculated for an aerosol with the ICRP Publication 66 default particle size distribution of 5-µm activity median aerodynamic diameter (ICRP 1994). The calculated terminal settling velocity was 7.5×10^{-4} m/s, which is within the range of deposition velocities (2.7×10^{-6} to 2.7×10^{-3} m/s) measured in various studies (NRC 2002).

The calculated surface contamination level from airborne dusts during the uranium rolling from February 24, 1948, to December 31, 1957, was 1.11×10^{7} pCi/m^2 (approximately 240,000 dpm/100 cm^2). The assumption was made that all the surface contamination was present for the entire period of AEC operations. Therefore, using a resuspension factor of 1×10^{-6}/m (Abu-Eid et al. 2002), the air concentration due to resuspension would have been 11.0 pCi/m^3. This value compares favorably with the air concentration of 25 µg/m3 (17 pCi/m^3) reported by the AEC in 1950 during an extended period without rolling operations and with the assertion by AEC in that same document that it would be "impractical to reduce the airborne uranium consistently below 15 µg/m^3 (10.2 pCi/m^3)" (AEC 1950). Table 3-5 lists the assumed inhalation intake rates from resuspension of deposited material. (Table 3-7 lists the intake rates in Table 3-5 added to the intake rates in Table 3-4.)

Table 3-5. Inhalation intake rates during non-AEC operations from resuspension of deposited uranium dust.

Work period		Hr/workday	Non-U rolling workdays per work period	Breathing rate (m^3/hr)	Resuspended air concentration (pCi/m^3)	Intake (pCi)
02/24/1948	12/01/1948	10	82	1.2	11.0	1.08E+04
12/01/1948	04/05/1949	10	38	1.2	11.0	5.02E+03
04/05/1949	04/13/1950	10	112	1.2	11.0	1.48E+04
04/13/1950	01/01/1954	10	387	1.2	11.0	5.12E+04
01/01/1954	12/31/1957	10	919	1.2	11.0	1.21E+05
Total						**2.03E+05**

When using air concentrations to calculate inhalation intake rates, dose reconstructors should also consider ingestion intake rates. NIOSH (2004) states that the daily ingestion rate in picocuries can be estimated by multiplying the daily air concentration in picocuries per cubic meter by a factor of 0.2 for an 8-hour workday. For a 10-hour workday, the multiplier would be 0.223. The daily ingestion rates during AEC uranium work are estimates based on the air concentrations in Table 3-3. The daily ingestion intake rates from resuspended uranium are estimates from Table 3-4. The ingestion intake rates are then the sum of the products of the ingestion intake rates and the number of workdays exposed at the calculated levels. The ingestion intake rates in Table 3-6 apply to all workers.

Table 3-6. Estimated amount of uranium ingested (based on Tables 3-3 and 3-4).

Work period		U rolling workdays	U ingestion rate during uranium rolling (pCi/workday)	Non-U rolling workdays	U ingestion rate during normal operation (pCi/workday)	Intake (pCi)
02/24/1948	12/01/1948	120	2.01E+02	82	2.46E+00	2.43E+04
12/01/1948	04/05/1949	52	1.01E+02	38	2.46E+00	5.32E+03
04/05/1949	04/13/1950	156	2.51E+01	112	2.46E+00	4.20E+03
04/13/1950	01/01/1954	585	1.51E+01	387	2.46E+00	9.77E+03
01/01/1954	12/31/1957	125	1.51E+01	919	2.46E+00	4.15E+03
Total						**4.78E+04**

Estimated uranium intake rates based on air concentrations are listed in Table 3-7.

Table 3-7. Estimated uranium intake rates based on time-weighted air concentrations.

Start	End	Intake route	Absorption type	Intake (pCi/d)
02/24/1948	12/01/1948	Inhalation	M, S	4.66E+03
02/24/1948	12/01/1948	Ingestion	([a])	8.66E+01
12/01/1948	04/05/1949	Inhalation	M, S	2.29E+03
12/01/1948	04/05/1949	Ingestion	([a])	4.28E+01
04/05/1949	04/13/1950	Inhalation	M, S	6.07E+02
04/05/1949	04/13/1950	Ingestion	([a])	1.12E+01
04/13/1950	01/01/1954	Inhalation	M,S	3.87E+02
04/13/1950	01/01/1954	Ingestion	([a])	7.20E+00
01/01/1954	12/31/1957	Inhalation	M, S	1.53E+02
01/01/1954	12/31/1957	Ingestion	([a])	2.84E+00

a. Ingestion absorption type should be selected consistent with that for inhalation.

Simonds periodically rolled enriched uranium and depleted uranium. The maximum enrichment of uranium is unknown. Available documents indicate that uranium as high as 2.5% enrichment was processed (Keller 1979). However, FMPC had two standard operating procedures for rolling uranium at Simonds, one for up to 2.75% enrichment (Schlitz 1954) and another for up to 7.2% enrichment (Schlitz 1955). Air monitoring data associated with these activities are summarized in Tables 3-8 and 3-9.

Table 3-8. Air concentrations during rolling – enriched uranium, 10-in. mill.[a]

Location	Air concentration (dpm/m^3)
Breathing zone air concentrations	
Foreman	701
Rougher, south side	372
Rougher, north side	1,061
Finisher, south side	406
Stranner, south side	5,031
Stranner, north side	9,001
Poke-in, north side	2,061
Straightener, north side	6,081
Straightener, run out	8,011
Rod stamper and straightener	2,041
General area air concentrations	
Behind rod straightener	208
Mill floor during cleanup	300
Mill floor during rolling	2,867
Rod area during rolling	1,678
Furnace area during rolling	2,186
Near bull head	1,196
10 foot east of mill	83

a. Information for this table, including location descriptions, is from Heatherton (1953b).

In the enriched uranium air study, a weighted exposure was calculated for the brief (80-minute) activity for the lowest- and highest-exposed individual. These were 0.9 MAC-days and 22.0 MAC-days for the South Side Rougher and North Side Stranner, respectively (Heatherton 1953b). These exposure rates correspond to daily weighted activities of 5.3 MAC and 128 MAC, respectively.

Table 3-9. Air concentrations during rolling – molybdenum depleted uranium, 16-in. mill.[a]

Location	Air concentration (dpm/m^3)		
	High	Low	Average
Breathing zone air concentrations			
Rougher, east side	20	15	18
Rougher, west side	209	5	51
Finisher, east side	452	47	192
Finisher, west side	2,866	939	1,903
General area air concentrations			
Weigh-in and furnace area	440	106	297
West side of mill	193	16	58
East side of mill	460	122	336

a. Information for this table, including location descriptions, is from Schumann (1953).

Forging operations using uranium were periodically conducted. Air sampling data for uranium forging operations on April 18, 1950, and July 12, 1956, are summarized in Tables 3-10 and 3-11. The April 1950 survey is discussed in an AEC air monitoring report (Heatherton 1950b):

> *The forge-hammering operation was very dusty. Individual general air dust samples collected in the vicinity of the forging were from 76 to 260 times the preferred level. Samples collected in the breathing zones of men handling the billets with tongs were 220 to 400 times the preferred level.*

Table 3-10. Airborne uranium dust from forging on April 18, 1950.[a]

Location/comment	Air concentration (dpm/m^3)
General area	
3 ft above 5 in. billet forged to 1.9375 in.	7,600 5,200 6,400 12,000
Forging 2 billets	13,000 3,800
Breathing zone	
Operator, east side forge	11,000
Tong man, east side of forge	20,000

a. Information for this table, including location/comment descriptions, is from air dust and urine data (AEC 1949–1954, pp. 58–60).

Documentation of an April 1956 hammer-forging operation did not contain any monitoring data. However, it did provide the following descriptive information (Magoun and Yocco 1956):

> *No salt or other coolant or oxidation inhibitor was used in this operation. Because of this, appreciable amounts of uranium oxide were formed on the slabs and thrown into the surrounding air by the heavy blows of the forge hammer. The operating personnel in the area were protected by respirators during the time the forging hammer was in use.*

3.1.3 Comparison of Uranium Bioassay and Air Concentration Estimates

The GM uranium intake rates based on air data were compared to the GM uranium intake rates based on bioassay data (calculated in Section 3.3). The GM intake rates based on air data generally fell between the type M and S intake rates based on bioassay data, as shown on the “Type M, GM bioassay” and “Type S GM bioassay” graphs in Attachment B. This would be a reasonable observation if workers were exposed to a source term that was not pure type M or S.

Table 3-11. Airborne uranium dust from forging – July 12, 1954.[a]

Location/comment	Air concentration (dpm/m^3)
General area	
Hammer, south	140 1,600 820 870 220
East of 7-t hammer, between hammer and furnace	630
35 ft east southeast of press	100
35 ft from hammer (lunch)	1100 990 850
Bench (lunch area), north	100
Bench, southwest of hammer (lunch)	27
Lunch area, south southwest hammer	48
15 ft southwest of hammer	160
20 ft southwest of hammer	43
1 ft south of 7-t hammer	2,100 10,000
Southeast of 7-t hammer	15,000
6 ft	180
5 ft	72
Breathing zone	
Hammer operating position downward	310 270 500
Charger atop unit	240 370 400
Northwest corner of hammer-2 ingots	1,900 3,500
Around hammer	8,300 29,000 3,600 650
Opening furnace door, removing ingot	4,500
Southwest of 7-t hammer	5,600 6,000 2,200
Northeast of 7-t hammer	730 770 950 4,000

a. Information for this table, including location/comment descriptions, is from Air Dust and Urine Data (AEC 1949–1954, pp. 145–148).

Intakes derived from bioassay data are preferred over intakes from air sampling because excretion is directly related to intake and does not rely on estimates of worker exposure times at various locations. Although not all Simonds workers submitted bioassay samples, there are 645 bioassay sample results for uranium from 25 sample dates from 1948 through 1952. Reports of the air sample studies indicated that the number of workers considered for uranium exposure in the rolling mill was between 28 and 45, depending on the date of the study. The number of workers submitting samples on each sample date was typically between 10 to 20, but it appears that on several sample dates all or nearly

all considered to be exposed to uranium submitted bioassay samples. Additionally, a few workers submitted samples on almost every sample date. Bioassay sample results have also been matched up with individuals identified in air sample reports as having high exposures.

For the above reasons, intakes derived from bioassay data will be used to assign intakes for unmonitored workers or for workers who do not have sufficient bioassay results to fully reconstruct dose.

Consideration was also given to stratification of intakes due to the varying level of intake as a function of job assignment or work location. The AEC air sample studies used work location and time studies to estimate daily weighted exposures (DWE); these data indicate that exposures varied depending on job assignment within the active uranium work areas. The varying level of intake is also supported by the varying level of bioassay sample results. Some trends of exposure based on job are suggested by the DWE data; however, those trends are not always consistent from one sample date to the next. Some of the bioassay data can be matched up with job assignments specified in air sample reports; however, the bioassay data also indicates that no particular job assignment is associated with the highest sample results on a given sample date. In consideration of these data, and the fact that there is no definitive way to determine a DWE for a particular unmonitored worker in the rolling mill, a favorable to claimant approach is used to bound intakes for unmonitored workers to assure that intakes are not underestimated. That information is provided in the Occupational Internal Dose Reconstruction Assumptions and Summary, Section 3.3.

3.1.4 Depleted, Enriched, and Recycled Uranium

Records for Simonds indicate that small quantities of depleted and enriched (up to 2.5% by mass) uranium were processed after 1951. Because the Simonds air samples were counted either with parallel-plate alpha counters or with alpha scintillation detectors (which detect radioactivity rather than mass), there is no need to adjust measured air concentration results for assumed uranium enrichment or depletion, even when the results were reported in micrograms per cubic meter.

Enrichment or depletion would affect assumptions about the radioactivity in the mass of the released or measured uranium because of differences in specific activities (activity per mass). Because this increase or reduction is no more than a factor of 3 for these limited processing campaigns, and because more than 99% of the material was natural uranium, this analysis makes no adjustment for specific activity. However, because of the unknown enrichment for a given period and the unknown fraction of enriched material that was processed for a given period, this document assumes that intake rates calculated from air data are ^{234}U for the purpose of calculating internal organ doses.

Heatherton (1953b) reported the results for an air sampling survey during enriched uranium rolling on January 17, 1953, at the 10-in. bar mill. The operation lasted for 80 minutes (versus the typical 8 to 10 hours). The GM concentration for 80 minutes was about 2,000 dpm/m^3 with a GSD of 3.0 (this is shown in Figure 3-1 as the last air sample). In reality, the actual worker exposure would have been lower by about a factor of 6, giving a daily weighted concentration of 330 dpm/m^3. Heatherton (1953b) noted that there was no ventilation at the 10-in. bar mill and that air dust respirators were worn by all mill workers at the time of the survey. Ventilation was recommended for any future work at the 10-in. bar mill. Because the number of uranium rolling days in 1953 was estimated to continue at 156 days (versus the estimated 15 days calculated in Section 2.0), it is believed that there is a sufficiently large overestimate of intake to not adjust intake rates for this work. For later years, where 28, 29, and 11 days of rolling are assumed and 31.2 is used in the intake calculations, the margin is not as large, but it is also likely that smaller runs were being made during this period that might not have consumed two full operating shifts per day.

Recycled uranium might have been processed at Simonds after 1952. An estimate of contaminants that might contribute the most to internal doses, based on a review of recycled uranium contaminants at the Hanford and FMPC sites, is shown in Table 3-12. It is unlikely that recycled uranium would constitute the entire Simonds source term. The activity fractions are based on the specific activity of depleted uranium, which increases the proportion of the contaminants by activity. The contaminant levels for depleted uranium overestimate the contaminants in uranium of normal enrichment by about 40%. The contaminants are assumed to be in the form of oxides.

Table 3-12. Estimate of contaminant activity fractions in a recycled depleted uranium source term (pCi contaminant per pCi uranium).

Uranium	Np-237	Pu-239	Tc-99
1	0.00182	0.00261	0.379

3.2 THORIUM

NIOSH has determined, and the Secretary of Health and Human Services has concurred, that it is not feasible to reconstruct internal radiation dose from exposure to thorium for individuals who worked at Simonds during the operational period (Sebelius 2011).

3.3 OCCUPATIONAL INTERNAL DOSE RECONSTRUCTION ASSUMPTIONS AND SUMMARY

The assumed uranium photofluorimetry urinalysis detection threshold is 10 µg/L. Uranium is assumed to be of natural enrichment, although small amounts of both depleted and 2.5% enriched uranium were rolled after 1951. The recycled uranium contaminants should be accounted for after 1952 using the activity fractions in Table 3-12. Uranium oxides can be either absorption type M or S. Neptunium oxides are type M. Plutonium oxides are assumed to be type M or S.

The assumed operational exposure period is from February 24, 1948, to December 31, 1957, which this analysis assumes to be the uranium intake period. For unmonitored workers or unmonitored periods, Table 3-13 lists intake rate assumptions for natural uranium. The intake mode is chronic. The dose distribution is assigned as a constant distribution. Intake rates are based on the data in Table 3-1 and derived intake rates in Table 3-2. However, to account for the degradation in engineering controls (as noted in Section 2.4.1), intake rates for the post-1952 period were set equal to those calculated for the initial 1948 time frame. Use of the 1948 data allows for the potential for elevated intakes that would not have been reflected in the available bioassay dataset (which ends with 1952) because, during this initial period, operations were conducted without engineering controls.

Table 3-13. Summary of internal intake rates for operational period February 24, 1948, to December 31, 1957.

Radionuclide	Start	End	Intake route	Absorption type	50th-percentile intake[a] (pCi/d)	95th-percentile intake[a] (pCi/d)
U-234[b] Choose M or S intake scenario, not both.	02/24/1948	12/01/1948	Inhalation	M	2.88E+02	8.87E+02
	12/01/1948	12/15/1950	Inhalation	M	1.18E+02	4.49E+02
	12/15/1950	12/31/1952[c]	Inhalation	M	2.25E+02	7.98E+02
	01/01/1953	12/31/1957[c]	Inhalation	M	2.88E+02	8.87E+02
	02/24/1948	12/01/1948	Inhalation	S	8.61E+03	2.67E+04
	12/01/1948	12/15/1950	Inhalation	S	1.20E+03	5.72E+03
	12/15/1950	12/31/1952[c]	Inhalation	S	3.63E+03	1.28E+04
	01/01/1953	12/31/1957[c]	Inhalation	S	8.61E+03	2.67E+04
Np-237	01/01/1953	12/31/1957[c]	Inhalation	M, if U is M	5.25E-01	1.61E+00
	01/01/1953	12/31/1957[c]	Inhalation	M, if U is S	1.57E+01	4.86E+01
Pu-239	01/01/1953	12/31/1957[c]	Inhalation	M, if U is M	7.52E-01	2.31E+00
	01/01/1953	12/31/1957[c]	Inhalation	S, if U is S	2.25E+01	6.97E+01
Tc-99	01/01/1953	12/31/1957[c]	Inhalation	M, if U is M	1.09E+02	3.36E+02
	01/01/1953	12/31/1957[c]	Inhalation	M, if U is S	3.26E+03	1.01E+04

a. Assigned as a constant distribution.
b. If individual bioassay data is available, it should be used instead of the these intake rates, which are based on coworker assessment.
c. Intake rates for after 1952 were set to those calculated in the initial, 1948 period, to account for the reduced use of engineering controls and lack of bioassay data for this later period.

The 95th-percentile intake rates in Table 3-13 should be applied to all Simonds mill workers, any other worker whose job could have involved work in or around the rolling mills or forge shop areas, and workers whose job is unknown. Workers whose job would not have required work in those areas (i.e., office workers) should be assigned the median intake rate to allow for being occasionally exposed in the general area of uranium processing areas.

4.0 ESTIMATION OF EXTERNAL EXPOSURE

Individual external dosimetry results for Simonds consist of doses AEC reported for 20 workers for the period from October 11 to 19, 1949 (AEC 1949c). A limited exposure period of less than 2 weeks might not be representative of exposures during the 9 years of AEC operations at Simonds, so external doses based on supplementary data are provided.

For dose reconstruction, when individual film badge data are not available or adequate to assign dose, this analysis provides dose estimated with the assumption that there was a potential for external exposure to natural uranium metal from five sources:

- Submersion in air contaminated with uranium dust,
- Exposure from contaminated surfaces,
- Exposure to electrons from the surface of the uranium billets and rods,
- Exposure to photons from the uranium billets and rods, or
- Exposure to occupationally required medical X-ray.

The majority of photons from natural uranium metals have energies in the range of 30 to 250 keV. Solid uranium objects provide considerable shielding of the lower energy photons and harden the spectrum, which causes the majority of photons from a solid uranium object, such as a billet or a rod, to have energies greater than 250 keV. While solid uranium sources have a hardened photon spectrum, exposure to a thin layer of uranium on a surface results in a larger fraction of exposure to lower energy photons. This analysis assumed workers were exposed to photon energies in the 30- to

250-keV range, which is favorable to claimants. Nonpenetrating dose from natural uranium consists primarily of electrons with energies above 15 keV. For consistent presentation, exposure or dose is reported as:

- Penetrating, assumed to be associated with photons with energies from 30 to 250 keV; and
- Nonpenetrating, assumed to be associated with electrons with energy of >15 keV.

The majority of photons from thorium metals have energies greater than 250 keV, and the solid matrix of billets and rods serves to harden the radiation energy spectrum. However, for the purpose of expediting dose reconstruction, it is favorable to claimants to assume workers were exposed to photon energies from 30 to 250 keV.

Summary of Available Individual Film Badge Data
AEC (1949c) issued 21 film badges to Simonds workers for the period from October 11 to 19, 1949. One of the badges was lost, so only 20 results were reported. No information was available to indicate when the workers actually wore the badges or where the badges were stored during off hours. The beta results ranged from 160 to 1,250 mR for the period, and the calculated GM was 362 with a GSD of 1.6. The gamma results ranged from not reported to 115 mR, and the calculated GM of the gamma results was 53 mR with a GSD of 1.9 (assuming 20 mR as half the limit of detection for zero readings). A quick scoping calculation, which assumed that the badges were worn for seven uranium rolling workdays and that there were 156 uranium rolling workdays per year, indicated annual GM beta and gamma doses of 8.1 and 1.2 R, respectively (95th percentile annual dose rates of 17.1 and 3.3 R, respectively).

External exposure estimates summarized in Table 4-3 in Section 4.4, which are based on consideration of source term and workplace information, are consistent with the limited film badge data. For a 156-day uranium rolling year, the results in Table 4-3 are based on the assumptions that the annual nonpenetrating exposure is 8.7 R and the assumed annual penetrating exposure is 1.2 R (95th-percentile annual dose rates of 28.9 and 7.8 R, respectively). Although the GMs of the two approaches are similar, the source term analysis results in a distribution that is more favorable to claimants should be used because of the limited film badge results.

4.1 SUBMERSION AND CONTAMINATION EXPOSURES

AEC suspended 20 film badges about 5 ft from the floor in the Simonds rolling mill for 192 consecutive hours “to determine the long term direct [external] radiation to individuals” (AEC 1949h). When the badges were retrieved, they were covered with radioactive dust from the plant, which would probably result in an overestimate of the true area radiation levels. The maximum results were reported as 5.6 mR/hr beta and 0.34 mR/hr gamma. This analysis assumed that (1) these results represented the general levels of external exposure from submersion in air and contaminated surfaces at Simonds, and (2) the data distribution was lognormal. The calculated GMs were 1.3 mR/hr with a GSD of 2.3 for nonpenetrating radiation and 0.26 mR/hr with a GSD of 1.2 for penetrating radiation. This assumption does not appear to be inconsistent with the reported Zeuto (portable ionization chamber) beta and gamma readings at Simonds of 2 mR/hr or less for most areas (AEC 1949h), some of which appear to be contact readings. The analysis assumed that the beta reading relates to the nonpenetrating dose and that the gamma reading relates to the penetrating dose (Table 4-3 in Section 4.4 lists these assumed exposures during operational years). This analysis assumed that all workers were exposed to penetrating and nonpenetrating radiation from submersion in air and contamination for 10 hours each workday.

4.2 BILLET AND ROD EXPOSURES

Another assumption was that workers received a deep dose due to photon exposure from the uranium billets and rods. The AEC work involved rolling uranium billets of 4- to 5-in. diameters and 15- to 28-in. lengths. The billets were rolled into rods 20 ft long of approximately 1.5-in. diameter (Smith 1951). Monte Carlo *n*-particle (MCNP) calculations determined the photon (including bremsstrahlung) dose rate at the surface, 1 ft, and 1 m from a 5-in.-diameter by 28-in.-long cylindrical billet and a 1.405-in. diameter by 20-ft-long rod. Table 4-1 lists calculated photon dose rates for the uranium billet and rod (Battelle Team 2006).

Table 4-1. Calculated photon dose rate for uranium billet and uranium rod (mrem/hr).

Distance from source	Billet dose rate	Rod dose rate
Surface	7.74	5.09
1 ft	0.703	0.285
1 m	0.108	0.0883

Several air exposure records were reviewed to estimate a worker's time near a billet or rod versus being in the general area. The records indicated that for most workers the time near the uranium billet or rod was less than 5 hours per shift, but some workers could have spent 6.5 hours near the rods and billets. Because workers changed jobs, this analysis assumed that workers were near the billets for 3.5 hours per rolling day and near the rods for 3.5 hours per rolling day. It also assumed that the dose rate at 1 ft was the median dose rate and the dose rate at the surface was the 95th-percentile rate. The annual penetrating dose rates in Table 4-3 (Section 4.4) were calculated by multiplying the median photon dose rates by the number of rolling days per year and the 3.5 hours per workday near the billets or the rods.

Shallow doses from the billets and rods were estimated using the measurements in Table 4-2. The units of measure were reported based on the rep (roentgen equivalent physical), which is a historical unit of dose equivalence approximately equal to a rem. These measurements were taken during an AEC survey in September 1948 (Piccot 1948) at Aliquippa Forge. Radiation measurements at Simonds appear to have been similar although, in general, the proximity of the Simonds radiation measurement to the source is not included. However, in April 1948, Hayden (1948a) reported measurements as low as background, 0.1 mrep/hr, and up to 40 mrep/hr at 8 in. from a rod storage pile. Direct beta readings were reported as 12 mrep/hr at 2 ft above an unswept steel floor and 4 mrep/hr after sweeping. Measurements at 2 in. from the floor dust indicated 20-mrep/hr beta radiation. In May 1948, Hayden (1948b) reported the maximum exposure rate near the rod cooling area as 0.16 mrep/hr and the radiation from the bottom of the quench tank as 25 and 8 mrep/hr at 6 in. and 2 ft, respectively. Reported radiation levels at various Simonds locations ranged from 0.5 to 12 mrep/ hr in October 1948 and from 0.5 to 15 mrep/hr in December 1948 (AEC 1949h). In August 1950, Heatherton (1950a) reported radiation levels of 1 mrep/hr within 1 to 50 ft of the Simonds rolls, with a maximum of 10 mrep/hr.

Table 4-2. Direct radiation measurements from September 1948 (mrep/hr).[a]

Location of measurement	Dose rate
Billet assumptions	
Contact with floor next to the quench tank where oxide scale has collected	8
Contact with floor in front of rolls where oxide scale has collected	5-10
Same location but 18 in. high	2-5
Rod assumptions	
4 ft above a pile of rods in the boxcar	20
5 ft from the end of a pile of rods next to the door of the boxcar	5
2 ft from the end of the same pile	13

a. Piccot (1948).

This analysis estimated the shallow dose from billets by assuming that the median dose rate was 5 mrem/hr and that the 95th-percentile dose rate was 10 mrem/hr, giving a GSD of 1.5. For rods, the assumed median dose rate was 5 mrem/hr and the assumed 95th-percentile dose rate was 20 mrem/hr, giving a GSD of 2.3. These exposure rates were multiplied by the assumed number of hours per workday near the rods or billets (3.5 hours) and by the number of uranium rolling days in the period. Table 4-3 (Section 4.4) lists the annual doses.

4.3 MISCELLANEOUS INFORMATION ABOUT EXTERNAL DOSE

This section includes external dose information that could be of value for specific dose reconstructions. This analysis did not consider such information generically because of its limited applicability or because of limited details.

AEC noted repeated instances of exposure to particles or chips of radioactive material, including stinging particles on the hands and face near the descaler (AEC 1949d) and chips of material embedded in the skin from work in the rod stamping area (AEC 1949–1954, p. 118; Heatherton 1951a). Consideration of exposure due to such materials should consider the guidance in ORAUT-OTIB-0017, *Interpretation of Dosimetry Data for Assignment of Shallow Dose* (ORAUT 2005).

4.4 OCCUPATIONAL EXTERNAL DOSE RECONSTRUCTION ASSUMPTIONS AND SUMMARY

Table 4-3 summarizes occupational external doses during uranium operations at Simonds.

Table 4-3. External annual exposure summary for February 24, 1948, to December 31, 1957.

Exposure mode	Exposure type	Exposure or dose rate	Basis	Assumed exposure time	Year	50th-percentile annual exposure rate[a,c,d]	95th-percentile annual exposure rate[a,c,d]
Submersion/ area contamination	Penetrating	0.26 mR/ hr	Film badge	2,500 workhours/ yr	1948[b]	0.554 R	0.748 R
					1949	0.650 R	0.877 R
					1950	0.650 R	0.877 R
					1951	0.650 R	0.877 R
					1952	0.650 R	0.877 R
					1953	0.650 R	0.877 R
					1954	0.650 R	0.877 R
					1955	0.650 R	0.877 R
					1956	0.650 R	0.877 R
					1957	0.650 R	0.877 R
	Nonpenetrating	1.3 mR/hr	Film badge	2,500 workhours/ yr	1948[b]	2.769 R	10.899 R
					1949	3.250 R	12.792 R
					1950	3.250 R	12.792 R
					1951	3.250 R	12.792 R
					1952	3.250 R	12.792 R
					1953	3.250 R	12.792 R
					1954	3.250 R	12.792 R
					1955	3.250 R	12.792 R
					1956	3.250 R	12.792 R
					1957	3.250 R	12.792 R

Exposure mode	Exposure type	Exposure or dose rate	Basis	Assumed exposure time	Year	50th-percentile annual exposure rate[a,c,d]	95th-percentile annual exposure rate[a,c,d]
Medical X-ray					1948[b]	Not assigned	
					1949		
					1950		
					1951		
					1952		
					1953		
					1954		
					1955		
					1956		
					1957		
U billets	Penetrating	0.703 mrem/hr	MCNP calculation	3.5 hr/ rolling day	1948[b]	0.327 rem	3.605 rem
					1949	0.384 rem	4.230 rem
					1950	0.384 rem	4.230 rem
					1951	0.384 rem	4.230 rem
					1952	0.384 rem	4.230 rem
					1953	0.384 rem	4.230 rem
					1954	0.076 rem	0.837 rem
					1955	0.076 rem	0.837 rem
					1956	0.076 rem	0.837 rem
					1957	0.076 rem	0.837 rem
	Nonpenetrating	5 mrep/hr	Instrument measurement	3.5 hr/ rolling day	1948[b]	2.326 rep	4.532 rep
					1949	2.730 rep	5.319 rep
					1950	2.730 rep	5.319 rep
					1951	2.730 rep	5.319 rep
					1952	2.730 rep	5.319 rep
					1953	2.730 rep	5.319 rep
					1954	0.543 rep	1.058 rep
					1955	0.543 rep	1.058 rep
					1956	0.543 rep	1.058 rep
					1957	0.543 rep	1.058 rep
U rods	Penetrating	0.285 mrem/hr	MCNP calculation	3.5 hr/ rolling day	1948[b]	0.133 rem	2.328 rem
					1949	0.156 rem	2.732 rem
					1950	0.156 rem	2.732 rem
					1951	0.156 rem	2.732 rem
					1952	0.156 rem	2.732 rem
					1953	0.156 rem	2.732 rem
					1954	0.031 rem	0.543 rem
					1955	0.031 rem	0.543 rem
					1956	0.031 rem	0.543 rem
					1957	0.031 rem	0.543 rem
	Nonpenetrating	5 mrem/hr	Instrument measurement	3.5 hr/ rolling day	1948[b]	2.326 rep	9.155 rep
					1949	2.730 rep	10.745 rep
					1950	2.730 rep	10.745 rep
					1951	2.730 rep	10.745 rep
					1952	2.730 rep	10.745 rep
					1953	2.730 rep	10.745 rep
					1954	0.543 rep	2.137 rep
					1955	0.543 rep	2.137 rep
					1956	0.543 rep	2.137 rep
					1957	0.543 rep	2.137 rep

a. Assigned as a constant.
b. Prorated from 02/24/1948 to 12/31/1948.

c. Dose Reconstructors should use the guidance in Section 4.1.2 Exposure Energy and Geometry of OCAS-IG-001 (NIOSH 2007) for determination of the appropriate selection for DCF geometry.

d. The 95th-percentile dose rates in Table 4-3 should be applied to all Simonds mill workers, any other worker whose job could have involved work in or around the rolling mills or forge shop areas, and workers whose job is unknown. Workers whose job would not have required work in those areas (i.e., office workers) should be assigned the 50th-percentile dose rate to allow for being occasionally exposed in the general area of uranium processing areas.

5.0 ESTIMATION OF RESIDUAL EXPOSURE

The residual contamination at the former Simonds site is primarily in the "excised area," a 9- acre isolated area that includes Buildings 1, 2, 3, 4/9, 5, 6, 8, and 35. The rolling mills and forge shop that were used for AEC work are located in the area of Buildings 3, 6, and 8 (Vitkus 1999).

Buildings 6 and 8 are not physically separated and contain the 10-in. and 16-in. rolling mills, respectively. The Forge Shop during the AWE operational period was in Building 3, which is open to Buildings 6 and 8 (as well as Building 4/9).

Building 24 is not part of the excised area; however, the southern end of Building 24 is contaminated and is adjacent to Building 8. Building 24 was constructed in parts over time. The southwestern portion is the original structure dating to 1941 and was once the loading dock of Building 8 and used for uranium packaging and weighing. Construction of the southeast portion of Building 24 was completed in 1959. At least some of the southeast section, including overhead beams, existed during the AEC contract period (which ended in 1957). Both of the southern portions of Building 24 have contaminated surfaces. Construction of the northern portion of Building 24 was completed in 1966 and it is essentially free of contamination (DOE 1979; Earth Tech 2010).

When the Simonds property was split in 1984, Building 24 was included in the sale of the 52-acre parcel to Allegheny Ludlum; it was an active warehouse during the 2007 surveys (Earth Tech 2010).

The buildings of interest in this evaluation are Buildings 3, 6, 8, and the southwest and southeast portions of Building 24, which occupies the entire south end of the building. The AEC operations occurred in all or parts of these four buildings. Although some contamination has been identified in other buildings, such as Building 4/9 and Building 2, it is not as notable.

5.1 RESIDUAL INTERNAL INTAKE RATES

Twenty-one general area air sample results were taken during uranium operations (some in close proximity to active work) in August and October of 1954 (AEC 1953–1954; NLO 1954). Ten of the results were from five different locations with samples collected twice during the day. Therefore, those air samples from the same locations were averaged to get an average air concentration for each location. This resulted in 16 independent location air concentration values. To determine intake rates for 1958 (start of the residual period), the GM alpha air concentration (122 dpm/m^3) from the 1954 data was used. Assuming a 2,500-hour work year and a 1.2-m^3/hr inhalation rate results in an annual intake of 3.66×10^5 dpm (1.65×10^5 pCi), or a calendar day intake rate of 1,003 dpm/d (452 pCi/d).

The total beta contamination measurements were analyzed for Buildings 3, 6, 8, and 24 South from the characterization surveys in 2007 (Earth Tech 2010). To determine intake rates for 2007, the 95th-percentile beta surface contamination results were calculated. The 95th-percentile value of the total beta contamination level was estimated to be 67,000 dpm/100 cm^2, based on the values for the south end of Building 24 in 2007. The uranium contamination level was assumed to be equal to the total beta contamination level based on equilibrium of ^{238}U, ^{234}Th, ^{234}Pa, and ^{234}U in normal uranium. Applying a resuspension factor of 1×10^{-6}/m results in an air concentration of 6.7 dpm/m^3

(3.0×10^{-12} µCi/mL). Assuming a 2,500-hour work year and a 1.2-m^3/hr inhalation rate results in an annual intake of 20,100 dpm (9,054 pCi), or 55 dpm/d (25 pCi/d).

The intake rates above were used to calculate a source term depletion rate based on guidance in ORAUT-OTIB-0070, *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT 2012). The source term depletion rate was calculated to be 1.62×10^{-4}/d.

Consideration of exposure to thorium dust could be included based on the relative fraction of thorium in the process material of 1%. This activity fraction was used to calculate the thorium intake rates in Table 5-1. Internal exposure from ingestion would be bounded based on guidance in OCAS-TIB-009, *Estimation of Ingestion Intakes* (NIOSH 2004). The contribution from recycled uranium contaminants can be bounded based on the uranium intake and using the nuclide ratios provided in Table 3-9.

Table 5-1. Annual internal exposure rates during the residual period.

Internal exposure rates (assign as a constant)										
	Uranium[a] (pCi/d)		Thorium[b] (pCi/d)		Np-237[c] (pCi/d)		Pu-239[c] (pCi/d)		Tc-99[c] (pCi/d)	
Year	Inh.	Ing.	Inh.	Ing.	Inh.	Ing.	Inh.	Ing.	Inh.	Ing.
1958	452	8.47	4.52	0.085	0.82	0.015	1.18	0.022	171.19	3.21
1959	426	7.98	4.26	0.080	0.77	0.015	1.11	0.021	161.35	3.03
1960	401	7.52	4.01	0.075	0.73	0.014	1.05	0.020	152.08	2.85
1961	378	7.09	3.78	0.071	0.69	0.013	0.99	0.019	143.34	2.69
1962	356	6.68	3.56	0.067	0.65	0.012	0.93	0.017	135.10	2.53
1963	336	6.30	3.36	0.063	0.61	0.011	0.88	0.016	127.34	2.39
1964	317	5.94	3.17	0.059	0.58	0.011	0.83	0.015	120.02	2.25
1965	298	5.60	2.98	0.056	0.54	0.010	0.78	0.015	113.12	2.12
1966	281	5.27	2.81	0.053	0.51	0.010	0.73	0.014	106.62	2.00
1967	265	4.97	2.65	0.050	0.48	0.009	0.69	0.013	100.50	1.88
1968	250	4.69	2.50	0.047	0.45	0.009	0.65	0.012	94.72	1.78
1969	236	4.42	2.36	0.044	0.43	0.008	0.61	0.012	89.28	1.67
1970	222	4.16	2.22	0.042	0.40	0.008	0.58	0.011	84.15	1.58
1971	209	3.92	2.09	0.039	0.38	0.007	0.55	0.010	79.31	1.49
1972	197	3.70	1.97	0.037	0.36	0.007	0.51	0.010	74.75	1.40
1973	186	3.49	1.86	0.035	0.34	0.006	0.49	0.009	70.46	1.32
1974	175	3.29	1.75	0.033	0.32	0.006	0.46	0.009	66.41	1.25
1975	165	3.10	1.65	0.031	0.30	0.006	0.43	0.008	62.59	1.17
1976	156	2.92	1.56	0.029	0.28	0.005	0.41	0.008	59.00	1.11
1977	147	2.75	1.47	0.028	0.27	0.005	0.38	0.007	55.61	1.04
1978	138	2.59	1.38	0.026	0.25	0.005	0.36	0.007	52.41	0.98
1979	130	2.44	1.30	0.024	0.24	0.004	0.34	0.006	49.40	0.93
1980	123	2.30	1.23	0.023	0.22	0.004	0.32	0.006	46.56	0.87
1981	116	2.17	1.16	0.022	0.21	0.004	0.30	0.006	43.88	0.82
1982	109	2.05	1.09	0.020	0.20	0.004	0.28	0.005	41.36	0.78
1983	103	1.93	1.03	0.019	0.19	0.004	0.27	0.005	38.99	0.73
1984	97	1.82	0.97	0.018	0.18	0.003	0.25	0.005	36.75	0.69
1985	91	1.71	0.91	0.017	0.17	0.003	0.24	0.004	34.63	0.65
1986	86	1.61	0.86	0.016	0.16	0.003	0.22	0.004	32.64	0.61
1987	81	1.52	0.81	0.015	0.15	0.003	0.21	0.004	30.77	0.58
1988	77	1.43	0.77	0.014	0.14	0.003	0.20	0.004	29.00	0.54
1989	72	1.35	0.72	0.014	0.13	0.002	0.19	0.004	27.33	0.51
1990	68	1.27	0.68	0.013	0.12	0.002	0.18	0.003	25.76	0.48
1991	64	1.20	0.64	0.012	0.12	0.002	0.17	0.003	24.28	0.46
1992	60	1.13	0.60	0.011	0.11	0.002	0.16	0.003	22.89	0.43
1993	57	1.07	0.57	0.011	0.10	0.002	0.15	0.003	21.57	0.40

Internal exposure rates (assign as a constant)										
	Uranium[a] (pCi/d)		Thorium[b] (pCi/d)		Np-237[c] (pCi/d)		Pu-239[c] (pCi/d)		Tc-99[c] (pCi/d)	
Year	Inh.	Ing.	Inh.	Ing.	Inh.	Ing.	Inh.	Ing.	Inh.	Ing.
1994	54	1.01	0.54	0.010	0.10	0.002	0.14	0.003	20.33	0.38
1995	51	0.95	0.51	0.009	0.09	0.002	0.13	0.002	19.16	0.36
1996	48	0.89	0.48	0.009	0.09	0.002	0.12	0.002	18.06	0.34
1997	45	0.84	0.45	0.008	0.08	0.002	0.12	0.002	17.02	0.32
1998	42	0.79	0.42	0.008	0.08	0.001	0.11	0.002	16.05	0.30
1999	40	0.75	0.40	0.007	0.07	0.001	0.10	0.002	15.12	0.28
2000	38	0.71	0.38	0.007	0.07	0.001	0.10	0.002	14.25	0.27
2001	35	0.66	0.35	0.007	0.06	0.001	0.09	0.002	13.44	0.25
2002	33	0.63	0.33	0.006	0.06	0.001	0.09	0.002	12.66	0.24
2003	31	0.59	0.31	0.006	0.06	0.001	0.08	0.002	11.94	0.22
2004	30	0.56	0.30	0.006	0.05	0.001	0.08	0.001	11.25	0.21
2005	28	0.52	0.28	0.005	0.05	0.001	0.07	0.001	10.60	0.20
2006	26	0.49	0.26	0.005	0.05	0.001	0.07	0.001	9.99	0.19
2007	25	0.47	0.25	0.005	0.05	0.001	0.06	0.001	9.42	0.18
2008	23	0.44	0.23	0.004	0.04	0.001	0.06	0.001	8.88	0.17
2009	22	0.41	0.22	0.004	0.04	0.001	0.06	0.001	8.37	0.16
2010	21	0.39	0.21	0.004	0.04	0.001	0.05	0.001	7.89	0.15
2011	20	0.37	0.20	0.004	0.04	0.001	0.05	0.001	7.43	0.14

a. Uranium intake should be assigned as 100% U-234. Solubility should be selected as type M or S, whichever is most favorable to the claimant.
b. An intake should be assigned at the indicated rate to each of the following: Th-232, Ra-228, Ac-228, Th-228, and Ra-224. Solubility should be selected to be favorable to the claimant, consistent with the guidance in ORAUT-OTIB-0060, *Internal Dose Reconstruction* (ORAUT 2014).
c. Solubility for recycled uranium components should be selected consistent with that chosen for the associated uranium intake, consistent with ORAUT-OTIB-0060 (ORAUT 2014).

Internal exposure from thoron was calculated using thorium material concentration (Earth Tech 2010). These data, listed in Table 5-2, provide 95% upper confidence level values (exposure point concentrations) for ^{232}Th and ^{228}Th in each of the described media. These concentration values were input to the RESRAD-Build computer program using site-specific input parameters in the 2010 Remedial Investigation Report (Earth Tech 2010, Table 6-7) to determine the corresponding thoron concentration and are summarized in Table 5-2.

Table 5-2. Thoron-232 and thoron air concentrations from remedial investigation.

Building	Th-232[a] (pCi/g)	Area (m^2)[a]	Height (m)[a]	Thoron[b] (WL)	Thoron[c] (WLM/year)
1	0.51	802	6	0.0022	0.032
2	1.65	5700	10.5	0.0037	0.054
3	1.16	4320	10	0.0039	0.057
4/9	1.16	4400	10	0.0039	0.057
5	0.34	348	5	0.0013	0.019
6	21.90	960	10	0.074	1.088
8	3.03	2700	10	0.01	0.147
24	16.44	7500	10	0.056	0.824
35	1.33	320	5	0.0051	0.075

a. Extracted from Earth Tech (2010).
b. WL = working level; calculated using the RESRAD-Build computer program.
c. WLM = working level month = WL × 2500/170

The bounding annual exposure rate of 1.088 working level month (WLM) per year based on the Building 6 contamination levels should be assigned for all workers as a constant distribution.

5.2 RESIDUAL EXTERNAL DOSE RATES

Dose rate measurements and characterization data from the residual period are available from surveys in 1957, 1976, 1980, 1984, 1999, and 2007 (Heatherton 1957; DOE 1979; FBDU 1981; Cottrell 1984; Vitkus 1999; Earth Tech 2010).

- 1957: Survey by NLO after clean-up and before contract termination. This survey included the areas where uranium was processed and stored but did not list specific number of measurements nor specify the completeness of the scans. Only selected spots that had the highest results were listed in the report. Highest 3-ft gamma dose rate was 0.080 mR/hr (Heatherton 1957).

- 1976: Extensive characterization survey by the Oak Ridge National Laboratory (ORNL) using grids and full scan of surfaces in contaminated areas. Highest 1-m gamma dose rate recorded was 0.048 mR/hr (DOE 1979).

- 1980: Engineering evaluation that cited ORNL survey data with a few additional measurements in the rolling mill area (FBDU 1981).

- 1984: Survey to verify conditions of plant after closure. One spot in the open area in the vicinity of the 10-in. mill furnace at had a 1-m dose rate of 0.120 mR/hr. In addition, a dose rate of 0.100 mR/hr was found in one location when the steel floor plates were removed (Cottrell 1984).

- 1999: 72 gamma measurements in excised area buildings. Highest dose rate at 1 m was 0.050 mR/hr in Building 8. 260 measurements taken in the exterior areas, both in and out of the excised area (Vitkus 1999).

- 2007: Gamma dose rate surveys were performed for the Remedial Investigation Report. The highest result in 2007 was 63 µR/hr in Building 2, which was from a hot spot. The second highest of the 428 measurements in Building 2 was 13 µR/hr. Building 2 was not one of the areas were AEC work occurred, although it was in use at the time and some contamination was found. The highest result in Building 3 was 21 µR/hr, the highest for Building 24 was 12 µR/hr, while the highest dose rate measured in the Buildings 6 and 8 rolling mill areas was 45 µR/hr. There were 29 measurements in Building 6/8 (Earth Tech 2010).

5.2.1 Penetrating Dose

Whole-body gamma dose rates from surveys from 1957 to the present were compiled. The dose rate measurements from outside the excised area were lower than the dose rates considered in this evaluation so the numerous survey data from those areas were not considered applicable to bounding dose from a maximally exposed mill worker. The dose rates this analysis used for the purpose of bounding dose to the maximally exposed worker were those in Buildings 3, 6, and 8, which were the locations of the rolling mills and forge shop.

The surveys from 1957 to 1999 are in general agreement, and there is no indication of any significant change in dose rates from 1957 to the present; the maximum 1-m gamma dose rate on the various surveys varied from 48 µR/hr to 120 µR/hr. Of the many measurements, only two reported results exceeded 80 µR/hr after the 1957 clean-up. These results reported in the 1984 survey: 120 µR/hr and 100 µR/hr measurements in an open area near the 10-in. furnace and an area next to the 16-in. rolling mill, respectively. Results indicate that these higher dose rates are spots from localized contamination in the dirt floor and not representative of dose rates for an area. The surveys in both 1979 and 1984 included characterization of hot spots in the floor.

Survey results from the rolling mill and forge area were compiled and analyzed to determine a distribution of dose rates likely to have been encountered in the work area. This resulted in 37 results at either 1 m or 3 ft from the various surveys. The dose rate data from 2007 from Buildings 6 and 8 was similar to the earlier data in the same areas, but not as detailed and was not included in the distribution. The range of results in Buildings 6 and 8 was 3 to 48 µR/hr and would be within the ranges of the measurements evaluated.

The number of measurements was reduced to 37 for the following reasons:

- Some building and area survey results from the 1976 and 1999 surveys listed the number of measurements but provided only the average and maximum results. For that situation the maximum dose rate was considered as a single measurement.

- Some of the survey reports (that were done to supplement earlier surveys) included previous survey results and new survey results; duplicate results were omitted.

- Measurements from outside of uranium process areas were not used (this eliminated many of the lower results).

The 37 measurements consisted of:

- 3 results documented from the 1957 survey, which were the areas with the highest gamma exposure;

- 23 measurements from a grid in the rolling mill area from the 1979 survey;

- 8 results from the 1984 survey, which were taken to supplement the 1979 measurements in the contaminated area; and

- 3 maximum building dose rates results from the 1999 survey (one each from Buildings 3, 6, and 8).

Some of the measurements were taken both with the steel floor plates in place and with them removed to characterize dose rates from the contaminated dirt floor.

The results were ranked and a lognormal distribution was fit to the data. The 95th percentile of the distribution is 75 µR/hr. Therefore, the 80-µR/hr dose rate from the 1957 survey provides a bounding dose rate. Although workers could have been exposed to isolated spots with higher dose rates, most of the work areas around the rolling mills and forge area measured less than 50 µR/hr.

The penetrating dose during the residual contamination period was calculated by assuming 2,500 hours of exposure per year at 80 µR/hr, resulting in an annual whole body photon dose of 0.200 R/yr. The value is considered bounding and should be applied as a constant in the Interactive RadioEpidemiological Program (IREP). Dose Reconstructors should use the guidance in Section 4.1.2, Exposure Energy and Geometry of OCAS-IG-001 (NIOSH 2007) for determination of the appropriate selection for DCF geometry.

5.2.2 Nonpenetrating Dose

The 1957 survey indicated the maximum 3-ft beta dose rate was from the 10-in. bar mill bed, which measured between 1 and 1.7 mrep/hr, with contact beta-gamma being between 10 and 20 mrep/hr.

The 1976 characterization survey recorded contact beta-gamma measurements on a 15-ft grid but no measurements at 3 ft; neither did subsequent surveys.

Nonpenetrating dose from electrons during the residual period were estimated based on exposure at the 10-in. bar mill. The midpoint of the 1.0 to 1.7 mrad/hr range of dose rates, 1.35 mrad/hr, was used to estimate dose for exposure for 2,500 hr/yr and resulted in an annual beta dose of 3.375 rem. The value is considered bounding and thus will be applied as a constant in IREP. Table 5-3 lists annual external exposure rates during the residual period.

Table 5-3. Annual external exposure rates during the residual period.

Annual external exposure rates					
Start	**End**	**Exposure**	**Energy**	**R/yr**	**IREP distribution**
01/01/1958	Present	Penetrating	100% 30–250 keV photon	0.200	Constant
01/01/1958	Present	Nonpenetrating	100% >15 keV electron	3.375	Constant

6.0 ATTRIBUTIONS AND ANNOTATIONS

All information requiring identification was addressed via references integrated into the reference section of this document.

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ATTACHMENT A
COWORKER BIOASSAY DATA BY SAMPLE DATE

Uranium urinalyses in mg/L.

		<0.01 mg/L insufficient for reliable detection							
11/01/1948	11/03/1948	11/04/1948	11/08/1948	11/11/1948	11/15/1948	Pre roll 01/06/1949	Pre roll 04/27/1949	HNO_3 treated pre 3rd roll 11/04/1949	Last day of roll 11/17/1949
0.01	0.01	0.01	0	0	0	0	0.007	0.004	0
0.01	0.01	0.01	0	0.01	0	0.001	0.008	0.007	0
0.01	0.01	0.01	0.01	0.01	0.01	0.002	0.010	0.007	0
0.01	0.01	0.02	0.01	0.01	0.01	0.008	0.011	0.007	0
0.01	0.02	0.02	0.01	0.01	0.01	0.009	0.017	0.011	0
0.02	0.02	0.02	0.01	0.02	0.02	0.009	0.019	0.013	0
0.02	0.02	0.02	0.01	0.02	0.02	0.010	0.019	0.013	0
0.03	0.03	0.02	0.01	0.02	0.02	0.013	0.023	0.013	0
0.03	0.03	0.04	0.02	0.04	0.04	0.013	0.023	0.014	0
0.04	0.04	0.07	0.02	0.05	0.04	0.015	0.024	0.015	0
0.04	0.04	0.07	0.03		0.05	0.018	0.029	0.016	0
0.14	0.09						0.036	0.021	0
								0.024	0
								0.027	0
								0.028	0
								0.272	0
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0.001
									0.001
									0.001
									0.002
									0.002
									0.003
									0.003
									0.003
									0.003

ATTACHMENT A
COWORKER BIOASSAY DATA BY SAMPLE DATE (continued)

11/01/1948	11/03/1948	<0.01 mg/L insufficient for reliable detection				Pre roll 01/06/1949	Pre roll 04/27/1949	HNO_3 treated pre 3rd roll 11/04/1949	Last day of roll 11/17/1949
		11/04/1948	11/08/1948	11/11/1948	11/15/1948				
									0.004
									0.004
									0.006
									0.006
									0.007
									0.010
									0.011
									0.011
									0.013
									0.014
									0.014
									0.015
									0.017
									0.029
									0.030
									0.036
									0.164

ATTACHMENT A
COWORKER BIOASSAY DATA BY SAMPLE DATE (continued)

Uranium urinalyses in mg/L.

Pre roll 01/06/1950	Post roll 01/19/1950	05/15/1950	Post roll 05/23/1950	Second shift less supervision		09/23/1950	09/25/1950	10/20/1950	10/25/1950
				Pre roll 08/14/1950	Post roll 08/28/1950				
0	0	0	0	0.015	0	0	0	0	0
0	0	0	0	0.016	0.009	0	0.004	0	0
0	0	0	0	0.017	0.012	0	0.005	0	0.002
0	0	0	0	0.017	0.015	0	0.005	0	0.002
0	0	0	0	0.018	0.015	0	0.009	0.002	0.002
0	0	0	0	0.018	0.016	0	0.009	0.002	0.002
0	0	0	0.002	0.022	0.016	0	0.009	0.002	0.002
0	0	0	0.003	0.022	0.016	0	0.009	0.004	0.004
0	0	0.001	0.003	0.024	0.016	0	0.011	0.004	0.006
0	0	0.002	0.003	0.028	0.017	0	0.013	0.004	0.006
0	0	0.003	0.006	0.028	0.017	0	0.013	0.008	0.008
0	0.001	0.005	0.013	0.028	0.017	0.002	0.014	0.012	0.010
0	0.002	0.007	0.014	0.031	0.017	0.004	0.014	0.012	0.010
0	0.002	0.007	0.014	0.033	0.019	0.005	0.015	0.022	0.010
0	0.003	0.008	0.016	0.033	0.019	0.005	0.015	0.024	0.010
0	0.006	0.008	0.016	0.035	0.019	0.005	0.016	0.027	0.017
0	0.007	0.012	0.016	0.035	0.025	0.014	0.018	0.028	0.017
0	0.008	0.014	0.016	0.037	0.033	0.014	0.023	0.044	0.019
0	0.012	0.015	0.017	0.046		0.018	0.024	0.067	0.043
0.001	0.013	0.015	0.017	0.102		0.020			
0.001	0.013	0.015	0.017						
0.001	0.014	0.015	0.017						
0.001	0.015	0.016	0.018						
0.001	0.015	0.016	0.019						
0.002	0.015	0.022	0.034						
0.002	0.015								
0.002	0.016								
0.003	0.016								
0.003	0.016								
0.003	0.016								
0.003	0.016								
0.003	0.016								
0.004	0.017								
0.006	0.018								
0.006	0.018								

ATTACHMENT A
COWORKER BIOASSAY DATA BY SAMPLE DATE (continued)

Pre roll 01/06/1950	Post roll 01/19/1950	05/15/1950	Post roll 05/23/1950	Second shift less supervision		09/23/1950	09/25/1950	10/20/1950	10/25/1950
				Pre roll 08/14/1950	Post roll 08/28/1950				
0.006	0.018								
0.006	0.019								
0.008	0.020								
0.009	0.020								
0.011	0.021								
0.012	0.022								
0.012	0.022								
0.012	0.027								
0.014	0.031								
0.014	0.031								
0.014	0.031								
0.017	0.033								
0.018	0.033								
0.023	0.035								
0.026									

ATTACHMENT A
COWORKER BIOASSAY DATA BY SAMPLE DATE (continued)

Uranium urinalyses in mg/L.

			Samples collected at 5 p.m.	
11/09/1950	11/16/1950	12/14/1950	Preroll 12/20/1952	Postroll 12/22/1952
0	0	0	0.001	0.001
0	0	0	0.002	0.003
0	0	0	0.002	0.003
0	0	0	0.002	0.004
0	0	0	0.004	0.004
0	0	0	0.006	0.004
0	0	0.002	0.006	0.005
0.002	0.002	0.002	0.007	0.005
0.002	0.002	0.002	0.010	0.006
0.004	0.002	0.002	0.010	0.006
0.004	0.002	0.004	0.011	0.006
0.004	0.002	0.004	0.011	0.008
0.006	0.004	0.004	0.011	0.008
0.006	0.004	0.004	0.012	0.008
0.006	0.004	0.004	0.012	0.008
0.006	0.004	0.005	0.012	0.010
0.015	0.004	0.006	0.013	0.010
0.015	0.006	0.006	0.013	0.010
0.030	0.006	0.006	0.013	0.010
	0.006	0.006	0.013	0.011
	0.006	0.007	0.013	0.012
	0.006	0.007	0.014	0.012
	0.009	0.007	0.015	0.013
	0.009	0.008	0.015	0.013
	0.009	0.008	0.016	0.014
	0.009	0.008	0.016	0.014
	0.009	0.009	0.016	0.015
	0.009	0.009	0.017	0.015
	0.009	0.010	0.017	0.015
	0.011	0.011	0.017	0.015
	0.013	0.011	0.017	0.016
	0.015	0.015	0.017	0.016
	0.015	0.015	0.018	0.017
	0.017	0.015	0.018	0.017
	0.017	0.015	0.018	0.017
	0.017	0.016	0.020	0.018
	0.017	0.017	0.021	0.018
	0.020	0.019	0.022	0.019
	0.022	0.024	0.023	0.020
	0.028	0.080	0.023	0.021
			0.023	0.022
			0.023	0.022
			0.024	0.022
			0.024	0.025
			0.024	0.025
			0.024	0.026
			0.027	0.026
			0.027	0.027

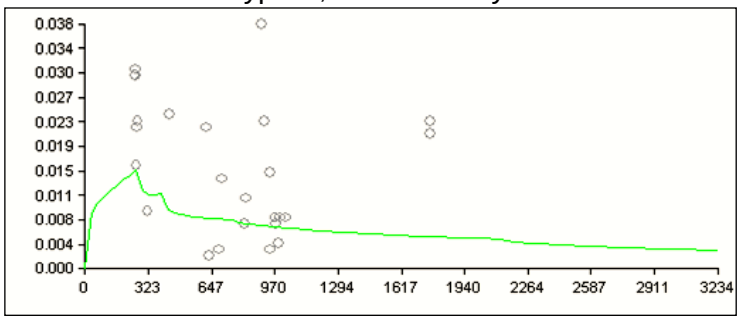
ATTACHMENT A
COWORKER BIOASSAY DATA BY SAMPLE DATE (continued)

			Samples collected at 5 p.m.	
11/09/1950	11/16/1950	12/14/1950	Preroll 12/20/1952	Postroll 12/22/1952
			0.028	0.029
			0.028	0.030
			0.029	0.030
			0.029	0.032
			0.033	0.033
			0.034	0.036
			0.037	0.036
			0.037	0.036
			0.041	0.041
			0.044	0.046
			0.048	0.048
			0.048	0.050
			0.056	0.053
			0.066	0.054

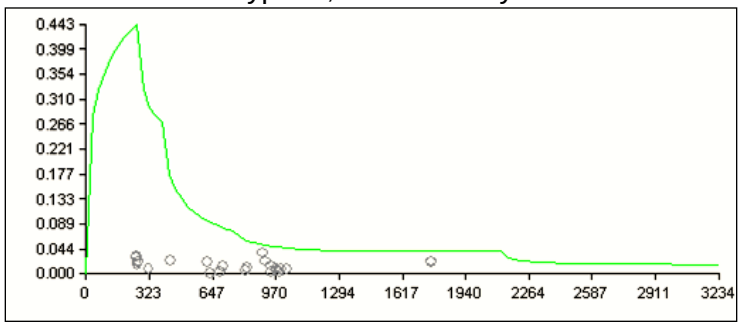
ATTACHMENT B
GRAPHS SHOWING PREDICTED BIOASSAY FROM AIR AND FITS OF COWORKER BIOASSAY

The graphs show predicted bioassay results from the estimated air intakes, superimposed on the GM, 84th-percentile, and maximum coworker bioassay results. Asterisks (*) identify reasonable fits. X-axis is days (0 = February 24, 1948). Y-axis is mg/day.

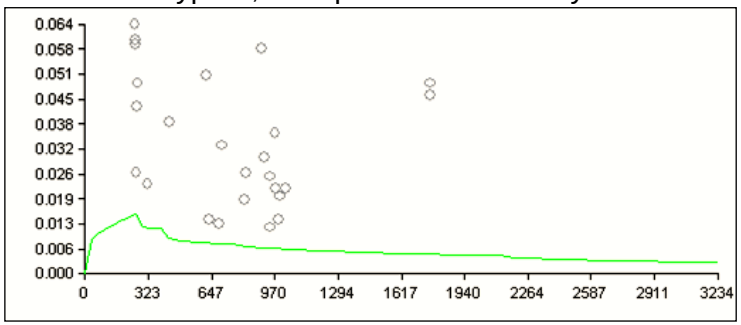
Type S, GM bioassay*



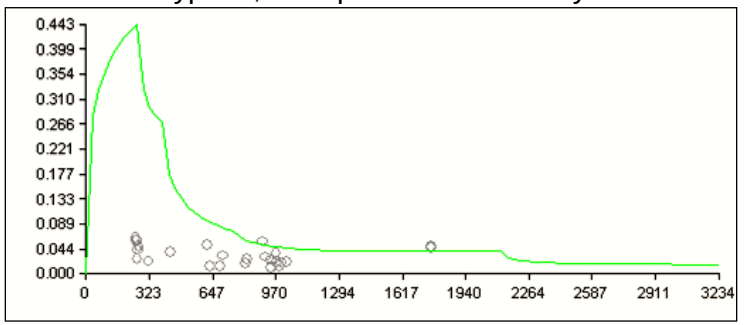
Type M, GM bioassay



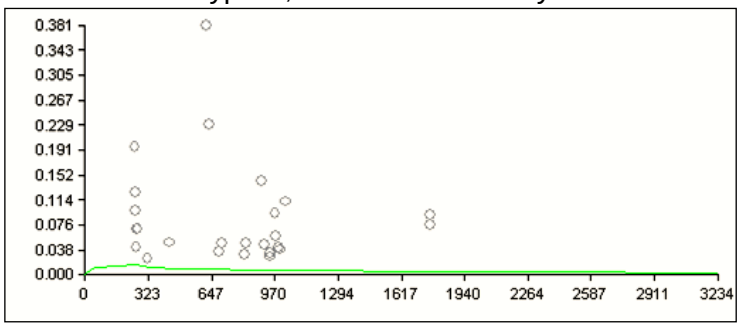
Type S, 84th-percentile bioassay



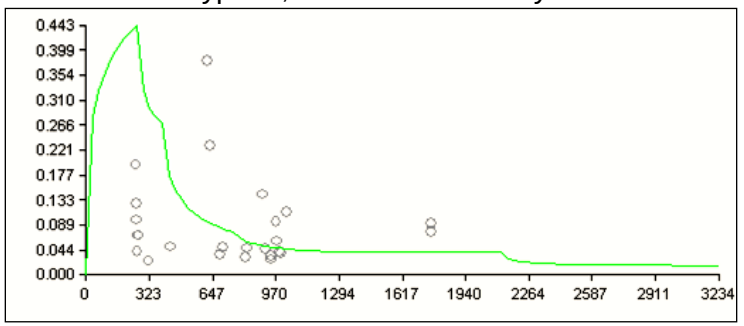
Type M, 84th-percentile bioassay



Type S, maximum bioassay



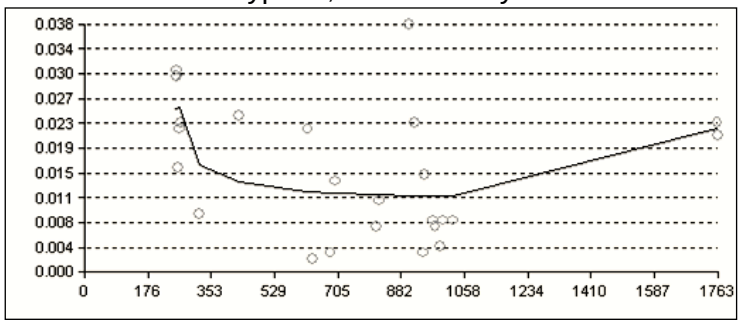
Type M, maximum bioassay*



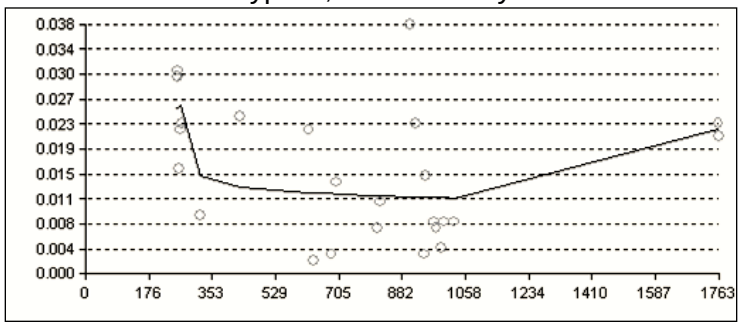
ATTACHMENT B
GRAPHS SHOWING PREDICTED BIOASSAY FROM AIR AND FITS OF COWORKER BIOASSAY (continued)

Graphs showing fits of coworker bioassay data to three inhalation intakes. X-axis is in days (0 = February 24, 1948). Y-axis uranium urinalyses results in mg/day.

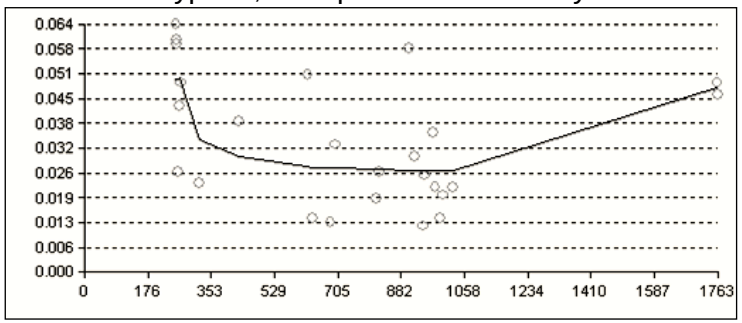
Type M, GM bioassay



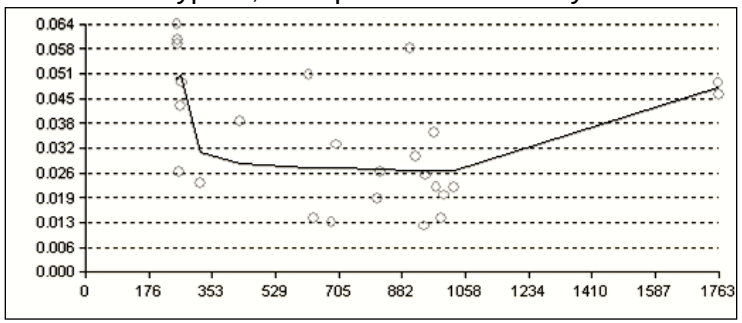
Type S, GM bioassay



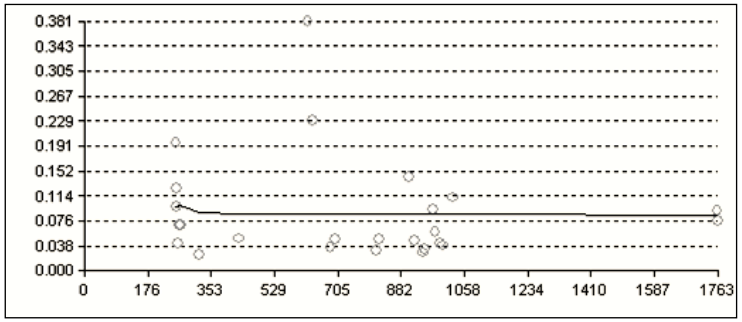
Type M, 84th-percentile bioassay



Type S, 84th-percentile bioassay



Type M, maximum bioassay



Type S, maximum bioassay