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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
11/15/2004	00-A	New Technical Basis Document: Basis for the Development of an Exposure Matrix for Simonds Saw and Steel, Lockport, New York. Initiated by Shelby L. Gubin.
01/09/2005	00-B	Incorporated OCAS and ORAU Team comments. The more significant changes are listed here. The residual exposure period was extended. Information was removed from Section 2.4.1 to improve readability. The bioassay detection threshold value was changed. EU assumption for later bioassay data was added. RU instructions were clarified. The similarity between the film badge results and the workplace exposure assumptions was noted. Additional contamination information was added in Section 4.3. The wording regarding exposure time was corrected in Section 4.3. Referral to ORAUT-OTIB-0006 is made regarding medical X-ray exposure assumptions. Initiated by Shelby L. Gubin and Robert Vogel.
04/27/2005	00-C	Minor editorial revisions, references corrected, added assumption of type M, as well as type S plutonium. A new section was added on coworker uranium bioassay analysis, and estimated uranium intakes for coworkers are now based on the uranium urinalyses. A small section comparing air concentration and bioassay derived intake rates was added. Initiated by Cindy W. Bloom.
05/10/2005	00-D	Modified uncertainty approach based on informal OCAS comment. Added bias for coworker data, and adjusted uranium and recycled uranium intake numbers in Table 15. Clarified intake apportioning and basis for GSD in thorium section. Initiated by Cindy W. Bloom.
05/31/2005	00	First approved issue. No training required. Initiated by Cindy W. Bloom.
06/06/2005	00 PC-1-A	Page change to correct error in Pu-239 and Np-239 end dates on Table 15, page 27. 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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
cm	centimeter
dpm	disintegrations per minute (also d/m)
ft	foot
FUSRAP	Formerly Utilized Sites Remedial Action Program
GM	geometric mean
GSD	geometric standard deviation
hr	hour
Ha	hectare
ICRP	International Commission on Radiological Protection
in.	inch
keV	kilovolt-electron, 1,000 electron volts
L	liter
m	meter
MAC	maximum allowable concentration
MCNP	Monte Carlo *n*-particle
mg	milligram
min	minute
mrad	millirad
mR	milliroentgen
mrem	millirem
mrep	millirep
NIOSH	National Institute for Occupational Safety and Health
NLO	National Lead of Ohio
NYOO	New York Operations Office
PA	posterior–anterior
pCi	picocuries
R	roentgen
s	second
U.S.C.	United States Code
yr	year
µg	microgram
µm	micrometer

1.0 INTRODUCTION

Technical Basis Documents and Site Profile Documents are general working documents that provide guidance concerning 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 the National Institute for Occupational Safety and Health (NIOSH) 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 facility" or a "Department of Energy facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [42 U.S.C. Sections 7384l(5) and (12)].

This document provides an exposure matrix for workers at the facility listed as Simonds Saw and Steel Company (Simonds) 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. The facility is now owned by Allegheny Ludlum Corporation.

2.0 SITE DESCRIPTION AND OPERATIONAL HISTORY

The information that follows applies to a period of AEC operations at Simonds Saw and Steel from February 24, 1948, to December 31, 1956, involving AEC-contracted uranium and thorium work. This analysis assumed that the residual contamination period was from January 1, 1957, through the present, although the buildings were closed and the contaminated areas were isolated as of May 1, 1983.

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.

Simonds performed an experimental rolling for AEC on February 24, 1948, before entering into a contractual agreement with the U.S. Atomic Energy Commission (AEC). The first contract, AT-30-1 Gen-339, negotiated with the AEC New York Operations Office (NYOO) was initiated in May of 1948, and was renewed annually through February 1952. AT-30-1-Gen-339 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 of Ohio (NLO) in Fernald, Ohio, contract AT (30-1)-1156 with NYOO (Author unknown, no date a).

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 it 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 (Ford Bacon & Davis Inc. 1981).

Vitkus (1999) described the former Simonds site as a 28-hectare (one hectare equals 2.47 acres) area bordered by Ohio Street to the east, residential and commercial properties to the north, U.S. Route 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 constructed after the termination of AEC activities
- The 3.5-hectare landfill area in the northwest corner of the site
- The 3.6-hectare excised property, which includes nine buildings that existed during the AEC activities in the southeast corner of the site" (Vitkus 1999).

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

Table 1. Simonds buildings where contamination has been found.

Building number	Building letter	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

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 report on rolling procedure in 1951 the billets were initially either 5-1/8-in. in diameter and 15 to 20 in. long or 4-1/4-in. in diameter and 20 to 22 in. long (Smith 1951). The rolling reduced them to rods of 7/8-in. diameter each weighing approximately 200 lb. Thus, 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 min. The heated ingots or 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, where they were placed in tared H-beams, weighed, and loaded into railcars from the

shipping dock (DOE 1979; Keller 1979). AEC noted that trucks instead of railcars were being used as of August 1950, which eliminated daily handling and shoring of the load by shippers (AEC 1950a). The process generated a considerable amount of waste as evidenced from a 1952 Tonawanda Progress Report (AEC 1952): "Approximately fifty drums of [uranium-contaminated] scrap and oxide were received from Simonds at the completion of the January rolling."

The majority of the AEC work involved the straightforward task of rolling uranium, but occasionally tests were run to see 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 1951), which was deemed unsuccessful due to increased product problems and increased air concentrations, which could have been a result of the missing Plexiglas shields rather than the copper cladding.

Information on the Simonds uranium forging is limited, but records indicate that "some 15 of [or?] 20 ingots were processed in the hammer forge shop" (Keller 1979). AEC (1950b) concluded that forging was a very dusty operation and recommended not using the process based on health considerations.

In 1952, Fernald 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 Fernald. "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). Simonds did not process uranium and thorium after 1956.

2.3 SOURCE TERM

On February 24, 1948, two 13-in. and one 29-in. billets were rolled to see if additional rolling at Simonds would be desirable (Taussig 1948). In total, 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 in 1956 (Vitkus 1999). "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, up to 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 (8)], and approximately 15 to 20 ingots were processed in the hammer forge shop in Building B (3). Figures 1, 2, and 3 show the layouts.

The 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 takes up one shift (NLO 1953), so there were about 156 days per year, 2 shifts each day, 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 only available for those periods included in the reports of AEC visits. Based on the number of turnings reported by 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.

For fiscal year 1950 (beginning October 1949), Simonds agreed to meet all the AEC rolling requirements, as high as 170 tons per month, so AEC consolidated 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. This will

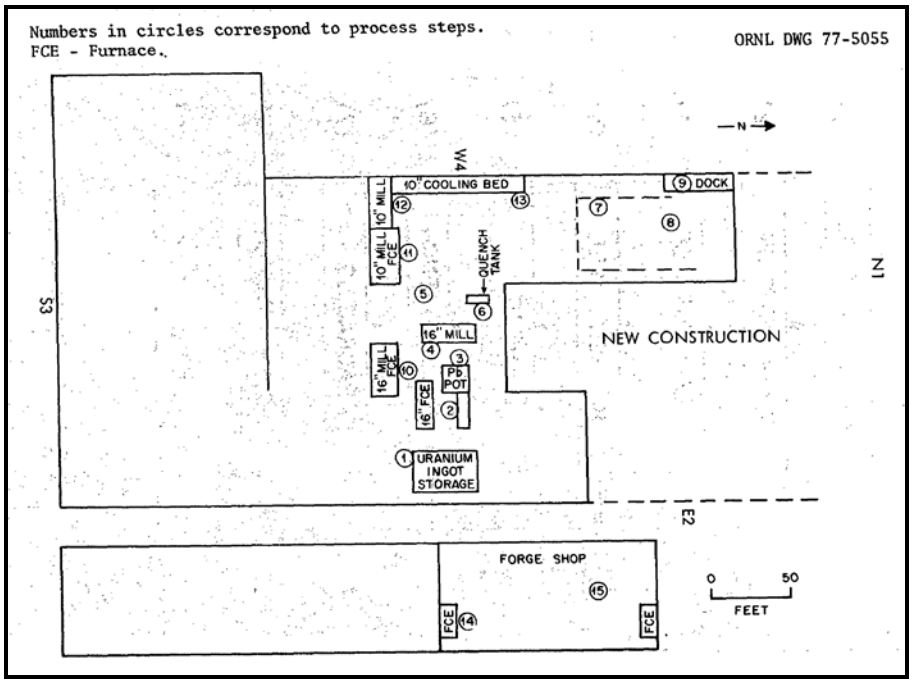

Figure 1. Simonds rolling mills and hammer forge areas (ORNL 1979).

allow the October uranium rolling to take place as scheduled" (AEC 1949b). Simonds also planned to roll 160 tons of uranium in November because they 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).

In relation to thorium, Huke (1951) reported:

> *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 … Most of the material received consisted of 3-in. diameter round billets in the range of 15-in. long.*

Tonawanda Area reported 36 thorium billets were shipped to Simonds for rolling on November 19, 1951 (AEC 1951a), 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 the months of May, September, and November 1952 (AEC 1953a). 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). These rollings account for more than half of the reported 30,000 to 40,000 lb that were processed.

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 intimately exposed to uranium. Air-sampling data indicated that there were 13 to 28 rolling-mill workers considered in the airborne uranium exposure studies on any one shift. Simonds worked two shifts and, because only a few workers worked the first shift, the maximum number of workers included 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).

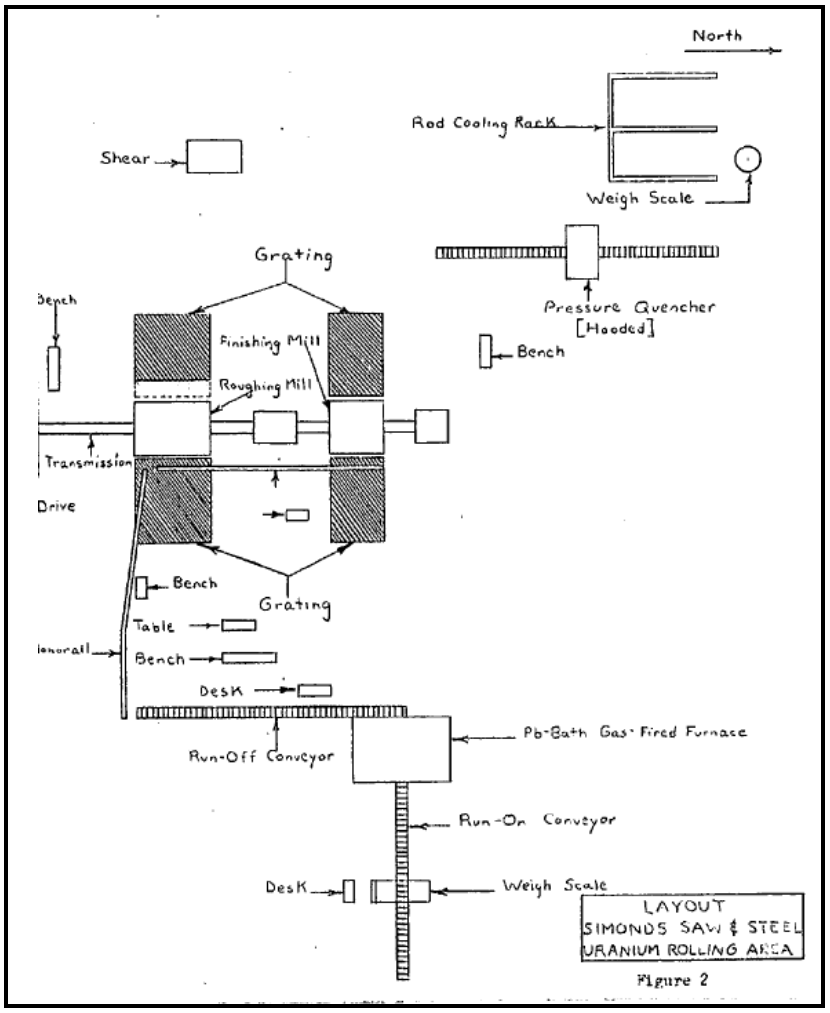

Figure 2. Simonds 16-in. rolling-mill area, Building 6 (AEC 1953b).

Table 2 lists the job categories included in the AEC and NLO 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-in. and the 10-in. bar mill. No specific worker data were found in relation to the limited forging of uranium.

Table 2. Some job titles involved in uranium rolling.

Foreman	Roller #2 (finisher)
Assistant Foreman	Shear Man
Drag Down Man	Straightener
Hook Man	Run-out
Billet loader	Stranner
Weighin (Weighup)	Dippers
Poke-in	(Pressure) Quencher
Furnace Man (heater)	Rod Stamper
Heater Helper	Weighers (Rod)
Roller #1 (rougher)	Shippers

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.

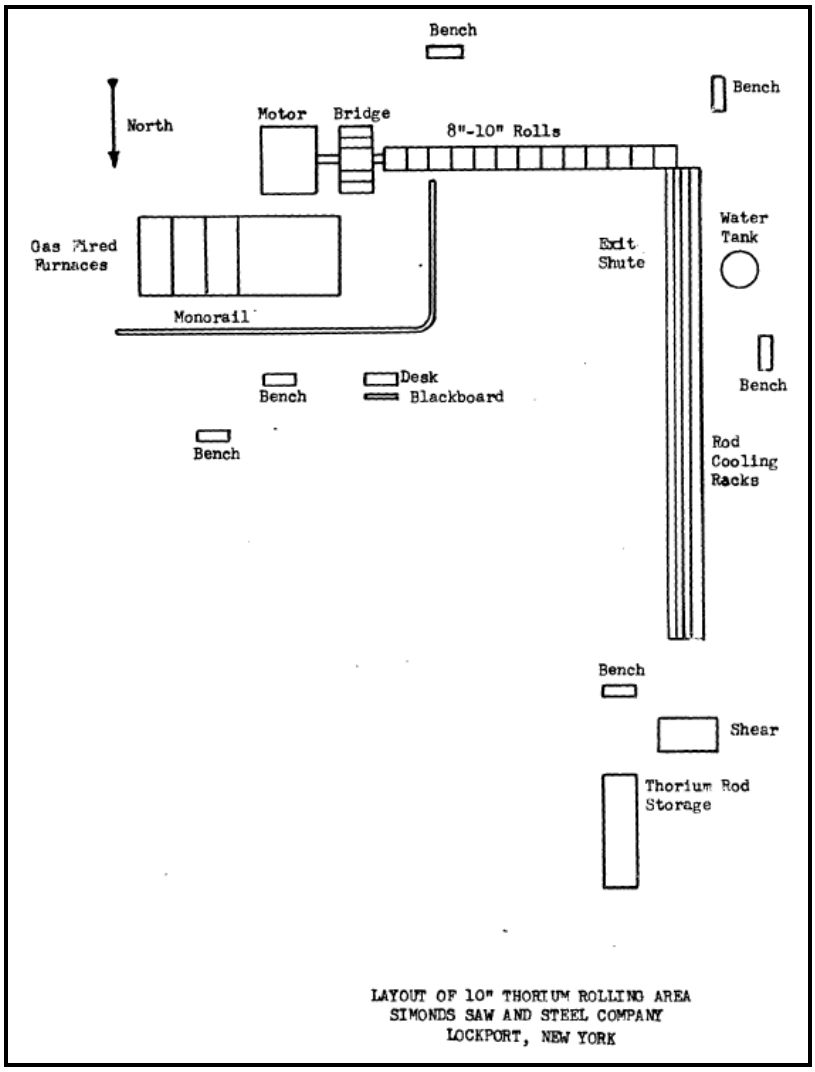

Figure 3. Simonds 10-in. thorium-rolling area, Building 8 (AEC 1953c).

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

2.4 SAFETY

Early in the contract, the AEC (Belmore 1948a) 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 (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. Medical examinations of the workers were required.

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, d, 1949d,e, 1950a,b,c, 1951b,c). 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, the "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 min 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 reportedly 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 brushing of uranium from the furnace and reduce exposures. December 1949 was dedicated to thoroughly clean areas most likely to be contaminated. Airborne radioactivity was expected to be at its lowest level yet during the January rolling (AEC 1949a, 1950c), which involved a trial run of 10 tons of uranium (AEC 1949f, 1950c) 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 1950c).

AEC reports document the effectiveness of recommended contamination controls, but noted inconsistency in their implementation. AEC and NLO constantly reminded Simonds to use the vacuum cleaner instead of broom sweeping the uranium dust areas. Use of the Plexiglas shields, floor grating, and ventilation system dust collectors appeared to be intermittent.

In late 1953 Heatherton (1953a) stated that to decontaminate Simonds, the ventilation over the bar mill would be removed rather than leave it for future rollings. He pointed out that cleaning up from a

single thorium rolling would result in less overall costs than maintaining the ventilation and that the workers would be provided with respirators.

The wearing of dedicated anticontamination clothing at Simonds appeared 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.

NLO's 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 instead of 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 their 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, d, 1949d,e, 1950a,b,c, 1951b,c).

In response to the January 1950 survey results, AEC (1950c) 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.*

AEC (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 dip-quenched instead of 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 1951d). AEC also reported that the Simonds Plexiglas shields were not in place due to an oversight.

NLO (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 on the rolling of 36 tons of depleted uranium billets. Air samples 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 were 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 related to the commercial thorium work process arranged by Babcock Wilcox. These results appear generally 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 (Heatherton 1948).

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 was an area on the floor near the furnace that measured

15 mR/hr beta/gamma, 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.

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

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

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

- 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

Physical examinations for all personnel were to include an annual X-ray, urinalysis (medical, not radioactive), and blood analysis (Belmore 1948a). Tabershaw (1948) stated that the physical examinations were done at the Bewly Building in Lockport, New York, and that X-ray and laboratory examinations were done at the local hospital. As of December 7, 1948, about 100 workers had been examined. Tabershaw (1948) noted, “The entire group of 150 workers will have been examined.” Tabershaw recommended that NYOO send a letter requesting annual X-ray examinations at Simonds, and on December 29, 1948, Morgan (1948) sent a letter requesting a preplacement physical examination of all employees including X-ray of chest, complete blood count, medical urinalysis, and history of radiation exposures (especially information on diagnostic radiographic examinations and X-ray or radium therapy). Morgan further noted that X-rays of the chest should be repeated yearly and that additional examinations (X-ray or physical) should be based on specific "symptomatology." Termination examinations were essentially repeats of the preplacement examinations. Morgan (1949) responded to Simonds on January 13, 1949, that the mention of a pelvis X-ray requirement was in error. Morgan stated further that although “no previous X-rays were included in the pre-placement examination, it would be well to have them included at termination.” Employee medical records from March 1948 indicate that X-ray examinations were included, so perhaps Morgan meant that the X-ray films were not available at Simonds. Tabershaw (1949) noted that 180 people at Simonds were examined under the clinical program for workers exposed to uranium, and 57 people were intimately exposed. Follow-up examinations were to be “essentially” limited to the 57 workers. In addition, Tabershaw (1949) stated, “The X-ray films would be kept in the plant in a fire proof cabinet.”

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

Section 2.3 of this analysis assumed there were 156 days of uranium rolling per calendar year before 1954. Beginning January 1, 1954 and running through December 31, 1956, the number of uranium workdays fell to 31 per year (20% of the earlier value). Table 3 shows the number of uranium rolling days and the number of non-rolling days for each work period. It was assumed that there were six thorium-rolling days per calendar year from January 1, 1951, to December 31, 1956. It was assumed that there were two work shifts for 10 hours each. It was assumed that operations in 1953 continued at the same level as 1952, although the available records indicate significant curtailment at the end of 1953.

Table 3. Number of assumed workdays and uranium-rolling days.

Start	End	Rolling workdays	Non-rolling workdays	Workdays
2/24/1948	12/1/1948	130	72	202
12/1/1948	4/5/1949	52	38	90
4/5/1949	4/13/1950	156	112	268
4/13/1950	1/1/1954	585	387	972
1/1/1954	1/1/1957	94	689	783

Mill workers whose duties involved or put them near the 10-in. and 16-in. bar rollers were likely to have the largest internal and external radiation exposures. Workers 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 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. This analysis did not divide Simonds' workers into exposure categories.

While different tasks in the mill resulted in differences in exposures, it is evident from the records that the mill workers did not always perform the same tasks. Workgroup exposure assignments are based on data that are suggestive of worker exposures and further modified by uncertainty parameters to ensure that the reconstructed dose distributions capture the larger exposures. Depending on the organ of interest and the supplemental data associated with a specific claim, additional considerations might be appropriate.

2.8 CLEANUP AND THE RESIDUAL CONTAMINATION PERIOD

In November of 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. The uranium and thorium operations at Simonds ceased by December 31, 1956, but there were no closeout surveys until 1957 and 1958.

The Formerly Utilized Sites Remedial Action Program (FUSRAP) began in 1976, and Simonds was revisited to determine if there was residual activity. ORNL (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 (3).

A radiological survey in October 1976 identified contamination (primarily ^{238}U) in and around onsite 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 of the uranium activity or just part, depending on actual analysis techniques and reporting procedures.]

Guterl Specialty Steel, who had bought Simonds, filed for bankruptcy in 1982 and closed its doors on May 1, 1983. Allegheny Ludlum purchased the site in 1984. The buildings 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 being done there. Buildings 1, 2, 3, 4, 5, 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 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/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.

3.0 ESTIMATION OF INTERNAL EXPOSURE

The primary sources of internal radiation exposure at Simonds Saw and Steel 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.

AEC measured particle sizes using a "modified cascade impactor" at Simonds on January 12 (Spiegl et al. no date; probably 1949 or 1950, the year was unspecified). 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 1994a), 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 7000 days, respectively). Other *in vitro* dissolution studies of compounds found 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 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 d and 75% dissolving with a half-time of 180 d. Because there was no specific information on the solubility of aerosols produced 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 (1950c, Table 4, footnote) notes that the 0.272 mg/L value from November 4, 1949, was obviously contaminated, 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 exposures assumptions are used to fit the multiple intakes at Simonds.

The uranium fusion photofluorimetry urinalyses performed by the University of Rochester and the AEC NYOO were similar to those performed 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 1958). Several early Simonds bioassay reports noted that the results of less than 0.01 mg/L were insufficient for reliable detection (Author unknown 1948). A set of bioassay results, dated November 4, 1949, includes the note "Urines had to be treated with concentrated HNO_3" (AEC 1949i). No reason was given. AEC (1950a) thought the uranium urinalyses for August 14 and 28 were higher than usual possibly because they were associated with workers from the second shift, which reportedly had less supervision (analysis errors, sample contamination and high internal exposures several hours before pre-roll sample collections were also listed as possibilities for the elevated urinalyses). AEC noted that some results were collected pre rolling and some were collected post rolling. About half of the geometric means for urinalyses that appear to be pre rolling are higher than the geometric means for post rolling urinalyses. Information regarding the time that had elapsed post rolling and prior to a pre rolling sample collection was not available. In addition, some post rolling samples might have been collected at the rolling day's end, i.e., at the very end of rolling, not after rolling.

For unmonitored workers or unmonitored periods, this Site Profile analyzes the bioassay results to provide estimates of coworkers' uranium intakes.

The first available bioassay samples for Simonds were dated November 1, 1948: urinalyses are 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 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 person's result was listed as 0; 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 used in the coworker exposure analysis are summarized in Appendix A. For each bioassay date, geometric means were estimated by ranking the data, determining the z-scores, and plotting the respective z-score versus the natural log of the data. A line was fit to the data, and e raised to the line's y-intercept value was assumed to be the geometric mean and e raised to the slope value was assumed to be the geometric standard deviation (GSD) of the data. Results reported as zero were ranked, but used only indirectly in the fitting of the line. The 84th percentile was estimated as the geometric mean multiplied by the GSD. Prior to 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 mg/L by reference man's daily urine output (1.4 L/day) (ICRP 1975). Appendix A shows the bioassay results used in the intake analyses. Table 4 shows a summary of the estimated geometric median, 84th percentile, and maximum uranium urinalyses used to derive intakes 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, 1956. Graphs showing the fits of these intake regimes are shown in Appendix 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.

Table 4. Bioassay results from coworker data.[a]

Bioassay date	Geometric mean bioassay (mg/L)	84th percentile bioassay (mg/L)	Maximum[b] bioassay (mg/L)
11/1/1948	**0.021**	0.045	0.140
11/3/1948	**0.022**	0.042	0.090
11/4/1948	**0.022**	0.043	0.070
11/8/1948	**0.011**	0.018	0.030
11/11/1948	**0.016**	0.031	0.050
11/15/1948	**0.016**	0.035	0.050
1/6/1949	**0.006**	0.016	0.018
4/27/1949	**0.017**	0.028	0.036
11/4/1949	**0.016**	0.036	0.272
11/17/1949	**0.001**	0.010	0.164
1/6/1950	**0.002**	0.009	0.026
1/19/1950	**0.010**	0.024	0.035
5/15/1950	**0.005**	0.014	0.022
5/23/1950	**0.008**	0.019	0.034
8/14/1950	**0.027**	0.041	0.102
8/28/1950	**0.016**	0.022	0.033
9/23/1950	**0.002**	0.009	0.020
9/25/1950	**0.011**	0.018	0.024
10/20/1950	**0.006**	0.026	0.067
10/25/1950	**0.005**	0.016	0.043
11/9/1950	**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/day to obtain results in mg/day for use in IMBA.
b. No one worker had maximum bioassay results.

The intakes were calculated with IMBA Expert™ OCAS-Edition, Version 3.2.20, assuming an absolute uniform error of 1 and normal error distributions for each bioassay result. The geometric standard deviations (GSDs) for the intakes were calculated by dividing the intake from the 84th percentile regime by the intake from geometric mean intake regime. Table 5 shows the inhalation intake distributions from the analyses of the Simonds uranium urinalysis data, assuming that either a type M or a type S (but not both) intake occurred. Intake rates are adjusted from mg/day to pCi/day by multiplying by 682.91 pCi/mg.

Table 5. Inhalation intakes based on coworker data.

Start	End	Type	Intake rate (mg/day)	GSD (Type M)	Type	Intake rate (mg/day)	GSD (Type S)
2/24/1948	**12/1/1948**	M	0.422	1.98	S	12.6	1.99
12/1/1948	**12/15/1950**	M	0.173	2.25	S	1.76	2.58
12/15/1950	**12/31/1956**	M	0.329	2.16	S	5.32	2.15

The maximum GSD is rounded up to 3 and is used for all the intake regimes. In addition, a factor is applied to the intake values, to account for possible biases in data measurements and applicability of assumed intake regimes to coworkers; for example, an unmonitored worker might be better represented by the larger bioassay results. Because the analyses are being used in a compensation program, only a positive bias factor is applied. For Simonds, a bias factor of 2 is assumed for the coworker intakes. The effect of the chosen bias factor is to move the calculated fit lines for the geometric means up by a factor of 2, which results in most of the bioassay data being less than the adjusted fit line.

3.1.2 Uranium Air Sampling

Air sampling was performed at Simonds during some of the uranium rolling campaigns (AEC 1948c,d, 1949d,e, 1950a,b,c, 1951b,c, 1953b; NLO 1953). The air samples consisted of collection on filters of radioactive particulate 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 alpha activity measured 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 workers' 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.

The AEC used the information on work tasks with the measured air concentration 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 group geometric means. The daily time-weighted average air concentrations were weighted further by the AEC-reported number of workers exposed at a given concentration. The geometric means of the workgroups' daily time-weighted average air concentrations were calculated and used to derive the intake rates. The GSDs of both 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 people 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 could represent the time-weighted exposures and the subsequently derived annual organ doses.

Table 6 lists the geometric means and GSDs for the job category 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 6. Daily time-weighted average air concentrations.

	Air sample collection dates				
	10/27/1948	**12/1/1948**	**1/10/1949**	**4/5/1949**	**5/2/1949**
Number of categories	9	9	9	9	10
Geometric means (dpm/m^3)	1,977	860	523	263	226
GSDs	3.0	1.9	2.9	1.8	1.8
Number of workers	32	30	28	30	40
Geometric means (dpm/m^3)	1,842	853	455	266	256
GSDs	3.0	1.9	3.2	1.8	1.9
Estimated air concentration (dpm/m^3)	**2,000**	**1,000**	**1,000**	**250**	**250**
	1/9/1950	**1/10/1950**	**4/13, 4/14, or 4/18, 1950**	**5/17, 5/18, or 5/22, 1950**	**8/14-16/1950**
Number of categories	10	10	13	13	11
Geometric means (dpm/m^3)	190	180	90	75	96
GSDs	1.8	1.9	1.9	2.7	1.5
Number of workers	40	40	45	45	38
Geometric means (dpm/m^3)	205	199	88	82	89
GSDs	1.9	1.9	1.9	2.7	1.5
Estimated air concentration (dpm/m^3)	**250**	**250**	**150**	**150**	**150**
	1/9-10/1951	**8/20-21/1951**	**1/1-31/1952**	**9/12/1952**	**1/4-21/1953**
Number of categories	10	13	13	13	11
Geometric means (dpm/m^3)	161	97	96	129	141
GSDs	2.8	1.4	1.5	1.6	2.4
Number of workers	38	42	42	43	34
Geometric means (dpm/m^3)	161	100	94	125	138
GSDs	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 measured at the plant during rolling operations both 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 general 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 4 shows the geometric means, 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 6 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 shown in Figure 4.

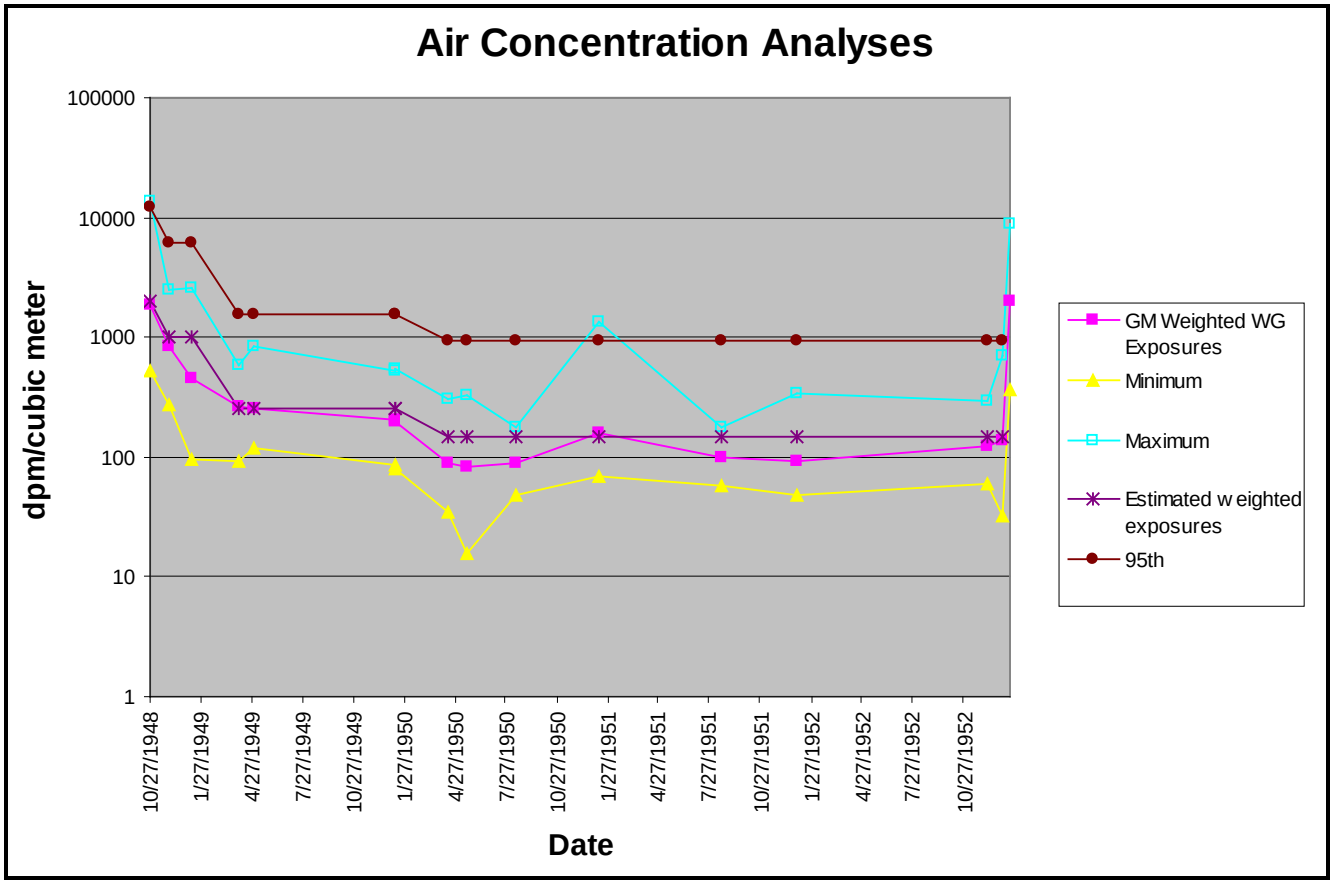

Figure 4. Workgroups' daily time-weighted average uranium air concentrations and estimated weighted exposures.

This analysis of intakes based on air concentrations assumed that uranium rolling took place between February 24, 1948, and December 31, 1956. Rolling was assumed to occur for 13 days of every month from February 24, 1948, to December 31, 1953, based on 312 turnings/yr and double shifts. The time assumption for the later period—January 1, 1954, to December 31, 1956—was reduced to 20%.

The breathing rate is based on the default for light work shown in ICRP Publication 66 (ICRP 1994a, Table 6, p. 23). Intakes in picocuries were calculated by dividing the estimated air concentration by 2.22 dpm/pCi and multiplying this result by the breathing rate and the assumed number of hours exposed at the given concentration. Several assumptions included in the dose reconstruction are likely to be overestimating assumptions, which increase the estimate of the median intakes from air concentrations. Table 7 lists estimated annual inhalation intakes during rolling based on air concentrations.

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.

Table 7. Inhalation exposures during rolling operations.

Work period		Number of potential AEC workdays	Air concentration (pCi/m^3)	Breathing rate (m^3/hr)	Hr/workday	Intake (pCi)
2/24/1948	12/1/1948	130	9.01E+02	1.2	10	1.41E+06
12/1/1948	4/5/1949	52	4.50E+02	1.2	10	2.81E+05
4/5/1949	4/13/1950	156	1.13E+02	1.2	10	2.11E+05
4/13/1950	1/1/1954	585	6.76E+01	1.2	10	4.74E+05
1/1/1954	12/31/1956	94	6.76E+01	1.2	10	7.62E+04
Total						**2.45E+06**

The level of contamination was determined by multiplying the air concentrations listed in Table 7 by the indoor deposition velocity and the assumed deposition time, which for uranium was 20 hr per rolling day. The indoor deposition velocity is dependent on the physical properties of the room (air viscosity and density, turbulence, thermal gradients, surface geometry, etc.). It is also dependent on the physical properties of the aerosol particles (such as 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 1994a). 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 2002a).

The calculated surface contamination level created from airborne dusts during the uranium rolling from February 24, 1948, to December 31, 1956, was 1.10×10^{7} pCi/m^2 (240,000 dpm/100 cm^2). The assumption was made that all of the surface contamination was present for the entire period of AEC operations. Therefore, using a resuspension factor of 1×10^{-6}/m (NRC 2002b), the air concentration due to resuspension would have been 11.0 pCi/m^3. Table 8 lists the assumed annual inhalation intake received from resuspension of deposited material. (Table 10 shows the intakes in Table 8 added to the intakes in Table 7.)

Table 8. Annual inhalation exposures 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)
2/24/1948	12/1/1948	10	72	1.2	11.0	9.52E+03
12/1/1948	4/5/1949	10	38	1.2	11.0	5.02E+03
4/5/1949	4/13/1950	10	112	1.2	11.0	1.48E+04
4/13/1950	1/1/1954	10	387	1.2	11.0	5.12E+04
1/1/1954	12/31/1956	10	689	1.2	11.0	9.11E+04
Total						**1.72E+05**

When using air concentrations to calculate inhalation intakes, the dose reconstructor should also consider ingestion intakes. 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-hr workday. For a 10-hr workday, the multiplier would be 0.223. The daily ingestion rates during AEC uranium work are estimates based on the air concentrations in Table 7. The daily ingestion intakes from resuspended uranium are estimates from Table 8. The ingestion intakes are then the sum of the products of the ingestion intake rates and the number of workdays exposed at the calculated levels. The ingestion intakes in Table 9 apply to all workers.

A summary of estimated uranium intake rates based on air concentrations is shown in Table 10.

Table 9. Estimated amount of uranium ingested (pCi) (based on Tables 7 and 8).

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)
2/24/1948	12/1/1948	130	2.01E+02	72	2.46E+00	2.63E+04
12/1/1948	4/5/1949	52	1.01E+02	38	2.46E+00	5.32E+03
4/5/1949	4/13/1950	156	2.51E+01	112	2.46E+00	4.20E+03
4/13/1950	1/1/1954	585	1.51E+01	387	2.46E+00	9.77E+03
1/1/1954	12/31/1956	94	1.51E+01	689	2.46E+00	3.11E+03
Total						**4.87E+04**

Table 10. Estimated uranium intake rates based on time weighted air concentrations.

Start	End	Intake route	Absorption type	Intake (pCi/d)
2/24/1948	12/1/1948	Inhalation	M, S	5.04E+03
2/24/1948	12/1/1948	Ingestion	(a)	9.36E+01
12/1/1948	4/5/1949	Inhalation	M, S	2.29E+03
12/1/1948	4/5/1949	Ingestion	(a)	4.26E+01
4/5/1949	4/13/1950	Inhalation	M, S	6.05E+02
4/5/1949	4/13/1950	Ingestion	(a)	1.12E+01
4/13/1950	1/1/1954	Inhalation	M,S	3.87E+02
4/13/1950	1/1/1954	Ingestion	(a)	7.19E+00
1/1/1954	12/31/1956	Inhalation	M, S	1.53E+02
1/1/1954	12/31/1956	Ingestion	(a)	2.84E+00

3.1.3 Comparison of Uranium Bioassay and Air Concentration Estimates

Summary estimates of uranium intakes (unadjusted for bias) shown in Section 3.3 are based on Simonds' workers' bioassay data. The estimates of intakes from air concentrations, which started high, decreased over time, and then leveled out tend to confirm the time pattern of intake from bioassay. The limited bioassay data indicate that the exposure rate might have increased in later years. The operational data and the air data neither confirm nor deny the increased intake rate determined for bioassay data in later years. There is indication that the throughput decreased significantly in later years, but this is offset both by the processing of some enriched uranium with its higher specific activity (radioactivity per unit mass) and the reportedly reduced usage of safety equipment, such as local ventilation.

Differences in the values of intake estimates from air and bioassay data are likely due to a multitude of factors, but the more significant factors are the assumptions regarding the time patterns of intakes and the absorption types of the material. For interpretation of both the air and bioassay data, intake pattern assumptions were simplified based on the limited information. If the time patterns of intake are assumed reasonable, it appears reasonable to conclude that workers were not exposed to a source term that was clearly pure type M or pure type S.

Graphs are provided in Appendix B that show how predicted urinalysis results from air concentrations compare to the coworker bioassay data. Graphs are also provided to show the fits of the coworker data used to obtain the three chronic uranium intakes summarized in Table 15.

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 uranium released or measured 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. But because of the unknown enrichment for a given period and the unknown fraction of enriched material processed for a given period, this document assumes that intakes calculated from air data are U^{234} 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 min (versus the typical 8 to 10 hr). The geometric mean concentration for 80 min was about 2,000 dpm/m^3 with a GSD of 3.0 (this is shown in Figure 4 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 on the 10-in. bar mill. Because the number of uranium-rolling days in 1953 was estimated to continue at 156 d (versus the estimated 15 d calculated in Section 2), 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 d 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 Hanford and Fernald, is shown below. 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 11. Estimate of contaminant activity fractions in a recycled depleted uranium source term (pCi contaminant per pCi uranium).

Uranium	Np-237	Pu-239
1	0.00182	0.00261

3.2 THORIUM

Thorium metal rapidly oxidizes, and particulates created during the metal-forming processes at Simonds were likely to be oxides. ICRP Publication 68 lists thorium oxides as absorption type S (ICRP 1994b). Freshly separated thorium consists of equal amount of ^{232}Th and ^{228}Th. During the Simonds' operational period, it is reasonable to assume that thorium intakes consisted of 50% ^{232}Th and 50% ^{228}Th. The contributions of ^{228}Ra and ^{224}Ra to 50-yr effective dose from inhalation intake of

thorium and its progeny (excluding ^{220}Rn) in full equilibrium are about 4% and 5%, respectively. Because it takes some time to reach full equilibrium, and because the air samples included activity from all the alpha emitters collected, and because the estimated initial fraction of ^{228}Th was overestimated, ignoring contributions from ^{228}Ra and ^{224}Ra in the operational years would not significantly change the estimated dose.

It was assumed that Simonds processed thorium from January 1, 1951, to December 31, 1956. Dates of thorium rollings included August 1951, November 1951, November 1952, and August 1954. (Huke 1951; AEC 1951a, 1953c; Belmore 1952; Harris 1954). Based on the available information, it appears to take about 1 day to roll 4 to 5 tons of thorium. However, the records show that Simonds processed various amounts: one ton of thorium on November 19, 1951 (AEC 1951a), and 4 tons on November 25, 1952 (Belmore 1952). This analysis assumed that there was 1 day of thorium rolling every 2 months from January 1, 1951, to December 31, 1956, and that the thorium rolling was done in a single 10-hr shift

Simonds workers have no thorium bioassay results. A November 25, 1952, set of daily time-weighted average air concentrations for specified job categories was the only job specific data found. This analysis assumed that the November 25, 1952, air sample results could be applied to the entire thorium-rolling period. This assumption appears to be justified by the Harris (1954) memorandum stating that conditions were similar to those in 1952 with an average (mean) weighted exposure of1,030 dpm/m^3. As in the uranium analysis above, the geometric mean and GSD of the workgroups' daily time-weighted average exposure were determined from the AEC air concentration. The geometric mean of the workgroup exposure was used to estimate inhalation and ingestion intakes from rolling activities and from resuspended contamination. The GSD for the calculated workgroup exposure was 4.0. Tables 12, 13, and 14 show the estimated thorium inhalation intake from rolling, the inhalation intake from resuspension, and the ingestion intake, respectively. In Table 15, the daily intake rates are divided equally between ^{232}Th and ^{228}Th.

Table 12. Inhalation exposures during thorium-rolling operations.

Work period		Number of potential AEC workdays	Air concentration (pCi/m^3)	Breathing rate (m^3/hr)	Hr/workday	Intake (pCi)
1/1/1951	12/31/1956	36	3.93E+02	1.2	10	1.70E+05

Table 13. Inhalation exposure during non-AEC operations due to resuspension of deposited thorium dust.

Work period		Hr/workday	Non-Th rolling workdays per work period	Breathing rate (m^3/hr)	Resuspended air concentration (pCi/m^3)	Intake (pCi)
1/1/1951	12/31/1956	10	1531	1.2	0.382	7.02E+03

Table 14. Estimated amount of thorium ingested (pCi) (based on Tables 12 and 13).

Work period		Th-rolling workdays	Ingestion rate during thorium rolling (pCi/workday)	Non-Th rolling workdays	Ingestion rate(during normal operation (pCi/workday)	Intake (pCi)
1/1/1951	12/31/1956	36	8.77E+01	1531	8.53E-02	3.29E+03

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 11. 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. Thorium oxide is absorption type S.

The assumed operational exposure period is from February 24, 1948, to December 31, 1956, which this analysis assumes to be the uranium intake period. The assumed intake period for thorium is January 1, 1951, to December 31, 1956.

For unmonitored workers or unmonitored periods, Table 15 lists intake rate assumptions for natural uranium and thorium along with GSDs. The intake mode is chronic. The dose distribution is assumed to be lognormal.

Intakes of neptunium and plutonium depend on the intakes of uranium. It is assumed that the solubility types of uranium and plutonium are independent. Therefore the phrases "if U is M" and "if U is S", have been added to the "Absorption Type" column. This is to indicate that the intake amounts of neptunium and plutonium are based on the intake amount of uranium. For both uranium and plutonium only one absorption type is chosen for dose reconstruction.

Table 15. Internal exposure summary for operational period February 24, 1948, to December 31, 1956.

Radionuclide	Start	End	Intake route	Absorption type	Intake (pCi/d)	GSD
Uranium-234	2/24/1948	12/1/1948	Inhalation	M	5.76E+02	3.0
	12/1/1948	12/15/1950	Inhalation	M	2.36E+02	3.0
Choose M or S intake scenario, not both.	12/15/1950	12/31/1956	Inhalation	M	4.49E+02	3.0
	2/24/1948	12/1/1948	Inhalation	S	1.72E+04	3.0
	12/1/1948	12/15/1950	Inhalation	S	2.40E+03	3.0
	12/15/1950	12/31/1956	Inhalation	S	7.26E+03	3.0
Neptunium-237	1/1/1953	12/31/1956	Inhalation	M, if U is M	8.18E-01	3.0
	1/1/1953	12/31/1956	Inhalation	M, if U is S	1.32E+01	3.0
Plutonium-239	1/1/1953	12/31/1956	Inhalation	M, if U is M	1.17E+00	3.0
	1/1/1953	12/31/1956	Inhalation	M, if U is S	4.48E+01	3.0
Choose M or S intake scenario, not both.	1/1/1953	12/31/1956	Inhalation	S, if U is M	6.26E+00	3.0
	1/1/1953	12/31/1956	Inhalation	S, if U is S	1.90E+01	3.0
Thorium-232	1/1/1951	12/31/1956	Inhalation	S	4.03E+01	4.0
	1/1/1951	12/31/1956	Ingestion	(a)	7.50E-01	4.0
Thorium-228	1/1/1951	12/31/1956	Inhalation	S	4.03E+01	4.0
	1/1/1951	12/31/1956	Ingestion	(a)	7.50E-01	4.0

a. Choose same f_1-value as used for inhalation per NIOSH (2004).

4.0 ESTIMATION OF EXTERNAL EXPOSURE

Individual external dosimetry results for Simonds Steel and Saw consist of doses reported for 20 workers for the period from October 11 to 19, 1949 (AEC 1949c). A limited exposure period of less than two weeks might not be representative of exposures received 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
- 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 emitted 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 claimant favorable. 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 of energies 30 keV or greater, and

- nonpenetrating assumed to be associated with photons of energies less than 30 keV or with electrons.

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, the claimant-favorable assumption is made that workers were exposed to photon energies from 30 to 250 keV. Nonpenetrating dose from natural thorium consists primarily of electrons with energies above 15 keV. The actual dose rate from thorium varies in relation to the age of the material. This analysis assumes that exposure rates from uranium and thorium materials during operations period were similar. Harris (no date) noted that thorium and uranium radiological hazards are similar for metal fabrication processes.

4.1 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 and derived geometric means were both 362 with a GSD of 1.6. The gamma results ranged from not reported (less than 50 mR) to 115 mR, and the derived geometric mean and GSD for the set were respectively 63 mR and 1.4. The calculated geometric mean of the positive gamma results was 73 mR. A quick scoping calculation, which assumed that the badges were worn for 9 uranium-rolling workdays and that there were 156 uranium-rolling workdays per year, indicated annual beta and gamma doses of 6.3 and 1.1 R, respectively. Assumptions about the length of exposure periods and exposure of the badge while not in use can increase or reduce this scoping value by a factor of about 3.

External exposure estimates summarized in Table 18 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 Table 18 assumed annual nonpenetrating exposure is 8.7 R and the assumed annual penetrating exposure is 1.2 R.

4.2 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 (1) that these results represented the general levels of external exposure from submersion in air and contaminated surfaces at Simonds and (2) that the data distribution was lognormal. The calculated geometric means were 1.3 mR/hr with a GSD of 2.3 for the nonpenetrating radiation and 0.26 mR/hr with a GSD of 1.2 for the 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 18 in Section 4.6 lists these assumed exposures at Simonds during operational years.) This analysis assumed that all workers were exposed to penetrating and nonpenetrating radiation from submersion in air and contamination for 10 hr each workday.

4.3 BILLET AND ROD EXPOSURES

Another assumption was that workers received a deep dose due to photon exposure from the uranium billets and rods. According to reports, the AEC work involved rolling uranium billets of 4 to 5 in. diameters and 15 to 28 in. long. The billets were rolled into rods 20 ft long of approximately 1.5 in. diameter. 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 16 lists calculated photon dose rates for the uranium billet and rod.

Table 16. Calculated photon dose rate for uranium billet and uranium rod.

Distance from source	Billet dose rate (mrem/hr)	Rod dose rate (mrem/hr)
Surface	7.74	5.09
1 ft	0.703	0.285
1 m	0.108	0.0883

Several of the air exposure records were reviewed to estimate a worker's time near a billet or rod versus just being in the general area. The records indicated that for most workers the time near the uranium billet or rod was less than 5 hr/shift, but some workers may have spent 6.5 hr near the rods and billets. Because workers changed jobs, this analysis assumed that workers were near the billets for 3.5 hr/rolling day and near the rods for 3.5 hr/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 18 (Section 4.6) 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 17. 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 (Belmore 1948b) 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. Although in April 1948, Hayden (1948a) reported measurements as low as background, 0.1 mrep/hr, up to 40 mrep/hr at 8 inches from a rod storage pile. Direct beta readings were reported as 12 mrep/h at 2 feet above an unswept steel floor and 4 mrep/hr after sweeping. Measurements taken at 2 inches 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, AEC (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 17. Direct radiation measurements from September 1948.[a]

Location of measurement	Dose rate (mrep/hr)[b]
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. Belmore (1948b).
b. A rep (roentgen-equivalent-physical) is a historical unit of dose equivalence approximately equal to a rem.

AEC reported thorium radiation levels from thorium being readied for shipment to Simonds as 15 mR/hr at the surface and 2 mR/hr at 1 m from a single crate, and 20 mR/hr at the surface and 10 mR/hr at 50 cm from an “entire pile” on December 14, 1951 (Rothenberg 1951).

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 plus thorium rolling-days in the period. Table 18 (Section 4.6) lists the annual doses.

4.4 OCCUPATIONALLY REQUIRED MEDICAL X-RAY

X-ray machine characteristics, beam measurements, and example films for Simonds were unavailable. Available documentation indicates that chest X-ray examinations were performed prior to or just as AEC work was starting, and were followed by annual chest X-rays. The type of X-ray examination should be based on current ORAU Team guidance. Organ doses can be obtained from the current revision of ORAUT-OTIB-0006, *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT 2003).

4.5 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 imbedded in the skin from work in the rod-stamping area (AEC 1951d; Heatherton 1951).

4.6 OCCUPATIONAL EXTERNAL DOSE RECONSTRUCTION ASSUMPTIONS AND SUMMARY

Table 18 summarizes occupational external doses during uranium operations at Simonds.

Table 18. External exposure summary for February 24, 1948, to December 31, 1956.

Exposure mode	Exposure type	Exposure or dose rate	Basis	Exposure time assumption	Year	Annual exposure	IREP distribution
Submersion/ area contamination	Penetrating	0.26 mR/hr	Film badge	2,500 work-hr/yr	1948 1949 1950 1951 1952 1953 1954 1955 1956	0.582 R 0.650 R 0.650 R 0.650 R 0.650 R 0.650 R 0.650 R 0.650 R 0.650 R	Lognormal GSD 1.2
	Non-penetrating	1.3 mR/hr	Film badge	2500 work-hr/yr	1948 1949 1950 1951 1952 1953 1954 1955 1956	2.912 R 3.250 R 3.250 R 3.250 R 3.250 R 3.250 R 3.250 R 3.250 R 3.250 R	Lognormal GSD 2.3
Medical X-ray		Initial plus one examination per year			1948 1949 1950 1951 1952 1953 1954 1955 1956	See ORAU 2003	
U billets	Penetrating	0.703 mrem/hr	MCNP calculation	3.5 hr/rolling-d	1948 1949 1950 1951 1952 1953 1954 1955 1956	0.352 rem 0.384 rem 0.384 rem 0.399 rem 0.399 rem 0.399 rem 0.091 rem 0.091 rem 0.091 rem	Lognormal GSD 4.3
	Non-penetrating	5 mrep/hr	Instrument measurement	3.5 hr/rolling-d	1948 1949 1950 1951 1952 1953 1954 1955 1956	2.503 rep 2.730 rep 2.730 rep 2.835 rep 2.835 rep 2.835 rep 0.648 rep 0.648 rep 0.648 rep	Lognormal GSD 1.5
U rods	Penetrating	0.285 mrem/hr	MCNP calculation	3.5 hr/rolling-d	1948 1949 1950 1951 1952 1953 1954 1955 1956	0.143 rem 0.156 rem 0.156 rem 0.162 rem 0.162 rem 0.162 rem 0.037 rem 0.037 rem 0.037 rem	Lognormal GSD 5.7
	Non-penetrating	5 mrem/hr	Instrument measurement	3.5 hr/rolling-d	1948 1949 1950 1951 1952 1953 1954 1955 1956	2.503 rep 2.730 rep 2.730 rep 2.835 rep 2.835 rep 2.835 rep 0.648 rep 0.648 rep 0.648 rep	Lognormal GSD 2.3

5.0 ESTIMATION OF RESIDUAL EXPOSURE

This analysis assumed that the Simonds' residual dose period began on January 1, 1957 (at the end of rolling operations) and continued through the present. An 8-hr workday was assumed for this period.

Before AEC uranium and thorium operations ended in 1956 at Simonds, some cleanup was planned and perhaps performed. In November of 1953, Blythe (1953) requested that arrangements be made for NLO to oversee the decontamination of Simonds. Simonds agreed to have six to eight workers for this work, which was to be scheduled on a weekend not to interfere with the rolling schedule (Heatherton 1953a). NLO raised a concern that additional thorium work could be requested within the next 6 months. AEC rolling did occur thereafter.

After the Simonds' AEC contract work ended, NLO surveyed Simonds in July 1957 to see the effectiveness of decontamination efforts (Heatherton 1957); Table 19 summarizes the results. On July 10, 1957, the forge area, the 16-in. bar mill, the 10-in. strip metal area, and the shipping and receiving areas were surveyed. All of these areas were found to be slightly above background, but

Table 19. Measured radiation levels on July 10, 1957.[a]

Location	Contact (mrep/hr) Beta/gamma	Beta (mrep/hr) 3 ft from surface	Gamma (mR/hr) 3 ft from surface
10-in. bar mill bed	10 to 20	1.0 to 1.7	0.04 to 0.05
Front of shear	1 to 2	0.4	0.08
Between plates on mill floor	0.15	0.05	None detected
Forge area	0.7 to 1.2	0.2	0.02
Top of furnace	1.0	No reading	No reading

a. Heatherton (1957).

at 3 ft about the floor, only two small areas exceeded 0.2 mrep/hr beta/gamma. Most contact readings were less than 0.5 mrep/hr (Heatherton 1957), and it was noted that while some contamination was found in inaccessible areas, it was estimated that a man would be exposed to less than 10 mrep/week.

Nuclear Science and Engineering Corporation and Carborundum Metals performed surveys in late 1958. The November 1958 survey results do not appear meaningful or consistent with earlier results (Glitzer 1958a). Alpha air activity was reported as 0 dpm with no indication of the air volume collected. The beta air activity was reported as 0 to 2.8 dpm. Smear samples were mostly less than 20 dpm except in the vicinities of the rollers and quenching areas, where the maximum removable activity appeared to be about 42 dpm and the maximum beta activity was 114.4 dpm. A second set of survey results dated 13 days later showed a maximum removable alpha activity of 404 dpm. A review of the data indicates that the alpha counting efficiency was lower than the beta counting efficiency. A single soil result, which is not very legible, appears to be reported as 39 mg uranium/gram of soil. After the November 1958 survey, the quench tank was removed and clean steel was placed over the floor (Author unknown, no date b). Smear samples collected by Carborundum Metals on December 12, 1958, were less than 10 dpm alpha and less than 25 dpm beta in the former quenching area (Glitzer 1958b).

ORNL performed a radiological survey in October 1976 to characterize the former Simonds site for FUSRAP (Author unknown, no date c). Removable contamination was not deemed excessive, but radiation exposures of greater than 1 mrad/hr beta/gamma were measured and ^{238}U soil concentrations were about 21,000 pCi/g underneath the floor plates. Two soil samples were analyzed

isotopically to check for enriched uranium (ORNL 1979); the ratios were consistent with natural, not enriched, uranium.

Simonds received essentially pure uranium and thorium metal (no radium) for processing. This is confirmed by the 1979 ORNL survey, which reported two radon results of less than 0.4 pCi/liter and two measurements to evaluate radon progeny with results of less than 0.001 Working Levels. Assuming 100% equilibrium of the progeny (a maximizing assumption) gave results of all four samples within the normal range of atmospheric radon concentration of 0.1 to 0.5 pCi/L (Eisenbud 1987). Soil concentrations of ^{226}Ra were equivalent to background concentrations. The largest soil concentration of ^{232}Th was 11 pCi/g, and 22 of 25 thorium soil samples had concentrations of less than 3 pCi/g. It was noted that ^{238}U concentrations were at least 100 times the ^{228}Th concentration, which was assumed to be in equilibrium with ^{232}Th.

The largest directly measured alpha contamination from ORNL (1979) was 4600 dpm/100 cm^2. Beta/gamma levels measured within 40 ft of the 16-in. rolling mill were above 1.0 mrad/hr. On the 16-in. rolling mill, the beta/gamma dose rates were as high as 3.5 mrad/hr. The highest external gamma level was 0.048 mR/hr at 1 m above the floor in the rolling mill and in the forge shop (Author unknown, no date a).

"On February 7, 1980, DOE determined that the Simonds Steel Division site required consideration for remedial action" (Author unknown, no date c). Guterl Specialty Steel filed for Chapter 11 protection in August 1982 (Author unknown, no date c). The Simonds Steel metal-rolling operation was closed on May 1, 1983 (Author unknown, no date d.) Allegheny International purchased the site in March 1984 (Author unknown, no date c). Although it is very unlikely that residual exposure occurred to site employees after May 1983, the contamination was still present, and this document assumes that exposure to residual radioactivity could have continued to occur.

To calculate internal exposure from residual activity this analysis assumed that the median uranium exposure was from uniform contamination of the buildings to a level of 4,600 dpm/100 cm^2. Using a resuspension factor of 1×10^{-6}/m (NRC 2002b) and an air intake rate of 2,400 m^3/yr, the calculated uranium annual inhalation intake was 497 pCi. Uranium enrichment does not need to be addressed during this period, because measurements were based on radioactivity, not mass, and because sample analyses indicate the uranium contamination was not enriched. It is assumed that recycled uranium contaminants would be an inconsequential component of residual contamination. Using the method described in Section 3.0, the calculated annual ingestion intake was 10.4 pCi. It was assumed that the ^{232}Th and ^{228}Th intakes were each 1% of the uranium intakes. Even though ^{224}Ra and ^{228}Ra would be much closer to equilibrium with the thorium during the residual exposure period, their contribution to internal dose was sufficiently small to be ignored.

To reconstruct external exposure to residual radioactivity after the end of AEC operations, this analysis assumed that workers were exposed to 0.08 mR/hr penetrating radiation, which was the upper end of the gamma exposure rate readings at 1 m in 1957. The residual penetrating radiation exposure was estimated by assuming that the 0.08 mR/hr was the median rate and the beta/gamma exposure rate at 3 ft (0.4 mrep/hr) was the 95th-percentile rate, which yields a GSD of 3.5. A nonpenetrating external exposure was estimated by assuming that the 0.2-mrep/hr beta/gamma reading at 3 ft from the floor in the forge area was the median rate and that the 1-mrep/hr beta/gamma reading at contact was the 95th-percentile rate, which yields a GSD of 2.6. The estimated annual external exposure to residual radioactivity from AEC operations at the site, listed in Table 20, was calculated by assuming that workers were exposed for 2,000 hr/yr.

Assumptions about residual exposures should be consistent with assumptions from the operational period.

Table 20 summarizes residual period intake rates and external exposure rates.

Table 20. Annual internal and external exposure to residual radioactivity.

Internal exposure						
Source	**Start**	**End**	**Exposure**	**Absorption type**	**Intake (pCi/d)**	**IREP distribution**
U-234	1/1/1957	Present	Inhalation	M, S	1.4E+00	Lognormal GSD 5
	1/1/1957	Present	Ingestion	(a)	2.8E-02	Lognormal GSD 5
Th-232	1/1/1957	Present	Inhalation	S	1.4E-02	Lognormal GSD 5
	1/1/1957	Present	Ingestion	(a)	2.8E-04	Lognormal GSD 5
Th-228	1/1/1957	Present	Inhalation	S	1.4E-02	Lognormal GSD 5
	1/1/1957	Present	Ingestion	(a)	2.8E-04	Lognormal GSD 5
External Exposure						
N/A	**Start**	**End**	**Exposure**	**Basis**	**R/yr**	**IREP distribution**
	1/1/1957	Present	Penetrating	Survey instrument	0.160	Lognormal GSD 3.5
	1/1/1957	Present	Non-penetrating	Survey instrument	0.400	Lognormal GSD 2.6

a. Choose same f_1-value as used for inhalation per NIOSH (2004).

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Appendix A
Coworker Bioassay Data by Sample Date

Uranium urinalyses in mg/L

<0.01 mg/L insufficient for reliable detection

HNO_3 treated

11/1/1948	11/3/1948	11/4/1948	11/8/1948	11/11/1948	11/15/1948	Pre roll 1/6/1949	Pre roll 4/27/1949	Pre 3rd Roll 11/4/1949	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
									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

Uranium urinalyses in mg/L

Pre roll 1/6/1950	Post roll 1/19/1950	5/15/1950	Post roll 5/23/1950	Second shift less supervision. Pre roll 8/14/1950	Post roll 8/28/1950	9/23/1950	9/25/1950	10/20/1950	10/25/1950
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								
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									

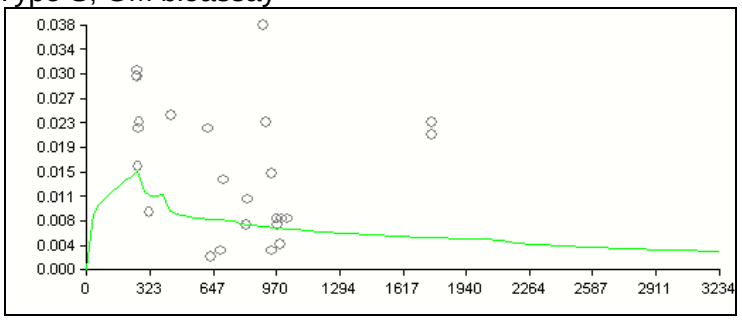
Uranium urinalyses in mg/L

			Samples collected at 5 p.m.	
			Preroll	Postroll
11/9/1950	**11/16/1950**	**12/14/1950**	**12/20/1952**	**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
			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

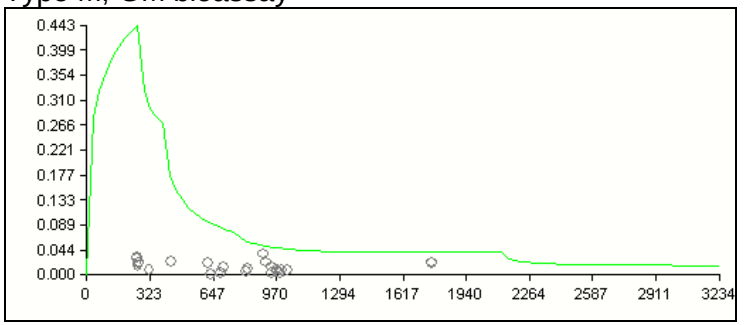
Appendix B
Graphs showing predicted bioassay from air, and fits of coworker bioassay

The graphs show predicted bioassay results from the estimated air intakes, superimposed on the geometric mean (GM), 84th percentile and maximum coworker bioassay results. Reasonable fits are starred (*). X-axis is days (0=2/24/1948). Y-axis is mg/L.

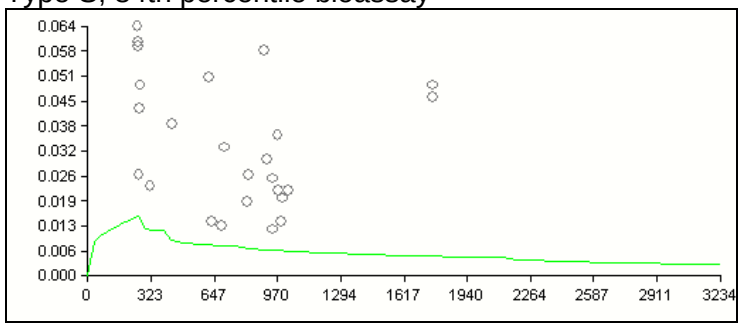
Type S, GM bioassay*



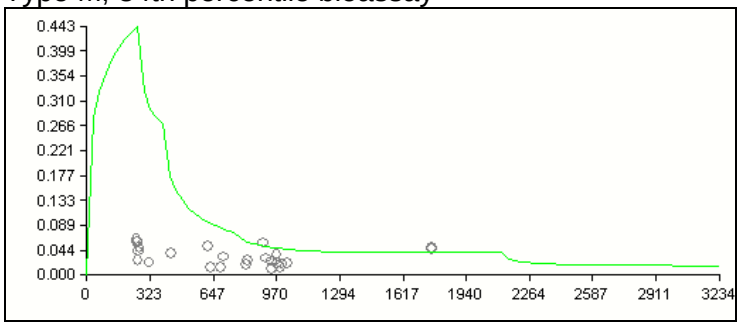
Type M, GM bioassay



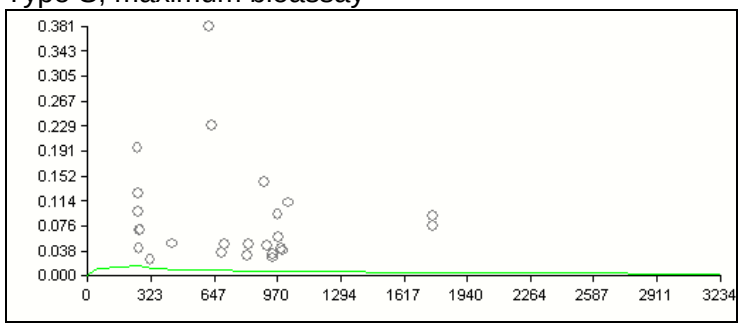
Type S, 84th percentile bioassay



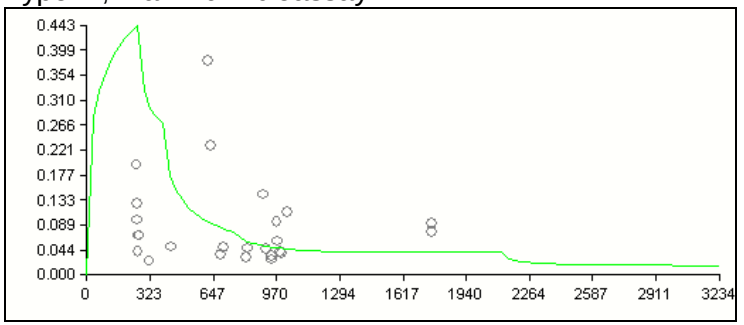
Type M, 84th percentile bioassay



Type S, maximum bioassay

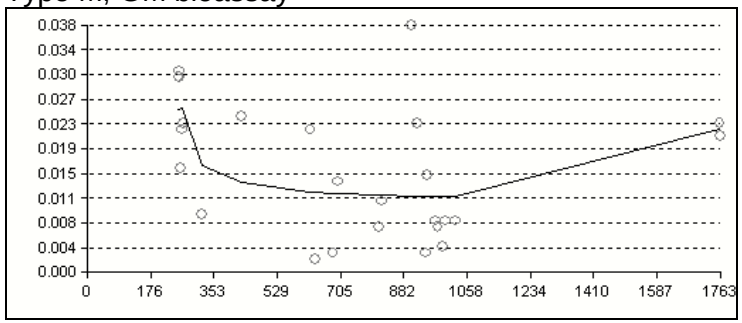


Type M, maximum bioassay*

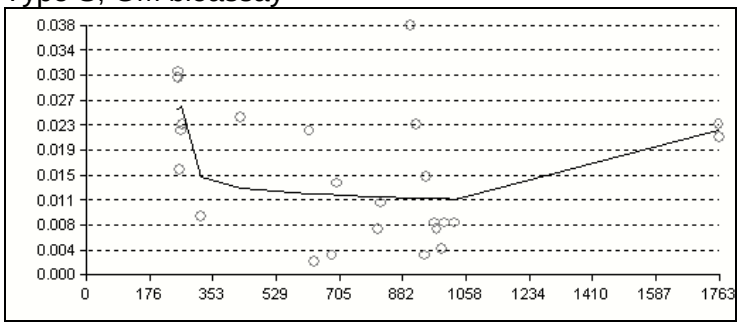


Graphs showing fits of coworker bioassay data to 3 inhalation intakes. X-axis is in days (0=2/24/1948). Y-axis uranium urinalyses results in mg/L.

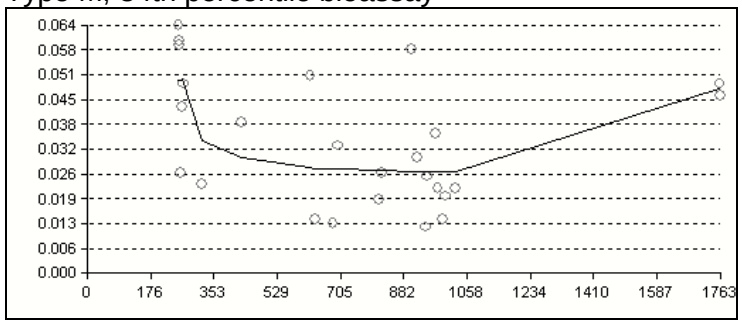
Type M, GM bioassay



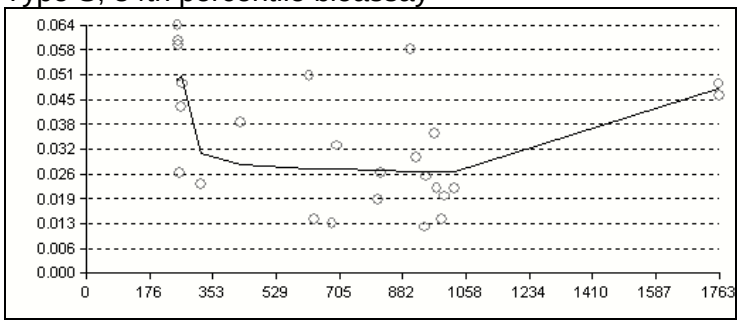
Type S, GM bioassay



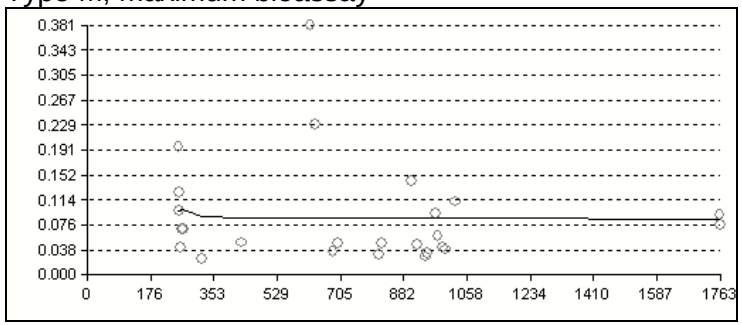
Type M, 84th percentile bioassay



Type S, 84th percentile bioassay



Type M, maximum bioassay



Type S, maximum bioassay