SEC Petition Evaluation Report
Petition SEC-00058

Report Rev: 2 **Report Submittal Date:** July 2, 2007

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Site Expert(s):	N/A

Petition Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition B Qualification Date	DOE/AWE Facility Name
SEC-00058	83.13	August 9, 2006	Blockson Chemical

Petitioner Class Definition
All Atomic Weapons Employer employees, contractors, and subcontractors, who worked in Building 55 at the Blockson Chemical Company (also known as Olin Mathieson) from January 1, 1951 to December 31, 1962.

Proposed Class Definition
All Atomic Weapons Employer personnel who worked on activities related to the production of uranium at Blockson Chemical Company, Joliet, Illinois, from January 1, 1951 through December 31, 1962.

Related Petition Summary Information			
SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
SEC-00045	83.13	Blockson Chemical	Under evaluation

Related Evaluation Report Information	
Report Title	DOE/AWE Facility Name
NONE	

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Peer Review Completed By:	[Signature on file] *Thomas P. Tomes*	07/02/2007 *Date*
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SEC Evaluation Approved By:	[Signature on file] *Dave Sundin for Larry Elliott*	07/03/2007 *Date*

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Evaluation Report Summary: SEC-00058, Blockson Chemical

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addresses a class of employees proposed for addition to the Special Exposure Cohort (SEC) per the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 U.S.C. § 7384 *et seq.* (EEOICPA) and 42 C.F.R. pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

Petitioner-Requested Class Definition

Petition SEC-00058, qualified on August 9, 2006, requested that NIOSH consider the following class: All Atomic Weapons Employer employees, contractors, and subcontractors, who worked in Building 55 at the Blockson Chemical Company (also known as Olin Mathieson) from January 1, 1951 to December 31, 1962. Another petition (SEC-00045), on behalf of a subset of the above-requested class of workers, was qualified and merged into SEC-00058.

NIOSH-Proposed Class Definition

Based on its research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all Atomic Weapons Employer personnel who worked on activities related to the production of uranium at Blockson Chemical Company, Joliet, Illinois, from January 1, 1951 through December 31, 1962. The class definition was modified because uranium recovery-related work was likely to have been performed in areas outside of Building 55. This work would have included rock-crushing activities, chemical oxidation (documents suggest this step was performed in a different building), and uranium recovery pilot studies (these studies would have been performed in other areas prior to the 1952 construction of Building 55).

Feasibility of Dose Reconstruction

Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose incurred by any member of the class; or (2) estimate radiation doses more precisely than a maximum dose estimate. Information available from the site profile and additional resources is sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specified period.

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is not required because NIOSH has determined that it has sufficient information to estimate dose for the members of the proposed class.

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SEC Petition Evaluation Report for SEC-00058

1.0 Purpose and Scope

ATTRIBUTION AND ANNOTATION: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the ORAU Team Lead Technical Evaluator: Robert M. Coblentz; Quantaflux, LLC. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

This report evaluates the feasibility of reconstructing doses for all Atomic Weapons Employer personnel who worked on uranium recovery activities at Blockson Chemical Company, Joliet, Illinois, from January 1, 1951 through December 31, 1962. It provides information and analyses germane to considering a petition for adding a class of employees to the Congressionally-created SEC.

This report does not make any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH. This report also does not contain the final determination as to whether the proposed class will be added to the SEC (see Section 2.0).

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. pt. 83, and the guidance contained in the Office of Compensation Analysis and Support's (OCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services (HHS) add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[1]

42 C.F.R. § 83.13(c)(1) states: *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose.*

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also then determine whether or not there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered

[1] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. pt. 82 and the detailed implementation guidelines available at http://www.cdc.gov/niosh/ocas.

the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioner(s) and to the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[2]

This Evaluation Report is a revision of a previous SEC Evaluation Report issued on September 1, 2006. It was revised pursuant to related discussions at the Advisory Board Meeting held December 11-13, 2006.

3.0 Petitioner-Requested Class/Basis & NIOSH-Proposed Class/Basis

Petition SEC-00058, qualified on August 9, 2006, requested that NIOSH consider the following class for addition to the SEC: All Atomic Weapons Employer employees, contractors, and subcontractors, who worked in Building 55 at the Blockson Chemical Company (also known as Olin Mathieson) from January 1, 1951 to December 31, 1962.

The petitioner for SEC-00058 stated his/her belief that accurate dose reconstruction over time is impossible because no monitoring was performed. Based on further research, NIOSH deemed the petitioner’s submission sufficient to qualify SEC-00058 for evaluation. Detail regarding the SEC-00058 petition basis is presented in Section 7.4.

Another petition, SEC-00045, on behalf of a subset of the above-requested class of workers, qualified on March 6, 2006 and was later merged into SEC-00058. The petitioner for SEC-00045 provided information and affidavit statements in support of the petitioner’s belief that accurate dose reconstruction over time is impossible. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00045 for evaluation:

[2] See 42 C.F.R. pt. 83 for a full description of the procedures summarized here. Additional internal procedures are available at http://www.cdc.gov/niosh/ocas.

The petitioner submitted twelve affidavits (from one former Atomic Weapons Employee and eleven survivors) to support his/her position that neither the government nor Blockson Chemical ever monitored Atomic Weapons Employee exposures to radioactive materials, or monitored the workplace for radiation levels.

The information and statements provided by the petitioner for SEC-00045 qualified the petition for evaluation. SEC-00045 was subsequently merged with SEC-00058. Details on the SEC-00045 petition basis are included in the discussion in Section 7.4.

Based on its research, NIOSH modified the petitioner-requested class for SEC-00058 to define a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all Atomic Weapons Employer personnel who worked on activities related to the production of uranium at Blockson Chemical Company, Joliet, Illinois, from January 1, 1951 through December 31, 1962. The class definition was modified because some uranium recovery-related work was performed in areas outside of Building 55. This related work included phosphate rock calcination and crushing, as well as phosphoric acid production, which included a chemical oxidation step. Additionally, research work on uranium recovery in the laboratory and in a pilot plant was conducted in other locations and prior to the 1952 construction of Building 55.

4.0 Data Sources Reviewed by NIOSH

NIOSH identified and reviewed numerous data sources to determine the availability of information relevant to determining the feasibility of dose reconstruction for the class of employees proposed for this petition. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following subsections summarize the data sources identified and reviewed by NIOSH.

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information concerning the documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to supplement, or substitute for, individual monitoring data. A Site Profile consists of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. The Site Profile for a small site may consist of a single document. As part of NIOSH's evaluation detailed herein, the following TBDs were examined for insights into Blockson operations or related topics/operations at other sites:

- *Basis for Development of an Exposure Matrix for Blockson Chemical Company, Joliet, Illinois; Period of Operation: March 1, 1951 through March 31, 1962,* ORAUT-TKBS-0002, Rev. 01; June 29, 2004; SRDB Ref ID: 19480 (NOTE: This document superseded by OCAS-TKBS-0002)

- *Technical Basis Document for Atomic Energy Operations at Blockson Chemical, Joliet, Illinois*, OCAS-TKBS-0002, Rev. 0; September 11, 2006; SRDB Ref ID: 31921

- *Technical Basis Document for Atomic Energy Operations at Blockson Chemical, Joliet, Illinois*; OCAS-TKBS-0002, Rev. 01; June 20, 2007; SRDB Ref ID: Not currently available in the SRDB

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs as part of its evaluation:

- *OTIB: Estimating the Maximum Plausible Dose to Workers at Atomic Weapons Employer Facilities*, ORAUT-OTIB-0004; Rev. 3 PC-1; November 18, 2005; SRDB Ref ID: 19421

- *OTIB: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, ORAUT-OTIB-0006; Rev. 3 PC-1; December 21, 2005; SRDB Ref ID: 20220

- *OTIB: Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*, ORAUT-OTIB-0024; Rev. 00; April 7, 2005; SRDB Ref ID: 19445

- *OTIB: Characterization of Occupational Exposure to Radium and Radon Progeny During Recovery of Uranium from Phosphate Materials,* ORAUT-OTIB-0043; Rev. 00; January 6, 2006; SRDB Ref ID: 22596

4.3 Facility Employees and Experts

Telephone interviews were conducted with five former Blockson Chemical employees to gain additional information and insight into the operations associated with uranium processing in Building 55. The information gained from these interviews has been compiled in NIOSH's OCAS SEC Application (OSA) system. These communications are documented under SEC-00058, under the Communications tab, dated August 17 and August 18, 2006. The primary interview questions included:

- How many people worked in Building 55?

- Was uranium extraction work confined to Building 55?

- Did work crews remain constant?

- How were the drums filled?

- Was localized ventilation used during drum filling?

- Was the work area cleaned regularly, and how was that done?

- Were there incidents or spills?

- Were there any implemented radiological controls?

- Do you recall any details regarding a uranium urinalysis program?

The respondents' answers are summarized as follows (OCAS, 2007):

- All respondents described the work crews in Building 55 as small (two to six people) and constant. They also confirmed that uranium extraction activities were confined to Building 55.

- An access security clearance requirement and access control by posted guard was confirmed by all but one individual (the one individual had no information regarding clearances or guards). *NOTE: Additional information regarding security requirements at the site are noted below.*

- Three out of five respondents had seen uranium drum loading. One thought that there had been a loading hopper, while two were certain that the drums were filled by hand-shoveling.

- Only one individual was certain that there was no localized ventilation in the drum loading area, while the other four were unsure. One of the four mentioned a "dust collector," but could not remember where it had been or how it had been used.

- Three respondents stated that the work area was cleaned regularly (one said each shift); two of the three recalled that the area was swept first, and then washed down using a water hose.

- None of the five recalled any uranium urinalysis program or any radiological controls program.

- One individual thought that there had been medical X-rays administered, while the other four did not know.

- Two of the five recalled small, occasional spills that required clean-up. One described spills as occurring when he had been involved in changing out cloth screens on the "Kelly Filters." Some of the uranium would fall off of the screens onto the floor and they would have to clean it up. He stated that the material was wet at that point in the process.

- When asked later if there was anything else the respondents thought was important, the individual who mentioned the Kelly Filters stated that when changing out the cloth screens, the screens were difficult to hold while wearing gloves, so they had to grab them using their bare hands.

Worker Outreach meetings were conducted in Joliet, Illinois, on January 24-25, 2007. Former Blockson employees and/or survivors were given opportunities to obtain information about the Blockson TBD and the SEC Evaluation Report, and were given the opportunity to provide information for consideration and possible use in dose reconstruction. The meetings were attended by representatives from NIOSH, OCAS, the ORAU Team, the Advisory Board on Radiation and Worker Health, Sanford Cohen & Associates (SC&A), the petitioning attorney for the Blockson Special Exposure Cohort, representatives from the offices of the U.S. Senator from Illinois and of U.S. Representatives, 11th and 13th Districts of Illinois, and approximately 30 former Blockson/Olin workers and survivors. Additional information provided by the attendees included:

- Confirmation from workers that approximately 20 workers were involved in the uranium extraction work in Building 55 (all work shifts combined).

- Additional detailed information regarding Building 55 processes; specifically, yellowcake drum-loading methods.

- Information regarding the phosphoric acid production building (Building 40).

- Indications that process materials were contact-handled by workers only in the yellowcake stages (i.e., Kelly press filters – wet; dryers and drum loading – dry).

- Workers mentioned that security requirements were eased in the late 1950s. This assertion was supported by a union agreement from that time period; the union agreement was presented at the meeting (NIOSH, 2007).
  NOTE: Records from 1955 from the AEC indicated that the AEC was planning to eliminate most of the security requirements at the phosphate plants (OCAS-TKBS-0002, Rev. 01)

4.4 Previous Dose Reconstructions

NIOSH reviewed its dose reconstruction database, NIOSH OCAS Claims Tracking System (NOCTS), to locate dose reconstructions under EEOICPA that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review for the period of January 1, 1951 through December 31, 1962. (Data available as of June 26, 2007)

Table 4-1: No. of Blockson Chemical Co. Claims Submitted Under the Dose Reconstruction Rule
(January 1, 1951, through December 31, 1962)

Description	Totals
Total number of claims submitted for dose reconstruction	115
Total number of claims submitted for energy employees who meet the proposed class definition criteria	111
Number of dose reconstructions completed for energy employees who meet the proposed class definition criteria	102
Number of claims for which internal dosimetry records were obtained for the identified years in the proposed class definition	0[1]
Number of claims for which external dosimetry records were obtained for the identified years in the proposed class definition	0

Notes:
[1] Data capture efforts identified internal monitoring data for three claimants that match the employment time frame (one based on last name and first initial and two based on last name only).

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. At the time that dose reconstructions were performed, NIOSH was not able to obtain personnel dosimetry records for any employee represented in an individual claim submitted for dose reconstruction under EEOICPA for the time period of January 1, 1951 through December 31, 1962. However, data capture efforts did locate internal monitoring data for 25 former Blockson Chemical employees who were monitored by urinalysis. This is discussed in

greater detail in Section 7.2.1. Computer Assisted Telephone Interviews (CATIs) were also conducted to obtain additional information relevant to the individual claim.
As part of the dose reconstruction process, the CATI summaries were carefully reviewed for relevant information. Particular attention was given to the interviews of former employees. To the extent that they related to the individual claims reviewed for this evaluation, the interviews provided information such as work location, hours worked, and job title. In addition, three of the employees interviewed indicated that some air monitoring was performed, and two other former employees stated that some sort of external radiation dosimetry monitoring was performed. However, no record of air or external dosimetry radiation monitoring was found. Most interviewees reported that no monitoring of any sort was performed.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database to locate documents supporting the evaluation of the proposed class. Ninety-six documents in this database were identified as pertaining to Blockson Chemical. These documents were evaluated for their relevance to this petition. The documents include historical background relating to site processes, proposals and contracts with the USAEC, uranium yellowcake production totals, FUSRAP activities, news articles, and general background documents. Documents containing radiological monitoring data include urine sample results for 25 employees between 1954 and 1958, FUSRAP radiological survey for March-November 1978, a radiological air monitoring survey for April 1983, a Building 55 demolition radiological survey for July 1996, and a September 1996 site radiological survey.

4.6 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating petitions SEC-00058 and SEC-00045, NIOSH reviewed the following documents submitted by the petitioners:

- (SEC-00058) Petition Form B and supporting information, received May 13, 2006; OSA Ref ID: 100356
- (SEC-00045) Petition Form B and supporting information, received January 26, 2006; OSA Ref ID: 101501
- (SEC-00045) Twelve affidavits by petitioners, received January 26, 2006; OSA Ref ID: 101504

The twelve affidavits in support of SEC-00045 and one affidavit in support of SEC00058 were provided by two former Atomic Weapons Employee and eleven survivors. Each party provided general employee information such as dates and location of employment, and nearly identical statements regarding the lack of personnel or area monitoring, and lack of protective gear provided to the employee.

5.0 Radiological Operations Relevant to the Proposed Class

The following subsections summarize both radiological operations at Blockson Chemical Company from January 1, 1951 through December 31, 1962 and the information available to NIOSH to characterize particular processes and radioactive source materials. NIOSH has gathered process and source information regarding radionuclides of concern and information describing processes through which radiation exposures may have occurred and the physical environment in which exposures may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 Blockson Chemical Plant and Process Descriptions

The Blockson Chemical Company produced technical grades of sodium phosphate compounds, such as disodium and trisodium phosphate, from phosphate rock obtained mainly from Florida sources. The naturally-occurring uranium content of the phosphate rock averaged about 0.014% U_3O_8. In the early 1950s, the U.S. Atomic Energy Commission (AEC) approached Blockson Chemical Company about the possibility of recovering uranium from the phosphate rock they processed (Stoltz, 1958).

On March 6, 1951, the AEC entered into letter contract number AT(49-1)-606 with Blockson Chemical Company to develop a process to extract uranium from wet phosphoric acid (DOE, 1985). Laboratory studies began at Blockson at about that time (Stoltz, 1958). Due to the urgency of the program, pilot plant construction began simultaneously with the start of laboratory work (Stoltz, 1953). Documentation indicates that pilot runs lasted about three weeks, 24 hours a day, at 25% of expected production capacity. Several runs were performed: April 29, 1951 to June 21, 1951; July 23, 1951 to August 10, 1951; and November 25, 1951 to January 6, 1952 (Stoltz, 1953). Various uranium recovery methods were investigated and tested through pilot plant runs, and in July 1951, Blockson had determined the most effective process (Lopker, 1951). From a process and an economic standpoint, using chlorine as an oxidizing agent and then adding sodium hydrosulfite to cause precipitation was determined to be the best option (Stoltz, 1953). Based on existing production, uranium production capacity was estimated to be 50,000 pounds per year on the basis of uranium oxide (yellowcake) containing 50% to 60% U_3O_8 (Lopker, 1951).

The letter contract was later replaced by contract number AT(49-1)-611 on October 18, 1951 (AEC, 1951), and under the contract, Blockson began construction of Building 55 (at its own expense) to house uranium recovery equipment at their plant in Joliet, Illinois. Laboratory work and pilot studies continued during construction of Building 55 in an effort to further improve uranium recovery processes. The uranium recovery plant was constructed to recover uranium from phosphoric acid being produced by Blockson from normal commercial operations. On August 15, 1952, Blockson began production and delivery of uranium concentrates to the AEC (Stoltz, 1958).

Blockson sent written correspondence to the AEC on July 31, 1951 (Lopker, 1951) in which the uranium recovery process is outlined. The letter includes best estimates of production, fixed capital requirements, manufacturing costs, and general contract conditions that Blockson required. The letter states that all process equipment could be housed in the new building (Building 55) with the exception of: (1) an 8x12 [units unstated] filter to enable all Blockson's liquors to be processed through the monosodium phosphate step; and (2) a monosodium phosphate liquor storage tank to provide storage capacity for monosodium liquors from which the uranium had been removed. These two items, with associated pumps and other accessories, were to be located in their existing plant buildings where those respective operations were currently being carried out. Additionally, the chlorination of the acid would also have to be performed in the building where the phosphoric acid was being produced. This building, according to former Blockson employees, was Building 40, previously known as Building 25 (NIOSH, 2007).

The total amount of uranium produced from 1955 through 1962 is not precisely known; however, information from a former AEC official indicates that from September 1952 through June 1960, a total of 118.3 tons of U_3O_8 had been produced for the AEC. Per a contract amendment in 1958, production was limited to 50,000 pounds of U_3O_8 per year (DOE, 1985). This would have been an average of about 1 drum of yellowcake per week. The AEC reported in December 1955 that Blockson had produced a total of 121,400 pounds in the 40 months of Blockson operations to that point, an average of about 3,035 pounds of U_3O_8 per month through 1955.

In 1955, the Blockson Chemical Company was sold to the Olin Mathieson Chemical Corporation, which assumed the liabilities and obligations under all Blockson contracts. The contract was amended in 1958, primarily to change the pricing structure for uranium. Production was also limited by this amendment to no more than 50,000 pounds of uranium concentrate per year starting in 1958 (DOE, 1985). The 1958 contract also removed the provision that made Blockson responsible for the health and safety of the workers. In March 1962, the uranium extraction work ended when the contract expired (DOE, 1985).

There is contradictory information in some literature regarding the total uranium production through 1955. A Department of Energy FUSRAP Report (DOE, 1985) indicates that 1.22 million pounds of uranium concentrates had been produced by the end of calendar year 1955. This is apparently an overestimate by a factor of 10 based on total production through 1955 given above. In order to produce 1.22 million pounds of U_3O_8 in that timeframe, Blockson would have had to double the capacity of the entire facility, use phosphate ores with the highest known uranium content (0.03%), and extract 100% of the uranium throughout each of its processes. In reality, uranium content of Florida phosphate ore averages 0.011% and maximum recovery for uranium for the various processes is 85% for rock digestion, 90% for monosodium phosphate precipitation, and 95% for U_3O_8 precipitation and upgrading. Those values, along with a throughput of 6,000 tons per week, were used to estimate the upper bound of production to be 50,000 pounds of U_3O_8 per year (Lopker, 1951). The 1955 AEC reports on the quantities of uranium produced through June 1960 indicate that, on average, Blockson produced less than 35,000 pounds per year. Documentation also indicates that on at least one occasion, uranium recoveries at Blockson were less than planned. Blockson attributed these lower recoveries to differences in the phosphate rock feed received by the plant (OCAS-TKBS-0002, Rev. 01).

Table 5-1 summarizes Blockson site development.

Table 5-1: Blockson Chemical Company Development Chronology		
Years	**Buildings**	**Comments**
1951-1952	Pilot Plant	Pilot Plant constructed and used to evaluate and refine the process. Laboratory work begins March 1951.
1951-1952	Building 55	Construction of Building 55, a one-story brick building of approximately 18,900 ft^2. Production begins in Building 55 on August 15, 1952.
1955	Building 55	Contract amended; contract work transferred from Blockson Chemical Company to Olin Mathieson Chemical Corporation.
1958	Building 55	Contract amended which: (1) limited production to 50,000 lbs uranium concentrate per year; and (2) deleted Olin Matheison's AEC health and safety enforcement responsibilities.
1962	Building 55	Contract ends; uranium production ceases.

5.2 Blockson Chemical Company Uranium Recovery Functional Areas

Blockson Chemical uranium recovery operations included the following main functional areas:

- Calcining (outdoor operation)
- Oxidation/chlorination of phosphoric acid to produce monosodium phosphate liquors (Bldg. 40)
- Recovery of uranium from monosodium phosphate liquors (Bldg. 55)
- Packaging of uranium concentrate (yellowcake) into drums for shipment to the AEC (Bldg. 55)

5.2.1 Recovery of Uranium from Phosphoric Rock

Early studies conducted to determine the feasibility of extracting uranium from phosphate rock concluded that, to be economically feasible, any suggested uranium recovery process should be designed so that it would fit into an already existent, self-sustaining phosphate process. Blockson Chemical Company, which was in the business of producing technical grade phosphates for industrial purposes, fit these criteria (Stoltz, 1958). Personnel at Blockson then researched and determined the most efficient uranium extraction process and proposed uranium production capabilities on the basis of treating all of their current phosphate production (Lopker, 1951).

The initial phases of the uranium recovery process at Blockson were similar to normal phosphate production. In normal phosphate production at Blockson, the phosphate rock is first calcined to remove organic matter, then pulverized to a fine material and reacted with sulfuric acid to produce phosphoric acid and phosphogypsum. The phosphoric acid is then used to produce phosphate-containing products and the phosphogypsum is a waste product. In this process, most of the naturally occurring uranium found in the phosphate rock ends up in the acid solution.

For uranium recovery operations, the phosphoric acid is separated for uranium extraction. The phosphoric acid is then converted into monosodium phosphate and other phosphorus derivatives. The uranium by-product is precipitated from the monosodium phosphate stream. The monosodium phosphate liquor is heated and clarified, and then sodium hydrosulfite ($Na_2S_2O_4$) is added to precipitate the uranium. The liquor is filtered and the filtrate is returned to the phosphate processing plant. The precipitate, containing about 5% U_3O_8 is slurried in water in which the uranium is re-dissolved. Next, the product is upgraded by precipitating and filtering out unwanted elements, as the uranium remains in solution (Stoltz, 1953). The uranium is then re-precipitated as sodium uranous phosphate. The slurry is filtered and the precipitate, known as yellowcake, contains 40 to 60% U_3O_8.

Two process modifications were made at Blockson to increase uranium recovery. First, initial calcining operations were changed to help maintain uranium in an oxidized state (Stoltz, 1958). This process modification was intended to maximize the quantity of uranium that went into the acid solution, thus minimizing uranium waste in the phosphogypsum. The second process modification was the addition of chorine to the phosphoric acid as an oxidizer to increase uranium recovery for the next process step, which was the addition of alkali to form monosodium phosphate (Stoltz, 1958). Production of monosodium phosphate was performed in Building 40 (once known as Building 25), for which a filter, tanks, and other equipment were added to increase capacity so all Blockson phosphate could be diverted through the uranium recovery process (Lopker, 1951). Former workers have indicated that the feed to Building 55 came from Building 40 (NIOSH, 2007). Since process modifications to maximize uranium recovery were made to the calcining and the oxidation operations in Building 40, these areas are assumed to have been affected by AEC activities.

5.2.2 Packaging of Uranium Concentrate for Shipment to the USAEC

In the final packing areas, the essentially-pure uranium compound is dried and packaged in drums for shipping, resulting in a potentially-dusty operation. Former workers describe the drum-loading process as shaking the uranium out of the drying pans into a cone-shaped funnel through which the uranium went down into the drums. They also describe the use of a dust collector over the drumming station and provided a photo of the drumming station with the filtration unit shown (NIOSH, 2007).

5.3 Radiological Exposure Sources from Blockson Chemical Operations

The primary source of radiological exposure from operations performed at Blockson Chemical Company from January 1, 1951 through December 31, 1962 was naturally occurring radioactive constituents contained in phosphate rock, primarily uranium and thorium, and all of their associated progeny. Uranium recovery operations in Building 55 produced uranium in the form of yellowcake, of which 40-60% was U_3O_8. Potential exposure pathways and other exposure sources to be considered include:

- Internal exposure through inhalation and ingestion of airborne radioactive dust, including uranium and associated progeny

- Internal and external dose from crushing and calcining of phosphate rock

- Internal exposure from radon and radon progeny

- External photon dose from drums of uranium yellowcake
- External photon dose from radium
- External beta dose from direct exposure to yellowcake material and from uranium skin contamination
- External neutron dose from drums of yellowcake
- Internal and external dose from residual contamination

The distributions of specific uranium and thorium decay chain radionuclides within phosphate source materials and within the various products and waste streams produced by the phosphate ore processing industry have been the subject of numerous studies. While distribution of radionuclides is in some respects a function of the specific process involved, some generalizations may be made specific to the process employed at Blockson (OCAS-TKBS-0002, Rev. 01):

- Radiological equilibrium in the uranium chain appears to be maintained in rock that has not been chemically processed (Roessler, 1979; OCAS-TKBS-0002, Rev. 01).
- Radium-226 and polonium-210 are retained in the phosphogypsum—i.e., do not enter the phosphoric acid stream to any significant degree (Guimond, 1975 page 15; OCAS-TKBS-0002, Rev. 01).
- Uranium and thorium tends to favor the phosphoric acid phase (Guimond, 1975; OCAS-TKBS-0002, Rev. 01).
- Since thorium-230 is present in the matrix with uranium-238, it is expected to go into solution along with the uranium when leached in sulfuric acid. Thorium-232, if occupying a different matrix in the rock, may not be as readily dissolved in sulfuric acid (OCAS-TKBS-0002, Rev. 01).
- Lead-210 is reported by some authors (OCAS-TKBS-0002, Rev. 01) as being retained in the phosphogypsum and by others as reporting to the phosphoric acid.

5.3.1 Alpha Particle Emissions

Alpha particle emissions from the radioactive materials handled at Blockson Chemical present the greatest potential for exposure through internal deposition via inhalation and ingestion (alpha particles do not present an external exposure hazard). The primary uranium isotopes in the phosphate rock include uranium-238, uranium-234, uranium-235, and associated progeny. Dosimetrically significant progeny include thorium-230, radium-226, radon, and associated progeny. Trace amounts of natural thorium (and associated progeny) are also present in phosphate rock (FIPR, 1995).

Uranium-238 and radium-226 are essentially in radioactive equilibrium in phosphate rock. During the process in which the phosphate rock is pulverized, mixed with sulfuric acid, and separated into phosphogypsum and phosphoric acid streams, uranium and radium are chemically separated such that the radium is concentrated in the phosphogypsum while the uranium is concentrated in the phosphoric acid. The distributions of specific uranium and thorium decay chain radionuclides within phosphate source materials and within the various products and waste streams produced by the phosphate ore processing industry have been the subject of numerous studies. While distributions of radionuclides in some respects are a function of the specific process involved, the following specific generalizations can be made for the process employed at Blockson:

- Radiological equilibrium in the uranium chain appears to be maintained in rock that has not been chemically processed (Roessler, 1979; FIPR, 1995).
- Radium-226 and polonium-210 are retained in the phosphogypsum; they do not enter the phosphoric acid stream to any significant degree (OCAS-TKBS-0002, Rev. 01; Guimond, 1975, page 15; FIPR, 1995, pages 1-16).
- Uranium and thorium tends to favor the phosphoric acid phase (OCAS-TKBS-0002, Rev. 01; Guimond, 1975; FIPR, 1995).
- Since thorium-230 is present in the matrix with uranium-238, it is expected to go into solution along with the uranium when leached in sulfuric acid. Thorium-232, if occupying a different matrix in the rock, may not be as readily dissolved in sulfuric acid (Coppinger, 1959, page 20).
- Lead-210 is reported by some authors as being retained in the phosphogypsum and by other authors as reporting to the phosphoric acid (OCAS-TKBS-0002, Rev. 01).

The Blockson process was specifically engineered to maximize carryover of uranium into the phosphoric acid phase. Other elements would be present at various stages according to their chemical properties. There are uncertainties with chemical recoveries and potential losses of some elements in some of the chemical steps. In lieu of this uncertainty, an exposure model is provided that makes assumptions that result in limiting doses from the various radionuclides that are present in the feed material. Assumptions for isotopic ratios in the phosphoric acid stream and monosodium phosphate pumped to Building 55 include:

- 85% of uranium reports to phosphoric acid (Lopker, 1951; OCAS-TKBS-0002, Rev. 01; Stoltz, 1958).
- Four percent of radium-226 reports to acid (Hull, 1996). No radium-226 was detected in the surveys done in the later years, although thorium-230 and natural thorium was detected.
- Thorium reports to acid in the same proportion as uranium. Several references indicate the thorium is likely to be somewhat lower than uranium. The assumption of equal recovery of thorium to uranium in the acid results in a higher source term for internal and external dose (OCAS-TKBS-0002, Rev. 01, page 15 of 46) modeling. If there were more thorium losses to the phosphogypsum stream, the doses would be lower.
- The radioactivity ratio of uranium-238 to thorium-232 in Blockson's rock was 30:1. This ratio is considered a bounding ratio to allow for natural thorium and progeny based on reported uranium-238 and thorium-232 concentrations in phosphate rock (ORAUT-OTIB-0043). Thorium-232 progeny are assumed to be in equilibrium. Although most of the radium-228 would have been

separated and removed with the phosphogypsum, it is assumed to be in equilibrium with thorium-232 for dose modeling to allow for ingrowth over the operational and residual contamination period.

- Lead-210 is assumed to report to the acid at 100%. Various references cite data indicating lead reports to the phosphogypsum, while other references report high percentages reporting to the phosphoric acid (OCAS-TKBS-0002, Rev. 01). For modeling purposes, bismuth-210 and polonium-210 are assumed to be equal to lead-210 for the purpose of bounding exposures and intakes from ingrowth over the operational and residual period.

- All isotopes reporting to the acid are carried through to the drum of dried uranium concentrate (highest potential source for internal dose and source for external dose model) in the same relative concentration as uranium-238 (OCAS-TKBS-0002, Rev. 01).

Table 5-2: Building 55 Relative Radionuclide Concentrations

Radionuclide	Relative Ratio[1]	Notes	Normalized to U-238[1]
U-238	85	Progeny in equilibrium through Th-230	1
U-235	3.87	Progeny in equilibrium	0.0455
Ra-226	4	Progeny in equilibrium	0.047
Pb-210	85	Equal to U-238	1
Bi-210	85	Equal to U-238	1
Po-210	85	Equal to U-238	1
Th-232	2.8	Progeny in equilibrium	0.033

Notes:
The data and information contained in this table are from Table 1 in OCAS-TKBS-0002, Rev. 01.
[1] Ratios given are for progeny without consideration of branching ratios, where applicable.

5.3.2 Beta Radiation Fields

Beta personnel exposure sources are discussed in Section 7.3.4.2 and include the following:

- Shallow dose from exposure to open drums of yellowcake during drum loading and sealing
- Shallow dose to skin contaminated with yellowcake
- Skin dose from contact with contaminated work clothing
- Skin dose from directly handling and cleaning filter media

5.3.3 Neutron Exposures

Uranium compounds can be a source of neutrons from both spontaneous fission occurring in the isotopes of uranium and from alpha-neutron reactions with low atomic number materials, such as oxides and impurities. Neutron exposures from yellowcake, a natural uranium compound, are not significant. ORAU Team Technical Information Bulletin, ORAUT-OTIB-0024, describes the expected neutron dose rates from the various forms of uranium compounds. In Table 5-2 of that document, the listed neutron dose rate at three feet from a source of natural uranium (U_3O_8) is 8.79E-13 R/hour-gram, with no alpha-emitting progeny.

5.3.4 Photon Exposures

Photon personnel exposure sources are discussed in Section 7.3.4.1 and include the following:

- Exposure to barrels of the final concentrated uranium product
- Occupationally required medical X-rays
- Exposure to contaminated surfaces

6.0 Summary of Available Monitoring Data for the Proposed Class

The terms of the October 1951, AEC contract indicate that Blockson was responsible for the health and safety of workers at the site and was responsible for conforming to AEC Health and Safety regulations. However, NIOSH has been unable to find evidence of regulatory inspections pertaining to radiological conditions. Although urine sample results are available, no evidence of an external dosimetry or area monitoring programs were found.

6.1 Blockson Chemical Company Internal Monitoring Data

As discussed in Section 5.3, the primary source of internal radiation exposure from uranium extraction operations at Blockson Chemical was uranium dust produced from the drying and loading of yellowcake into containers for transfer to the AEC. One hundred twenty-two urine sample results obtained from 25 different employees between the years 1954 and 1958 are available. These samples were requested by Blockson and analyzed by the AEC New York Operations Office, Health and Safety Division (Barr, 1953).

It is meaningful to note that while there are urinalyses results for 25 workers, there are 111 dose reconstruction claims on file. Based on claimant interviews, the dose reconstructions include workers who: (1) did not work in Building 55 during the covered time period; (2) worked in Building 55 on an infrequent basis; (3) never worked in Building 55; or (4) worked in Building 55 during the covered period as uranium process workers. Other documents on file support the conclusion that the urinalysis data include results for workers who had the potential for uranium intakes (see Section 7.2.1).

6.2 Blockson Chemical Company External Monitoring Data

NIOSH discovered no evidence of individual external exposure monitoring or area radiation monitoring at Blockson Chemical during uranium extraction operations.

6.3 Blockson Chemical Company Air Sampling Data

NIOSH discovered no evidence of air sampling during uranium extraction operations at Blockson Chemical Company. Air monitoring was performed between March and November, 1978, as a part of a characterization survey conducted by Argonne National Laboratory (ANL). Particulate air monitoring was performed and analyzed for both long-lived radionuclides and short-lived particulate radon progeny. The survey report states:

> *The radon decay-product concentrations in air samples collected at selected locations in the building, including the areas where contamination was found, ranged form 0.0014 to 0.0061 Working Levels (WL), including background……No long-lived radionuclides were detected in any air sample.* (ANL, 1978)

Air monitoring was conducted in April 1983 to determine whether or not employees at the plant were exposed to hazardous working conditions due to alpha radiation emission. Both general area and breathing zone air sampling was performed. Two types of alpha analyses were conducted: (1) gross alpha determination, which is specific for long-lived decay products of uranium-238; and (2) radon daughter analysis, which focused on the short-lived decay products radon-222. The survey report states:

> *Evaluation of the results of both types of analyses, using extremely conservative guidelines, revealed no levels above the Maximum Permissible Concentrations (MPC's) set by the Nuclear Regulatory Commission.*
>
> *No significant occupational health hazards from inhalation of alpha emitting isotopes existed at the time of this survey* (Marseglia, 1983).

6.4 Blockson Chemical Company Contamination Monitoring Data

The only available contamination/radiation monitoring results are from surveys done in March-November 1978, June 1996, and September 1996.

The 1978 survey was performed throughout Building 55, including plant surfaces, tanks, pipes, and other process equipment. A dose rate was taken at contact and at one meter on all 63 locations where contamination was detected. The dose rates at one meter on seven of the 63 "hot" spots ranged from 0.04 mrad/hour to 0.2 mrad/hour. The other 57 spots had one-meter dose rates indistinguishable from background (ANL, 1978).

The June 1996 survey (Olin, 1996) was conducted to "assess the radiological condition of the facility [Building 55], and to compare the findings with the unconditional release criteria established by the State of Illinois." (Note: The release criteria are essentially the same as those currently in use at DOE facilities.) Building 55 was partially demolished at the time of this survey. The survey consisted of general area photon dose rate measurements, wipe surveys throughout the building to assess loose contamination, and direct beta/gamma scans throughout the building structure and on piles of associated rubble, with particular attention paid to horizontal surfaces, drain lines, system piping, chemical vats, seams, openings, and other areas where contamination could likely collect. Twelve physical samples were also collected for laboratory analyses to identify activity and isotopes present. Of these twelve, eight were soil samples around the building perimeter, and four were from areas of elevated direct radiation readings. One of the four samples in Building 55 is described as "yellow powder" (likely uranium yellowcake) (Olin, 1996). The September 1996 survey was performed to assess radiological conditions across the remainder of the site.

7.0 Feasibility of Dose Reconstruction for the Proposed Class

The feasibility determination for the proposed class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(1). Under that Act and rule, NIOSH must establish whether or not it has access to sufficient information either to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or to estimate the radiation doses to members of the class more precisely than a maximum dose estimate. If NIOSH has access to sufficient information for either case, NIOSH would then determine that it was feasible to conduct dose reconstructions.

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class (discussed in Section 9.0 of this report). If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.6. This approach is discussed in OCAS's SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data (Section 7.1)
- The feasibility of reconstructing internal radiation doses (Section 7.2)
- The feasibility of reconstructing external radiation doses (Section 7.3)
- The bases for petitions SEC-00058 and SEC-00045 as submitted by the petitioners (Section 7.4)

7.1 Pedigree of Blockson Chemical Company Data

This subsection answers questions that need to be asked before performing a feasibility evaluation. Data Pedigree addresses the background, history, and origin of the data. It requires looking at site methodologies that may have changed over time; primary versus secondary data sources and whether they match; and whether data are internally consistent. All these issues form the bedrock of the researcher's confidence and later conclusions about the data's quality, credibility, reliability, and sufficiency for determining the feasibility of dose reconstruction.

7.1.1 Internal Data Review

NIOSH has records and data from 122 urine samples from 25 different employees collected from April, 1954 to February, 1958 (nineteen employees have multiple samples). Ten records of the urinalyses are available, with results for 12 to 13 workers on each report. Standard photofluorometric methods were used by the AEC New York Operations Office, Health and Safety Division (AEC, 1954-1958). Results of the samples ranged from 0 to 17 ug of uranium per liter of urine, and detection thresholds likely ranged between 2 and 3.8 ug of uranium per liter of urine (AEC, 1958).

The original New York Operations Office (NYOO) documentation is available for review and was used both to develop the Blockson TBD and in this evaluation. The hard-copy data sheets, provided on a standard NYOO form, include the site/plant identification, the individual sampled, the date(s) of the sample, the type of sample, information on the analysis performed, and the analysis results in ug/L (handwritten). No other source of information (database or otherwise) has been identified as of the time of this evaluation; therefore, a quality check of this data was not possible.

7.1.2 External Data Review

NIOSH has been unable to find any record of external dosimetry monitoring of Blockson uranium workers. Therefore, it is necessary to use source term data to estimate external exposures.

Although using a source term is not the preferred method for estimating external worker doses, in the absence of personal dosimeter or monitoring data, co-worker data, or area monitoring data, a source term with process information may be used to estimate and bound external doses (OCAS-IG-001, Table 1.1). The source term present at Blockson can be derived from the AEC monthly production reports, the design capacity of the uranium extraction process, contract limits on production, and the source term data input into *Monte Carlo N-Particle eXtended (MCNPX)* (version 2.5.0) for exposure rate calculation from drums of yellowcake (AEC, 1955; Lopker, 1951; AEC, 1951). A claimant-favorable assumption of worker occupancy in the vicinity of the source term can be used to bound the external doses.

NIOSH has not located any documentation regarding AEC-required physical examinations for Blockson employees. Nevertheless, several claimants reported that chest X-rays were performed as part of either pre-employment or periodic physicals. One claimant reported that he had received chest X-rays during work in the "HF" building after he had left Building 55. On this basis, NIOSH assumes employees received an annual chest X-ray and uses claimant-favorable methods and data to estimate related radiation doses.

7.2 Internal Radiation Doses at Blockson Chemical Company

During chemical processes through which uranium is concentrated, contamination and dust exposures are minimal. Such wet chemical processes occur in closed tanks and piping systems. The greatest potential for exposure to radioactive materials associated with a uranium recovery process arises in the final packing areas. Here the essentially-pure uranium compound is dried and barreled for shipping, resulting in a potentially-dusty operation (OCAS-TKBS-0002, Rev. 01). Another dust-generating operation was the calcining and crushing of dry phosphate rock upon arrival at the Blockson facility. However, the radioactivity concentration of the unprocessed rock was far lower than that of the yellowcake, as was the potential internal radiation dose from the inhalation of this dust. Dust from rock is expected to contain uranium, thorium, and their decay series radionuclides in secular equilibrium. The values of internal exposure that represent an upper bound are summarized in Section 7.2.3.1 of this document.

There was a potential for internal radiation dose during the development phase of Blockson's uranium extraction process, including laboratory experimentation and pilot plant operations. The pilot plant tested methods determined from laboratory scale testing. The operational systems in the pilot plant were assumed to be very similar to the production systems, although the exact configurations are not known. Laboratory and pilot plant work involved the same source of radioactive materials as those in Building 55, except on a much smaller scale and with intermittent operation for shorter periods of time. Therefore, the doses modeled for Building 55 workers are used to bound doses received by workers in the pilot plant operation.

The principal sources of internal radiation doses for members of the proposed class included dust from phosphate rock crushing and uranium dust from drying and loading yellowcake into containers for transfer to the AEC (OCAS-TKBS-0002, Rev. 01). Other sources of internal dose include (1) residual contamination on building and equipment surfaces; and (2) radon and radon progeny that may have been present on site.

7.2.1 Process-Related Internal Doses at Blockson Chemical Company

The preferred method for estimating internal dose from uranium is by urinalysis. Urinalysis results for total uranium are available for 25 Blockson workers from April 1954 through February 1958. The results are documented on 10 urinalysis reports, with 12 to 14 workers listed on each report. These workers include personnel assumed to be exposed to the highest concentrations present at the site (e.g., process operators), as well as workers unlikely to be regularly exposed to the highest concentrations.

The urinalysis data reports list individuals either by last name and first initial or by last name only. NIOSH has documentation confirming that five individuals were involved in uranium process work in Building 55. Their job titles were:

- Chemical Operator: Confirmed in NIOSH records as claimant in previous Blockson-related dose reconstruction; confirmed in urinalysis report by first and last name; confirmed by CATI interview; stated that he scraped dried yellowcake out of the drier and shoveled it into drums; stated it was a three-man operation that ran the powder form on day shift and performed wet processing on night shift.

- Supervisor: Identified by first and last name by the Chemical Operator listed above as his Supervisor during his uranium process work in Building 55; listed by last name and first initial in multiple urinalysis results.

- Chemical Product Analyst: Confirmed in NIOSH records as claimant in previous Blockson-related dose reconstruction; confirmed in urinalysis report by an uncommon last-name-only match; job title confirmed by CATI interview; stated that he sometimes analyzed uranium samples.

- Control Chemist: Confirmed in NIOSH records as claimant in previous Blockson-related dose reconstruction; confirmed by last name only on two urinalysis sample results; job title confirmed by CATI interview; stated he worked in Building 55 during uranium processing.

- Filter Operator: Petitioner for SEC-00058; initial and last name shown in urinalysis results match petitioner's middle initial and last name. Petitioner stated that he worked in Building 55 and that he was a filter operator.

The urinalysis data are considered to be that of actual Building 55 uranium workers, based on the following:

- A letter of request from Blockson Chemical to the AEC for personnel urinalysis for "about 20 workers involved in uranium work" (Barr, 1953)

- Blockson pre-operational labor estimates listing the need for 18 workers of specific types (Lopker, 1951)

- Urinalysis records of 122 samples for 25 workers with five names being confirmed as being involved in uranium process work in Building 55

- Three of the workers listed on urinalysis reports having Blockson-related dose reconstructions on file

- One of the three dose reconstruction claimants having performed work that would be considered having the highest potential for exposure (loading yellowcake into drums)

- The SEC-00058 petitioner, a Building 55 Filter Operator, having a last name and middle initial match an initial and last name listed in urinalysis reports

- The assumed workforce size being supported by former Blockson employees' estimates of the Building 55 work force

Based on review of the available data (i.e., production reports, contract limitations), uranium extraction operations performed at Blockson were consistent over the entire operational period. In an effort to further improve uranium recovery processes, laboratory work and pilot studies continued during the construction of Building 55. Building 55 was put into operation on August 15, 1952, and by February 1953, no major changes in processes were made (Stoltz, 1953). Based on production rate reports, NIOSH has assumed that the internal monitoring data represent the highest potential for exposure from 1951 to 1962. Exposure reports indicate that the average production was lower from August 1952 through the middle of 1955. Therefore, the urinalysis monitoring performed from April 1954 through February 1958 represents the highest production period and maximum potential for exposure. In the case of laboratory and pilot plant operations, this presents a claimant-favorable bounding estimate. Since this work involved the same source of radioactive materials as those in

Building 55, except on a smaller scale and only operated intermittently for short periods, the doses modeled for Building 55 workers are used to bound doses received by workers in the pilot plant operation and in the laboratory.

7.2.2 Ambient Environmental Internal Radiation Doses at Blockson Chemical

Ambient environmental dose is accounted for in the assignment of process-related dose.

7.2.3 Internal Dose Reconstruction

NIOSH evaluated the potential exposures from possible intakes of radioacitive material based on uranium extraction operations in Building 55 and related work at the Blockson Chemical facility. Although some of the work was not directly related to uranium extraction (e.g., the calcination of phosphate rock), potential radiological exposures associated with this work have been evaluated as it is considered work that is associated with uranium recovery activities because of changes made in the phosphate processing procedure at Blockson to improve uranium recovery in other processes. The calciner has been chosen to provide bounding intakes for the related work as discussed below (OCAS-TKBS-0002, Rev. 01).

Workers are assumed to have worked in either Building 55 full-time or elsewhere (outside of Building 55) full-time. The assumption is determined by the location that provides the highest dose to the organ or tissue of interest. Worker interviews indicate that some workers, such as maintenance workers, worked in various locations during their employment; this is consistent with industry practices. Since there is no definitive way to determine the amount of time any particular worker spent in one location or another, it will be assumed that a worker was always in the location that results in the largest radiation dose. Intake estimates are lower for workers outside of Building 55, but inhalation of Type S uranium (and other radionuclides) could have been present in the phosphate rock. For some tissues, such as the lungs, this results in a larger dose per unit intake than inhalation of the Type M material that was present in Building 55, such that the intakes from phosphate rock handling, and may result in a larger dose (OCAS-TKBS-0002, Rev. 01).

7.2.3.1 Calcining

A 1983 survey (Olin, 1996) provides dust measurements results of several locations in the Blockson plant for 12 general area and personnel breathing zones, none of which are Building 55. The maximum reported total dust result from the 1983 study was 6.37 mg/m^3 and was associated with trisodium phosphate operations. With the exception of a filter platform in Building 40, all gross alpha measurements of the air samples were less than the sensitivity of the equipment. Based on a more extensive study performed by the EPA at another wet process phosphate plant, all survey results are less than the intakes provided below. Therefore, the maximum result from the EPA study, described below, is used to bound intakes at Blockson (from work outside uranium extraction operations).

The EPA performed a thorough study of dust loading and radionuclide concentrations in air throughout phosphate ore processing at an Idaho Phosphate facility (EPA, 1978). The Idaho Phosphate facility utilized the wet-process method to process phosphate rock—the same method used by Blockson. Various air samples were taken at locations throughout the plant. The samples were analyzed for total dust loading and airborne radioactivity concentrations were reported. The atmospheric dust concentrations were not provided, but have been calculated from data. Specifically, the total reported mass of dust on the filter paper (in mg) was divided by the volume of air sampled to derive the atmospheric dust loading in units of mg/m^3, which are listed in Table 7-1. The highest dust concentration was from Calciner #3, which was 50.4 mg/m^3, and is indicative of an operation with visible dust. Information in the report indicates that Calciner #3 was located in the Calciner Building; however, no other information on Calciner #3 was provided in the report. Samples were also taken from several locations in the phosphoric acid building.

Table 7-1: Dust Concentration in Air During Phosphate Industry Processes

Material	Dust Loading (mg/m^3)
Grinder mill	6.29
Ore unloading, storage	5.43
Calciner control room	1.73
Calciner	50.4
Phos. Acid digester	15.3
Outside control room	6.5
Continuous filter	2.72
Control room	1.5
TSP storage	1.37
TSP dryer	33.9
Acidulation TSP disch.	2.63
200 Ammophos plant	18.6
100 Ammophos plant	8.68
Library	0.92
100 plant storage	8.61
200 plant storage	4.12

Notes:
The data and information contained in this table are from Table 2 in OCAS-TKBS-0002, Rev. 01.

Blockson operated a calciner to break down organic matter and to roast the rock into a form that optimized recovery of uranium and for other processing purposes unrelated to uranium extraction work. The calciner was a large outdoor furnace that utilized a dust collector (OCAS-TKBS-0002, Rev. 01).[3] The dust concentrations at Blockson's calciner would be expected to be lower than the one listed in Table 7-1 because of dilution with open air. The use of a dust collector at Blockson also indicates that some effort was made to control dust. Although it could be expected that some localized areas may have had high concentrations for short durations, such as when sampling the calcined rock, average dust concentrations would be expected to be lower than that reported for the operations at the phoshate plant, as discussed above. Therefore, these dust concentrations are being used to determine bounding dust concentrations for operations at Blockson outside of Building 55.

Worker exposure from calcining was calculated based on airborne dust data, presented above. Intake quantities for uranium and thorium nuclides (and associated progeny) were calculated based on continuous exposure to an airborne dust loading of 50.4 mg/m^3. Bounding intakes from uranium and thorium (and associated progeny) were calculated based on a breathing rate of 1.2 m^3/hour and being

[3] OCAS-TKBS-0002, Rev. 01 references NIOSH, 2007.

exposed to that high level of dust for 2,000 hours per year. For these calculations, the uranium mass was assumed to be all uranium-238, as it represents over 99% of the uranium mass in natural uranium (OCAS-TKBS-0002, Rev. 01). Uranium-234, thorium-230, radium-226, and other nuclides in the uranium-238 chain listed in Table 7-2 are assumed to be in equilibrium with uranium-238 during phosphate rock crushing and calcining operations. Uranium-235 was not included because the method of calculating uranium activity allowed for the small intake contribution from uranium-235. An additional parameter used in the calculation includes an assumed 0.014% uranium content in phosphate rock (Stoltz, 1958). Intake values have been normalized to calendar days. Ingestion intakes were calculated using the intake quantities and applying the methodology in OCAS-TIB-0009, *Estimation of Ingestion Intakes.*

Polonium has a boiling point of 962°C, or 1764°F. Due to the high temperature used in the furnace, calcining temperatures in other phosphate facilities are known to have increased airborne particulate concentrations of polonium-210. Radiological data from the Idaho Phosphate Facility calciner indicate that polonium-210 concentration levels in the air at the calciner were 10 times higher than the uranium-238 concentration (EPA, 1978). Elevated polonium-210 concentrations from phosphate facility calcination have also been reported by Boothe (OCAS-TKBS-0002, Rev. 01). Consequently, intakes of polonium-210 from calcining are estimated to be 10 times higher than intakes of uranium-238, as shown in Table 7-2.

Table 7-2 Inhalation and Ingestion Rate for Calcining[1, 2]

Radionuclides	Inhalation pCi/day	Ingestion pCi/day
U-238, Th-230, U-234, Ra-226, Pb-210	16	0.47
Po-210	160	4.7
Th-231, Pa-231, Ac-227[3]	0.73	0.021
Th-232, Ra-228, Th-228	0.52	0.016

Notes:
The data and information contained in this table are from Table 3 in OCAS-TKBS-0002, Rev. 01.
[1] Intakes have been normalized to calendar days.
[2] Both inhalation and ingestion should be assigned for calcining operations.
[3] Uranium-235 is allowed for in the uranium-238 and uranium-234 values. Values given are for radionuclides in the uranium-235 chain.

7.2.3.2 Building 55

No air sampling results are available from Blockson to characterize airborne radioactivity concentrations. However, air sampling results from mills with some common activities have been published. The greatest potential for internal uranium exposure in the Blockson uranium recovery process is most likely associated with handling dried uranium compounds in the packaging areas. There, the uranium concentrate (yellowcake) was dried and barreled for shipping, resulting in a potentially dusty operation (NRC, 2002; Eidson, 1984; Personal Communication, 2002).

While there are no air sampling results available from Blockson to characterize airborne concentrations of uranium, air sampling results from mills with similar activities have been published. For example, a study was performed relating to uranium aerosols generated during yellowcake packaging operations at four uranium mills. The study showed that precipitated yellowcake was de-watered in a filter process and then dried in an oven and placed in 55-gallon drums. Blockson also de-watered the yellowcake prior to packaging it in drums (Lopker, 1951; NIOSH, 2007; Clegg, 1958).

Eidson and Damon's study described a sequence of steps common to all four uranium ore processing mills:

- Step One—No activity: This is when the plant is shut down for maintenance or when all available yellowcake has been barreled. Worker exposure to airborne yellowcake is minimal in this step.

- Step Two—Barrel loading: This occurs when a barrel is placed under a hopper containing the dried yellowcake. The yellowcake is allowed to fall into the barrel. The amount of time workers spend in this area depends on the volume of the yellowcake in the hopper.
  NOTE: Former Blockson workers indicate a manual method of drum loading was used at Blockson, in which, the dried yellowcake was poured from a drying pan into a funnel-type chute located over an open drum.

- Step Three—Barrel uncovering: This step occurs when a filled barrel is removed from beneath the hopper. In some cases, the barrel may be vibrated to compact the yellowcake before removing the barrel from beneath the hopper.
  NOTE: There is no indication that barrels at Blockson were vibrated.

- Step Four—Powder sampling: This occurs when a worker takes a sample of yellowcake for laboratory analysis.

- Step Five—Lid sealing: This occurs when a worker places a lid on the barrel and seals it.

- Step Six—Other activities: This step included maintenance and cleaning the area with hoses.

7.2.3.3 Building 55 Personnel Monitoring

No air sampling results are available for estimating intakes to Blockson workers. However, uranium urinalysis results are available for some Blockson workers, which is the preferred method of estimating internal dose received from exposure to uranium. Bioassay results are not available for individual claims submitted to NIOSH for dose reconstruction under EEOICPA, although the names on available results match a few workers whose job descriptions at Blockson are known.

Bioassay results were evaluated to provide claimant-favorable intake rates that are considered bounding for Blockson workers. This evaluation assumes two categories of workers. One category of workers includes those that are considered to have the highest potential for exposure; this category includes operators who routinely handled and packaged dried yellowcake. In this evaluation report, these workers are categorized as production workers. Because there are no definitive data to differentiate exposure rates for production workers who are exposed to the highest concentrations and those exposed only intermittently, such as maintenance mechanics, all production workers are assumed to be exposed to the bounding concentration. The second category of exposure in this evaluation is administrative workers. Intake rates for administrative workers are based on the assumption that they were not in close proximity to the dried uncontained material, but could have been exposed to elevated levels of general area airborne uranium contamination on a continual basis.

Records indicate that Blockson employed approximately 20 people in the uranium recovery operations. In 1951, prior to start up of operations, Blockson sent a document to the AEC that included a best estimate of manufacturing costs, with a breakdown of labor by category. Blockson projected the following personnel needs for the uranium operations: two operators (per shift), one chemist (per shift), two daymen, two mechanics (on average), one clerk, one development chemist, and one foreman. From the rate information and total estimate provided, it could be determined that Blockson assumed 4.2 shifts per day, which would allow for 24-hour operations each day of the week. According to pre-operational estimates, this would result in about 18 full-time personnel and two part-time personnel (Lopker, 1951).

In September 1953, after start up of operations, the AEC received a request for bioassay analysis services for "about twenty production workers engaged in uranium processing at Blockson Chemical Company" (Barr, 1953). The first known sample results from these services were reported in April 1954 by the AEC New York Operations Office Health and Safety Laboratory (HASL). Subsequently, bioassay results on nine other occasions were reported by HASL through February 1958. Sample results are available for twenty-five different workers.

Urinalysis records were found on reports from the AEC New York Operations Office, Health and Safety Division. One hundred twenty-two sample results are available with results ranging from 0 to 17 μg uranium per liter (the analyses were performed by fluorimetry). Of the twenty-five workers, nineteen workers had multiple bioassay results and six workers had a single sample result reported. The nineteen workers with multiple results were used to determine a distribution of inhalation intake rates. One of the nineteen workers had multiple samples over two different time periods with a two year break without urinalysis. For purposes of estimating worker intakes, that worker's results were analyzed as two workers, resulting in a distribution of intake rates for twenty workers. The workers with only one sample result were not used; however, those six results ranged from 0 to 6 μg per liter, which fit in the distribution of bioassay results.

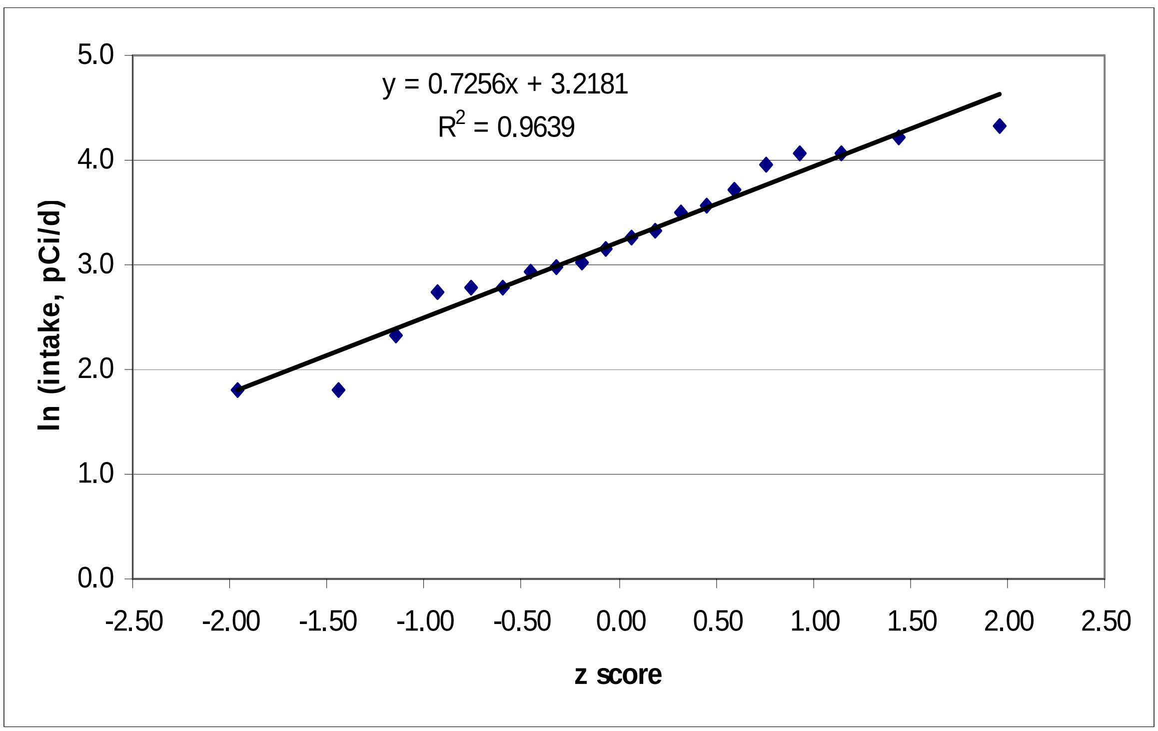
Some of the names on the urinalysis reports have been matched with names of workers whose jobs in Building 55 during uranium recovery work are known. These workers include two process operators, two chemists/analysts, and a supervisor. Their bioassay results support the exposure assumptions in this evaluation—the highest exposed of those known workers was an operator whose job included drumming dried yellowcake. The intake recommendations in this evaluation are favorable in comparison to the data for those workers.

Based on the clearance rate from the lungs, the International Commission on Radiological Protection (ICRP) recommends three material types for solubility of inhaled uranium: Types F, M and S (ICRP 66). Various studies have shown that U_3O_8 closely corresponds to the clearance rate associated with material Type M. Studies have also shown that high fired material can produce uranium compounds that clear more slowly from the lungs—indicative of material Type S (Rucker, no date). Based on the process used at Blockson, Type M uranium is the most appropriate lung solubility material type. The U_3O_8 product was produced from wet phosphoric acid by filtering the precipitated uranium and then using a dryer to de-water the solids (Stoltz, 1953). Calcination was performed on phosphate rock prior to chemical processing where the intakes of highly insoluble Type S material from calciner could have occurred. After the calcined rock was digested in sulfuric acid and oxidized, no additional calcining or high firing was performed in Building 55. Based on these processes and the results of various studies that have been summarized by Rucker, et al., Type M material is being used in this evaluation to derive intakes from bioassay results (Rucker, no date).

The Blockson bioassay results were reported in µg per liter, were converted to µg per day by multiplying by a daily excretion rate of 1.4 liters, and then converted to pCi/day by multiplying by 0.677 pCi per µg of natural uranium. Individual worker intakes were determined using IMBA-Expert™ by assuming a chronic inhalation intake of Type M uranium with parameters recommended by the ICRP (OCAS-TKBS-0002, Rev. 01).

For daily intake rate calculation purposes, intakes were assumed to have occurred beginning in the year sampled and ending with the last sample date. The results were given an absolute error of 1.0, which equally weights the sample results for fitting purposes in IMBA-Expert. Daily intake rates ranged from 6 to 76 pCi/day. The intake rate results fit well to a lognormal distribution having a median value of 25 pCi/day with a geometric standard deviation of 2.1, as shown in Figure 7-1. The analysis of bioassay results with the assumption of 100% of the intake via inhalation is a claimant-favorable assessment of intakes from all pathways except when calculating dose to certain tissues of the gastrointestinal tract. Dose from ingestion is discussed below.

Figure 7-1: Distribution of Daily Uranium Intakes



Source: OCAS-TKBS-0002, Rev. 01

Production workers are assumed to have been continually exposed at the 95th percentile intake rate and administrative personnel are assumed to have been exposed continually at the median intake rate. The total uranium intakes are applied as 50% uranium-238 and 50% uranium-234, which allow for intakes of uranium-235. Intakes of those long-lived radionuclides that are significant to internal dose are listed in Table 7-3.

Table 7-3: Inhalation Rate for Building 55[1, 2, 3]

Radionuclides	Production workers Intake (pCi/d)	Administrative workers Intake (pCi/d)
U-238, Th-230, U-234, Pb-210, Po-210	41	13
Th-231, Pa-231, Ac-227[4]	1.9	0.59
Ra-226	1.9	0.59
Th-232, Ra-228, Th-228	1.4	0.41

Notes:
The data and information contained in this table are from Table 4a in OCAS-TKBS-0002, Rev. 01.
[1] Intake rates are normalized to units of calendar days.
[2] Intakes are based on Type M lung solubility for materials likely to have been present in Building 55 operations except for lead and polonium. Lead-210 and polonium-210 are Type F or M per ICRP 68.
[3] See Table 7-4 for dose to tissues of the gastrointestinal tract.
[4] Uranium-235 is allowed for in the uranium-238 and uranium-234 values. Values given are for radionuclides in the uranium-235 chain.

Due to contact with contaminated surfaces and/or from eating or drinking, workers also had the potential to ingest uranium. When deriving intakes from the bioassay results, a chronic ingestion of uranium results in a higher dose to certain tissues of the gastrointestinal tract than when compared to the dose from the inhalation intakes. Therefore, intakes are presented in Table 7-4 based on the presumption that all the uranium in the workers urine was due to ingestion. Although inhalation is the most common mode of intake in a production facility, the presumption of the ingestion pathway provides an upper bounding value for dose from ingestion.

Table 7-4: Ingestion Rate for Building 55[1, 2]

Radionuclide	f1 Values[4]	Production Workers Intake (pCi/d)	Administrative Workers Intake (pCi/d)
U-238, U-234 Th-230 Pb-210 Po-210	0.02 0.0005 0.2 0.1	139	41
Th-231, Pa-231, Ac-227[3]	0.0005	6.4	1.9
Ra-226	0.2	6.4	1.9
Th-232, Th-228 Ra-228	0.0004 0.2	4.5	1.4

Notes:
The data and information contained in this table are from Table 4b in OCAS-TKBS-0002, Rev. 01.
[1] Intake rates are normalized to units of calendar days.
[2] Ingestion intakes provide bounding dose to the stomach, small intestine, upper large intestine, lower large intestine, and colon. See Table 7-3 for estimating dose to all other tissues.
[3] Uranium-235 is allowed for in the uranium-238 and uranium-234 values. Values given are for radionuclides in the uranium-235 chain.
[4] f1 values are from ICRP 66.

7.2.3.3 Pilot Plant and Laboratory

The location of the Pilot plant that was built and used in 1951 and early 1952 has not been determined. The purpose of the Pilot plant was to collect data and operate at a much lower capacity than Building 55. The Pilot plant ran intermittently during developmental work. The Pilot plant tested methods determined from laboratory scale testing. The operations performed in the Pilot plant were documented by Blockson (Stoltz, 1953). Since this work involved the same source of radioactive materials as those in Building 55, except on a smaller scale with shorter periods of operation, the doses modeled for Building 55 workers are used to bound doses received by workers in the Pilot plant and workers in the laboratory.

7.2.3.4 Radon Exposures

Radon exposures to workers from uranium extraction work at phosphate plants have been evaluated (ORAUT-OTIB-0043). For reconstructing lung doses, all workers at Blockson are assigned an exposure at the 95th percentile of 0.112 WLM (working level month) per year, due to radon progeny. Doses to other organs are assigned as alpha doses. Table 7-5 lists doses from radon exposures.

Table 7-5: Radon Exposures

Dose Component	Annual Dose/Exposure[1]	Distribution
Radon progeny	0.112 WLM (lungs only)	Constant value
Radon progeny	ET1 and ET2 tissues[2]	Constant value
Radon gas	0.002 rem alpha (non-respiratory tract tissues only)	Constant value

Notes:
The data and information contained in this table are from Table 5 in OCAS-TKBS-0002, Rev. 01.
1. Exposure and dose values from ORAUT-OTIB-0043. Values are normalized for a 365 day year.
2. ET1 and ET2 doses are to be applied as alpha dose and calculated from WLM values using conversion factors in OCAS-TIB-0011.

7.2.3.5 Residual Radioactivity

Internal inhalation doses from residual contamination, as addressed in OCAS-TKBS-0002, Rev. 01, are derived from the internal dose estimates from the operational period intakes and from estimated airborne radioactivity that is based on the 1978 FUSRAP survey data (ANL, 1978). The internal dose estimates and estimated airborne radioactivity are used to derive two estimated intake rate values (1962 and 1978, respectively), which in turn are used to model an exponential reduction constant. The reduction constant is then used to derive annual intakes for the entire residual contamination period up to the year 1996, when Building 55 was demolished.

To estimate bounding intakes for ingestion during the residual contamination period, the daily ingestion rate is reduced at the same rate as the inhalation intakes, via the derived exponential reduction constant previously discussed. The bounding ingestion intake on April 1, 1962 (which is based on urinalysis data) is used as the starting point, and the exponential reduction model is applied through the number of elapsed exposure days after April1, 1962.

These residual radioactivity approaches are reasonable in that the intake rate at the beginning of the residual period (April 1, 1962) is based on urinalysis and production rate data, and the 1978 airborne estimate is based on documented radiological survey data. The two data points provide the basis for extrapolating annual intakes for the entire residual contamination period.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

This evaluation concludes that internal dose reconstruction for members of the proposed class is feasible, based on: (1) the availability of representative personnel uranium internal monitoring data for workers in Building 55, (2) the application of 95th percentile doses that are bounding, and (3) the use of claimant favorable assumptions with regard to other non-uranium radionuclides and potential uptakes in plant areas outside of Building 55.

7.3 External Radiation Doses at Blockson Chemical Company

Because phosphate rock contains Naturally Occurring Radioactive Material (NORM), any work involving phosphates potentially exposes workers to radioactivity. The principal sources of external radiation doses for members of the proposed class include:

- Drums of yellowcake
- Residual contamination
- Radium
- Medical X-rays

7.3.1 Process-Related External Radiation Doses at Blockson Chemical

External dosimetry data are not known to exist for Blockson workers, and data capture efforts for the EEOICPA dose reconstruction project have not found any direct radiation survey results for the Blockson facility during the uranium extraction operational period. Exposure from operations outside of Building 55 has been considered based on studies of doses received by workers at similar plants. Those studies did not include dose received from uranium extraction operations. Therefore, source term information has been used to estimate external doses to workers involved in uranium extraction operations.

7.3.2 Ambient Environmental External Radiation Doses at Blockson Chemical

Ambient environmental dose is accounted for in the assigning of process-related dose.

7.3.3 Blockson Chemical Occupational X-Ray Examinations

OCAS-TKBS-0002, Rev. 01 discusses the method for evaluating and assigning dose associated with occupational medical X-rays (required as a condition of employment) at the Blockson Chemical Company, although NIOSH has discovered no documents indicating that Blockson or the AEC required X-rays of the workers.

7.3.4 Previous External Dose Reconstructions

By June 26, 2007, 111 EEOICPA claims meeting the proposed class definition being evaluated in this report had been submitted to NIOSH. Of those 111 claims, NIOSH has completed dose reconstructions for 102 claims. These claims cover the entire range of operations at Blockson Chemical; however, no indication of personnel external radiation exposure monitoring was indicated.

There is an established protocol for assessing external exposure when performing dose reconstructions (these protocol steps are discussed in the following subsections):

- Photon Dose
- Beta Dose
- Neutron Dose
- Unmonitored Individuals Working in Production Areas
- Medical X-ray

7.3.4.1 Photon Dose

The primary source of photon dose to Blockson workers was from drums of uranium yellowcake. Other sources to be considered are residual contamination and radium.

Exposure to Drums of Uranium Yellowcake — *Monte Carlo N-Particle eXtended* (version 2.5.0) was used to determine the dose rate per Curie of uranium-238 regardless of the actual activity in the drum. This was later adjusted for actual source activity to compare actual dose rates. All radionuclide concentrations were calculated based on the ratio to uranium-238 for determination of the number of photons and electrons per decay of uranium-238. For the purposes of this evaluation, branching ratio adjusted equilibrium was assumed.

The dose rate was determined at 77.9 cm above the ground, and 30 cm from the edge of the drum for both the photon and beta emissions of natural uranium and its progeny. NIOSH used ICRP Publication 74 (Table A.1) to convert the photon flux to units of air kerma (ICRP 74; OCAS-TKBS-0002, Rev. 01). Results are provided in Table 7-6.

Table 7-6: Uranium Dose Rates from Drums of Yellowcake

Density of U_3O_8 (g/cm^{-3})	Activity of U in drum (Ci)	Photon emission dose (rad/hr)	Bremsstrahlung dose (rad/hr)	Total dose rate at 30 cm (rad/hr)
1	6.242E-02	5.62E-03	4.08E-04	5.53E-03
2	1.248E-01	5.97E-03	4.39E-04	6.06E-03
4	2.497E-01	5. 99E-03	4.62E-04	6.43E-03
6	3.745E-01	6.02E-03	4.38E-04	6.43E-03
6.7	4.182E-01	5.12E-03	4.52E-04	6.47E-03

Notes:
The data and information contained in this table are from Table 7 in OCAS-TKBS-0002, Rev. 01.
*** The drum begins to noticeably impact the dose rates at low material concentration.**

The air kerma dose rates were converted to annual organ doses by assuming a worker's exposure time was lognormally distributed. The median exposure time was determined by assuming all workers were working eight hours per day, one day per week, at a distance of one foot from the drum. This was normalized to 400 hours per work-year. The 95th percentile exposure time was determined by assuming the worker spent a standard 2000-hour work-year at a distance of one-foot from the drum. This results in a whole body dose distribution with a median value of 2.572 rad per year with a geometric standard deviation of 2.7.

To calculate organ doses for use in the NIOSH Interactive RadioEpidemiological Program (NIOSH-IREP), Monte Carlo methods were used to multiply the whole body dose and energy split by the triangular organ dose conversion factors for kerma to organ dose found in the NIOSH *External Dose Reconstruction Implementation Guideline* (OCAS-IG-001). The results are annual doses that are lognormally distributed and can be seen in Table 8 of OCAS-TKBS-002, Rev. 01. For skin, air kerma values were multiplied by an organ dose conversion factor of 1.0.

Photon Dose from Residual Contamination — Photon dose from residual contamination is estimated by analyses of the radiological survey performed by Argonne National Laboratory in November 1978 (ANL, 1978). A dose rate was taken at contact and at one meter on all 63 spots in which contamination was detected. The dose rates at one meter on seven of the 63 "hot" spots ranged from 0.04 mR/hr to 0.2 mR/hour. The other 56 spots had one-meter dose rates indistinguishable from background. The reported background dose rate on the instrument used was between 0.02 mR/hr and 0.03 mR/hr. The results of the seven spots with measurable one-meter dose rates included the background dose rates. From a review of the survey map and results, it seems improbable that a worker could be significantly exposed above the background rate of 0.03 mR/hr for significant time. However, in the absence of individual dosimeter data, whole body dose rates are modeled by a lognormal distribution by assuming a worker was exposed to the 0.03 mR/hr rate for 2,000 hours per year, which results in an annual exposure of 60 mR, or 0.06 R. To allow for uncertainty this value is applied as the median of a lognormal distribution. The geometric standard deviation is 3.2, which was determined by assuming that the 95th percentile dose rate is equal to the maximum observed result of 0.2 mR/hr (OCAS-TKBS-0002, Rev. 01).

The 1978 survey suggests that the Blockson facility was only contaminated in localized spots or that some areas of surface contamination were not subject to the same contamination depletion rate that would be expected from natural processes and from general cleaning and weathering that would have occurred since 1962. The seven spots were on small areas of floor (reported to be about 0.5 m^2 each), on a pipe inlet, and on a machine (OCAS-TKBS-0002, Rev. 01). Additionally, since the normal non-AEC related operations at Blockson produced byproduct that contained small amounts of uranium and daughter products, it is unknown if the byproduct would have contributed to the contamination of the facility after AEC operations ended in 1962. Based on the above considerations and the absence of more data, a claimant-favorable assumption is made for deriving dose rates prior to 1978. It is assumed that the few spots in the facility with measurable dose rates were representative of the entire facility from the operational period to the present or until the end of the workers' EEOICPA covered employment.

Photon Dose from Radium — OCAS-TKBS-0002, Rev. 01 assumes that 4% of radium-226 reports to the phosphoric acid. ORAUT-OTIB-0043 estimates an upper bound external dose to workers at wet process phosphate plants at 0.220 rem/year, divided equally between 30-250 keV photons and photons >250 keV. These doses would include external exposures to the radium bearing phosphogypsum that is filtered out during phosphoric acid production, but would not have included doses that have been received due to concentration of uranium, such as Blockson did in Building 55. The 0.220 rem/year bounding external dose from other phosphate facilities are lower than the modeled external doses from Building 55 discussed in Section 4.2. Therefore, Building 55 modeled doses are considered to be an upper bound of the external dose from the entire Blockson facility.

7.3.4.2 Beta Dose

The principal sources of beta exposure considered for Blockson workers include shallow dose from exposure to open drums of yellowcake, shallow dose from skin contaminated with yellowcake, skin dose from contact with contaminated work clothing, and skin dose from handling and cleaning filter media. Each potential source is discussed below.

Shallow Dose from Drums of Yellowcake — It is assumed that there was a potential for workers to receive a shallow dose from exposure to open drums of yellowcake during drum loading and sealing. The dose rate at one foot from the surface of aged yellowcake is between 1 and 2 mrem/hour. It is assumed that the production workers spent eight hours per week, 50 weeks per year, at one foot from the surface of aged yellowcake at a dose rate of 2 mrem/hour. To allow for uncertainty, the time of exposure was assumed to be lognormally distributed with the 95th percentile exposure time assumed to 40 hours per week, 50 weeks per year. This assumption results in an upper shallow beta dose of 0.8 rem/year with a geometric standard deviation of 2.7. The 0.8 rem per year was adjusted to allow for beta dose from other radionuclides that are assumed to be present in the uranium, with branching ratio adjusted equilibrium assumed. The relative activity of each radionuclide was applied to Federal Guidance Report No. 12 dose conversion factors for skin for exposure to contaminated surfaces. Those factors indicate that uranium-238, thorium-234, protactinium-234m, protactinium -234, and uranium-234 account for about 66% of the skin dose. Adjusted beta dose is provided in Table 7-7. The calculated beta dose has not been reduced to allow for doses to areas of the skin that are typically covered by clothing (which results in a reduction of beta dose to the skin) (OCAS-TKBS-0002, Rev. 01).

Shallow Dose from Skin Contamination — It is also assumed that there was a potential for workers to receive a shallow dose from electrons due to skin contaminated with yellowcake. The amount of skin contamination can be calculated by using the measured deposition velocity of 4-µm particles to skin of .012 m/s (Andersson, 2002; Fogh, 1999), assuming that the material was deposited on the skin for an entire 8-hour shift. Modeled dose from this method is negligible when compared to the shallow dose estimate from exposure to a drum of aged yellowcake discussed above and estimated skin dose from contaminated clothing as discussed below and shown in Table 7-6.

Beta Dose from Contaminated Clothing — Skin dose from contamination transfer to the skin and from contact with contaminated work clothing was also considered. Mallinckrodt Chemical Company dose rate studies from contaminated clothing were evaluated and average dose rates from contaminated clothing at Mallinckrodt indicate levels of 1.5 mrem/hour (AEC, 1958). The Mallinckrodt dose rate is used as a bounding condition for Blockson because Mallinckrodt handled materials of similar radiological constituents, but in larger quantities and with a higher radioactive material content. It is assumed that the workers were exposed to that level for 1,000 hours per year, which is considered an upper bound condition. This results in a dose to the skin of 1.5 rem per year. Doses are applied as electrons > 15keV.

Direct Handling of Yellowcake Filter Media — Former workers have indicated that the filtering operation in Building 55 exposed their hands directly to filter cake that contained uranium. Blockson workers indicate that while they wore gloves for this work, they would sometimes have to take the gloves off and use their bare hands to remove the product from the filters (NIOSH, 2007). Dose from filtering operations have been estimated for the hands and forearms. Yellowcake concentrations in the product delivered to AEC was estimated to be 40% to 60%. To bound the dose, an estimate was made of shallow dose to the hands based on direct contact with pure yellowcake. Surface dose rates on yellowcake have been reported to be about 203 mrad per hour (DOE, 2000). The time of direct contact has been assumed to be 2 hours per week, 50 weeks per year during the operational period. This results in an annual dose of about 20.3 rem to the hands and forearms. An adjustment was applied to account for the presence of other radionuclides, resulting in a dose of 30 rem per year, as indicated in Table 7-7. These doses apply to filter operators only and are applied as electrons > 15keV.

Table 7-7: Shallow Dose for Building 55 Workers

Dose Component Beta Dose, E>15keV	Annual Dose[1]	Distribution
Dose from drums of yellowcake	1.2 rem per year	Lognormal, GSD=2.7
Dose from contaminated clothing	1.5 rem per year	Constant
Dose to hands and forearm from contact with yellowcake	30 rem per year (filter operators only)	Constant

Notes:
The data and information contained in this table are from Table 9 in OCAS-TKBS-0002, Rev. 01.
[1] Beta dose is applicable for the operational period only.

7.3.4.3 Neutron Dose

There is no indication that personnel monitoring for neutrons was performed at Blockson. Technical Information Bulletin ORAUT-OTIB-0024 describes the expected neutron dose rates from the various forms of uranium compounds. In Table 5-2 of that document, the listed neutron dose rate at three feet from a source of natural uranium (U_3O_8) is 8.79E-13 R/hr-gram, assuming no presence of alpha-emitting progeny (Roessler, 1979). Assuming both that a drum of yellowcake weighs 1000 pounds, and 2000-hour occupancy, the estimated annual neutron dose would be <0.001 rem. This level of exposure is insignificant for purposes of dose reconstruction.

7.3.4.4 Unmonitored Individuals Working in Production Areas

Records indicate that no personnel were monitored for photon, electron, or neutron doses at Blockson. Methods for dose reconstruction are discussed in the preceding sections.

7.3.4.5 Medical X-ray

Dose from occupationally-required medical X-rays has also been considered and assumed to have occurred. For the AEC operational period at Blockson, employees are assumed to have received an annual chest X-ray. Organ doses are listed in Table 7-7 and are based on an assumed Posterior-Anterior (PA) exposure with minimal collimation. Dose values are reproduced from *Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures* (ORAUT-OTIB-0006, Table 6-5). The annual doses are applied as dose from 30-250 keV photons using the values in Table 7-8 as the mean of a normal distribution with a 30% standard deviation.

Table 7-8: Annual Organ Doses From Medical X-rays

Organ	**Annual dose, rem photon 30-250 keV**
Thyroid	3.48E-02
Eye/brain	6.40E-03
Ovaries	2.5E-02
Liver/gall bladder/spleen	9.02E-02
Urinary bladder	2.5E-02
Colon/rectum	2.5E-02
Testes	5.0E-03
Lungs (male)	8.38E-02
Lungs (female)	9.02E-02
Thymus	9.02E-02
Esophagus	9.02E-02
Stomach	9.02E-02
Bone surfaces	9.02E-02
Remainder	9.02E-02
Breast	9.80E-03
Uterus	2.5E-02
Bone marrow (male)	1.84E-02
Bone marrow (female)	1.72E-02
Skin	2.70E-01[1]

Notes:
The data and information contained in this table are from Table 10 in OCAS-TKBS-0002, Rev. 01.
[1] Skin dose is for skin in the primary beam where the beam enters the body.

7.3.5 External Dose Reconstruction Feasibility Conclusion

This evaluation concludes that external dose reconstruction for members of the proposed class is feasible. By modeling external dose from bounding source term estimates and by making exposure time estimates which are favorable to the claimant, dose estimates are plausible and bounding.

7.4 Evaluation of Petition Basis for SEC-00058

The following assertions were made on behalf of petition SEC-00058 (and SEC-00045, as notated) regarding work at Blockson Chemical Company.

7.4.1 Evaluation of Major Topics Detailed in Petition SEC-00058

The following major topics were detailed in petition SEC-00058. Italicized statements are from the petition; the comments that follow are from NIOSH.

7.4.1.1 No Monitoring of Worker Exposures

SEC-00058: [From petitioner's Form B statement] *"While extracting uranium there was no monitoring of dose received, no safety or protective equipment furnished and inadequate ventilation in the building. No exposure records were ever kept."*

SEC-00045: [From the 12 Affidavits] "*….that neither the government nor Blockson Chemical ever monitored (worker's) exposure to radioactive materials; that neither the government nor Blockson Chemical ever monitored the radiation levels and/or exposure of Building 55 during…" (the proposed class dates relevant to this petition).*

NIOSH obtained results from 122 uranium urine samples collected from 25 different workers between 1954 and 1958. Furthermore, according to a document provided by Blockson to the AEC with estimates of anticipated labor needs for uranium extraction work, about 18 people were employed in Building 55 operations (Lopker, 1951). Additionally, as verified in NOCTS, the results include three workers for which a dose reconstruction was performed or initiated. One of the three worked as a Chemical Operator who was involved in drum-loading activities with direct handling of yellowcake material. As explained in Section 7.2.1, the urine data are considered representative of the potential exposures from the uranium operations being performed by Blockson Chemical. It can be concluded that this group of workers was selected because they had jobs with a potential for exposure, and includes those individuals with the highest potential for exposure, as well as those considered to be only intermittently exposed.

No evidence of air monitoring or external radiation monitoring during uranium extraction activities was found; however, knowledge of the source term and processes can provide a means for estimating radiological conditions and external dose for members of the proposed class.

7.4.1.2 Particle Size Used is Not Claimant Favorable

SEC-00045: *Numerous studies have determined that a significant portion of dusts less than 5 micron collects in tissue deep in the lungs and can cause significant damage to surrounding tissue. It is not clear that the TBD adequately accounts for the accumulation of material in the lungs other than a "calculated" chronic intake rate of 24 pCi/day using broad assumptions that do not necessarily reflect more recent published research.*

The derived intakes in the Technical Basis Document OCAS-TKBS-0002, Rev. 01 are based on the particle size recommendations contained in ICRP Publication 66. Calculations using urinalysis data indicate that the lung dose from inhalation of 1 micron AMAD particles is only marginally higher than the dose from inhalation of 5 micron AMAD particles. The TBD internal dose model assumes that all production workers were continually exposed at the 95th percentile value, which is a conservative bounding dose.

7.4.1.3 Ingestion of Radioactive Material in Phlegm Not Considered

SEC-00045: *The TBD also appears to fail to account for radioactive material that can be ingested as phlegm from previously inhaled matter.*

The amount of material transferred to the gastrointestinal tract from inhaled particles (ingestion as phlegm) is included in the ICRP Publication 66 lung model being used for dose reconstructions (ICRP 66). Material that is ingested (not via inhalation) is also addressed in the Technical Basis Document OCAS-TKBS-0002, Rev. 01. Ingestion intakes can be bounded by assuming all uranium in urine is the result of eating or ingesting uranium. Therefore, the available bioassay data can be utilized to estimate bounding doses from ingestion.

7.4.1.4 Uranium Daughter Beta/Gamma Emitters Not Considered

SEC-00045: *The 24 pCi/day value does not appear to address the presence of the beta-emitting isotopes thorium-234 and protactinium-234(m). These isotopes have short half-lives of 24 days and a few hours respectively.*

Progeny in-growth is addressed in Technical Basis Document OCAS-TKBS-0002, Rev. 01 and is assumed to have occurred. The dose calculated from intakes of uranium account for the presence of thorium-234 and protactinium-234m.

7.5 Other Issues Relevant to the Petition Identified During the Evaluation

During the feasibility evaluation for SEC-00045 (later merged with SEC-00058), one issue was identified that required further analysis and resolution. There was a potential for beta dose to worker hands from the handling of uranium filter screens without gloves. It was determined that the source term information available in the site profile and other sources was sufficient to determine the maximum dose that one could receive from direct contact with the uranium yellowcake material. This is discussed in Section 7.3.4.2 of this document.

7.6 Summary of Feasibility Findings for Petition SEC-00058

This report evaluated the feasibility for completing dose reconstructions for employees at Blockson Chemical Company from January 1, 1951 through December 31, 1962. NIOSH found that the monitoring records, process descriptions and source term data available are sufficient to complete dose reconstructions for the proposed class of employees.

Table 7-9 summarizes the results of the feasibility findings at Blockson Chemical Company for each exposure source for the time period January 1, 1951 through December 31, 1962.

Table 7-9: Summary of Feasibility Findings for SEC-00058 January 1, 1951 through December 31, 1962		
Source of Exposure	**Reconstruction Feasible**	**Reconstruction Not Feasible**
Internal	X	
-U-238 and associated progeny	X	
-U-235 and associated progeny	X	
-Th-232 and associated progeny	X	
External	X	
-Gamma	X	
-Beta	X	
-Neutron	N/A	
-Occupational Medical X-ray	X	

As of June 26, 2007 a total of 111 claims have been submitted to NIOSH for individuals who worked at Blockson Chemical and are covered by the proposed class definition evaluated in this report. Dose reconstructions are complete for 102 individuals (92%).

8.0 Evaluation of Health Endangerment for Petition SEC-00058

The health endangerment determination for the class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(3). Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. Section 83.13 requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

Our evaluation determined that internal doses can be estimated with sufficient accuracy using the available bioassay data, and maximum external doses can be estimated using knowledge of the source term and processes at Blockson Chemical. Therefore, this evaluation determined that it is feasible to estimate radiation dose for members of the proposed class with sufficient accuracy based on the sum of information available from available resources. Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is not required.

9.0 NIOSH-Proposed Class for Petition SEC-00058

Based on its research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all Atomic Weapons Employer personnel who worked on uranium recovery activities at Blockson Chemical Company, Joliet, Illinois, from January 1, 1951 through December 31, 1962.

NIOSH has carefully reviewed all material sent in by petitioners for SEC-00058 (and SEC-00045 which was merged with SEC-00058), including the specific assertions stated in the petitions, and has responded to them herein (see Section 7.4). NIOSH has also reviewed available technical resources, and many other references, including the Site Research Database (SRDB) for information relevant to SEC-00058. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining that it would be feasible to reconstruct the dose for the class proposed in this petition.

10.0 References

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