SEC Petition Evaluation Report
Petition SEC-00088

Report Rev #: 0

Report Submittal Date: January 18, 2008

Subject Expert(s):	Chris Miles, Joe Guido
Site Expert(s):	N/A

Petition Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition B Qualification Date	DOE/AWE Facility Name
SEC-00088	83.13	August 17, 2007	Texas City Chemicals, Inc. (TCC)

Petitioner Class Definition

All employees who worked in all areas at Texas City Chemical, Inc. from January 1, 1952 through December 31, 1956.

Proposed Class Definition

All workers who worked in any areas at Texas City Chemicals, Inc., from January 1, 1952 through December 31, 1956.

Related Petition Summary Information			
SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
NONE			

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

ORAU Lead Technical Evaluator: Chris Miles	**ORAU Review Completed By:** Michael Kubiak

Peer Review Completed By:	[Signature on file] *Thomas P. Tomes*	1/18/2008 *Date*
SEC Petition Evaluation Reviewed By:	[Signature on file] *J. W. Neton*	1/18/2008 *Date*
SEC Evaluation Approved By:	[Signature on file] *Larry Elliott*	1/29/2008 *Date*

This page intentionally left blank

Evaluation Report Summary: SEC-00088, Texas City Chemicals, Inc.

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-00088, qualified on August 17, 2007, requested that NIOSH consider the following class: *All laborers who worked in all areas at Texas City Chemical, Inc. from January 1, 1952 through December 31, 1956.*

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 employees who worked in any areas at Texas City Chemicals, Inc., from January 1, 1952 through December 31, 1956.

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, 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 (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. Available information about the site 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.

This page intentionally left blank

Table of Contents

Tables

SEC Petition Evaluation Report for SEC-00088

ATTRIBUTION AND ANNOTATION: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the Oak Ridge Associated Universities Team Lead Technical Evaluator: Christopher J. Miles; 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.

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked in any areas at Texas City Chemicals, Inc., from January 1, 1952 through December 31, 1956. 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, then NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires

[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.

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 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]

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

Petition SEC-00088, qualified on August 17, 2007, requested that NIOSH consider the following class for addition to the SEC: All laborers who worked in all areas at Texas City Chemical, Inc. from January 1, 1952 – December 31, 1956.

The petitioner provided information and affidavit statements in support of the petitioner's belief that it is not feasible to estimate with sufficient accuracy the radiation doses received by workers at TCC. NIOSH deemed the information and affidavit statements provided by the petitioner to be sufficient to qualify SEC-00088 for evaluation. This information may be summarized as follows:

> *Radiation monitoring records for members of the proposed class may have been lost, falsified, or destroyed.*
>
> *Information regarding monitoring from TCC is unavailable.*

The information and statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

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-

[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.

proposed class includes all employees who worked in any areas at Texas City Chemicals, Inc., from January 1, 1952 through December 31, 1956. Even though TCC operations did not begin until October 1953, and operations ceased before December 31, 1956, NIOSH evaluated the entire time period proposed by the petitioner. In this evaluation, NIOSH considered exposures to all workers in order to bound the estimates of potential exposure for the petitioner's proposed class of "laborers." The class was modified because radiation monitoring records are unavailable for TCC workers for the specified period and all TCC employees were potentially exposed to radioactive materials as a result of U.S. Atomic Energy Commission (AEC)-related uranium extraction processes.

4.0 Data Sources Reviewed by NIOSH

NIOSH identified and reviewed numerous data sources to locate 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. NIOSH has not developed a Site Profile for TCC; however, as part of NIOSH's evaluation detailed herein, it examined the following TBDs for insights into TCC operations or related topics/operations at other sites:

- *Technical Basis Document for Atomic Energy Operations at Blockson Chemical, Joliet, Illinois*; OCAS-TKBS-0002, Rev. 02; November 21, 2007; SRDB Ref ID: 36611

- *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

- *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium*, Battelle-TBD-6001, Rev. F0; December 13, 2006; SRDB Ref ID: 30673

- *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium, Appendix BH – International Minerals and Chemical Corporation,* Battelle-TBD-6001, App. BH, Rev. 0; July 16, 2007; SRDB Ref ID: 35365

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. An ORAU Procedure provides specific requirements and guidance regarding EEOICPA project-level activities, including preparation of dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs as part of its evaluation:

- *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 one former TCC employee and a TCC petitioner whose spouse worked at the TCC site. The purpose of these interviews was to gain additional information and insight into TCC operations during the applicable time period. The questions and responses have been documented in the Site Research Database (SRDB). Worker Outreach meetings were also held.

- Personal Communication, 2007a, *Personal Communication with Former TCC Employee*; Telephone Interview by ORAU Team; October 2, 2007; SRDB Ref ID: 35466

- Personal Communication, 2007b, *Personal Communication with Survivor of Former TCC Employee*; Telephone Interview by ORAU Team; October 2, 2007; SRDB Ref ID: 35465

- NIOSH Worker Outreach Meetings; 2:00 PM and 7:00 PM CDT; October 18, 2007; International Union of Operating Engineers Union Hall; 2800 Texas Avenue; Texas City, Texas. Meeting minutes will be made available on the OCAS website (http://www.cdc.gov/niosh/ocas).

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH OCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of January 18, 2008)

Table 4-1: No. of TCC Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	13
Total number of claims submitted for energy employees who meet the proposed class definition criteria (employment during the period January 1, 1952 through December 31, 1956)	13
Number of dose reconstructions completed for energy employees who meet the proposed class definition criteria	2
Number of claims for which internal dosimetry records were obtained for the identified years in the proposed class definition	0
Number of claims for which external dosimetry records were obtained for the identified years in the proposed class definition	0

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. No records were found for either internal or external monitoring.

4.5 NIOSH Site Research Database

NIOSH data capture efforts have included Internet searches and contacts with the existing company (Amoco BP), a DOE representative for exception facilities, Texas State Radiation Group, U.S. Environmental Protection Agency (USEPA) Region 6, and the Texas Commission for Environmental Quality. Data have also been sought from the Federal Records Center in Fort Worth, Texas. NIOSH has reviewed the pertinent data collected by these combined efforts.

NIOSH has also reviewed its Site Research Database to locate documents supporting the evaluation of the proposed class. A number of documents in this database were identified as pertaining to TCC. These documents were evaluated for their relevance to this petition. The documents include historical background on the process materials, the industrial process, and later Formerly Utilized Sites Remedial Action Program (FUSRAP)-related residual contamination surveys.

4.6 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following documents submitted by the petitioners:

- *Form B with attachment*, petition and miscellaneous information from survivor of former TCC employee; received March 13, 2007; OSA document id: 102669

- *Affidavit*, site and medical information from survivor of former TCC employee; received April 4, 2007; OSA document id: 103975

- *Proof of Relationship*, affidavit of marriage and employment from survivor of former TCC employee; April 17, 2007; OSA document id: 102839

5.0 Radiological Operations Relevant to the Proposed Class

The following subsections summarize both radiological operations at TCC from January 1, 1952 through December 31, 1956 and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing both processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 TCC Plant and Process Descriptions

In February 1952, the AEC contracted with Texas City Chemicals, Inc., to construct a phosphate fertilizer plant in Texas City, Texas, with the capacity to process 100,000 tons of Florida phosphate rock a year (AEC Contract, 1952). In addition, this plant was to have a unit capable of recovering uranium from the phosphoric acid solution used to produce the fertilizer. The contractor was to sell to the AEC the entire output of the TCC uranium recovery building. Contract terms limited the obligations of both the AEC and TCC to not more than 50,000 pounds of U_3O_8 annually, specified as a concentrate containing at least 50% U_3O_8. The term “U_3O_8” was loosely used by the AEC for inventory purposes to include many uranium forms, not necessarily only U_3O_8.

According to an internal AEC memorandum (Johnson, 1953), shakedown operations began at the TCC plant on October 5, 1953. “Full-scale” operations were scheduled to begin December 4, 1953, at which time the company had planned a ceremony with state and local dignitaries. However, other documentation indicates that TCC never achieved full-scale uranium extraction operations. According to the memorandum, the expected level of uranium recovery during full production was about 12 tons/yr. An AEC Monthly Report on Activities of Domestic Production Phosphates (AEC Monthly, Dec. 1955), states that TCC operations were shut down from January 1954 to the date of the report for “modifications in base plant” and had only produced an estimated 303 pounds of U_3O_8 from “intermittent shake-down operations” through December 1953. According to *Uranium Recovery from Wet Process Phosphoric Acid, History and Present Status*, the TCC plant was “never successfully brought on stream due to complications both in the uranium recovery process and the basic phosphate plant" (Wilkinson, 1976). An additional AEC contract was issued to TCC for development work. That contract expired September 30, 1955 and an additional contract was issued. Terms of the latter contract are unknown (ERDA, 1976).

The references discussed above indicate that there were problems in the TCC uranium extraction process. Problems were known to exist at some of the other plants that employed organic extraction of uranium from phosphoric acid. On April 25-26, 1955, a meeting was held in Florida to discuss issues associated with the recovery of uranium from commercial phosphoric acid (Robinson, 1955). This meeting was well-attended. Participants included representatives from the AEC, Blockson Chemical Co., Davidson Chemical Co., International Minerals & Chemical Corp., National Lead Co. of Ohio, Smith-Douglass Co., U.S. Phosphoric Products, Victor Chemical Co., Virginia-Carolina Chemical Corp., and the Joint Congressional Committee on Atomic Energy. One of the major topics at this meeting was associated with problems encountered by organic uranium extraction methods. There was no specific mention of TCC in the meeting minutes (Florida Meeting, 1955); however, several companies known to be developing methods for extracting uranium from Florida phosphates were in attendance.

The TCC plant was one of four uranium recovery plants built in the early to mid-1950s. The other three plants were Virginia-Carolina Chemical Corporation, International Minerals & Chemicals Corporation (IMCC), and U.S. Phosphoric Products. These four plants were designed for uranium recovery from phosphoric acid using a solvent extraction process developed by Dow Chemical Company. The TCC and Virginia-Carolina uranium extraction plants were never successfully placed into production (Wilkinson, 1976). Although it is known that TCC encountered production problems, and was at least researching plant modifications, documentation has not been discovered specifying the exact nature of the problems. One common problem discussed at the above-mentioned AEC meeting in 1955, and discussed by Greek et al., was the forming of an emulsion resulting from organics, which caused problems during production and for the AEC when they received the product (Florida Meeting, 1955; Greek, 1957). Although records of TCC problems are not available, this or some other problem prevented the plant from achieving full production.

Specific details of the TCC process are unavailable; however, given the common origin of the extraction process (Dow), it was likely that the TCC process was similar to that used at the IMCC plant in Bonnie, Florida. The Bonnie process involved using alkyl pyrophosphoric acids to extract uranium from the phosphoric acid. In essence, the phosphoric acid containing the uranium from the acid plant was reduced with iron. Then a pyrophosphate ester was added, which complexed the uranium. The organic complex was then separated from the phosphoric acid solution, which was sent back to the plant for continuation of the fertilizer production process. Sulfuric acid was used to remove calcium, iron, and other ions from the organic complex, and the uranium was recovered by reaction with hydrofluoric acid. The recovered uranium was dried, packed in drums, and shipped to the AEC for further processing (Greek, 1957).

Texas City Chemicals filed for bankruptcy in July 1956 and, shortly thereafter, became part of the Smith-Douglass Company. Uranium recovery was not pursued by Smith-Douglass which operated the plant solely for fertilizer and feed production (Powers, 1979). According to a U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FUSRAP) report, "AEC work at the site ceased about 1956, when Texas City Chemicals went bankrupt" (Elimination Report, 1986). The uranium recovery plant was torn down in the late 1970s. Fertilizer production ended at the site in September 1977, and the remaining facilities were sold to the American Oil Company on December 15, 1977. The site is currently operated by BP Amoco Chemicals (Elimination Report, 1986; Survey, 1980).

Based on the available historical information, NIOSH has evaluated the TCC activities and timeframes and designated three evaluation periods for analysis, as shown in Table 5-1. These three periods differ in their durations, source terms, potentials for exposure, and exposure environments, as discussed in subsequent subsections.

Table 5-1: Relevant TCC Chronology and NIOSH-Designated Evaluation Periods

(NIOSH-proposed class period: 01-01-52 through 12-31-56)

TCC Activities	Dates	NIOSH-Designated Evaluation Periods
From petitioner-requested SEC class start date to TCC signing of AEC letter contract. (No AEC work)	**Jan 1, 1952** thru Feb 25, 1952	Facility Construction-Only Period
From AEC letter contract signing to earliest plausible arrival of phosphate rock for on-site storage. (Facility construction only)	Feb 26, 1952 **thru Dec 31, 1952**	
From earliest plausible arrival of phosphate rock to onset of "intermittent shake-down operations." (Facility construction and phosphate rock receipt, unloading, and storage)	**Jan 1, 1953 thru Oct 4, 1953**	Pre-Operational Period
From onset of "intermittent shake-down operations" to shutdown for "modifications in base plant." (Production of 303 lbs. of U_3O_8 through Dec 1953)	**Oct 5, 1953** thru Dec 1953	Operational Period
From shutdown to issuance of AEC Dec55 Monthly Report. (development activities; possible studies to solve process problems)	Jan 1954 thru Dec 1955	
From AEC Dec55 Monthly Report to TCC bankruptcy declaration. (development activities; possible studies to solve process problems)	Jan 1956 thru Jul 1956	
From bankruptcy to petitioner-requested SEC class end date and end date of AEC operational period. (No AEC production work)	Aug 1956 **thru Dec 31, 1956**	

5.2 TCC Source Term

TCC operations began with raw phosphate rock from Central Florida. This rock contained naturally-occurring radioactive constituents of uranium and thorium and their associated progeny. The uranium content of the phosphate rock was reported to be as high as 0.014% U_3O_8 (Stoltz, 1958). Concentrations of other naturally-occurring radionuclides in the phosphate rock are discussed below, along with some discussion of their fate in the TCC process.

U-238 and Ra-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 in such a manner that the radium is concentrated in the phosphogypsum while the uranium is concentrated in the phosphoric acid (OCAS-TKBS-0002; Guimond, 1975; FIPR, 1995).

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 the distributions of radionuclides are, in some respects, a function of the specific process, the following generalizations can be made for the TCC process:

- Radiological equilibrium in the uranium chain appears to be maintained in rock that has not been chemically processed (Roessler, 1979; FIPR, 1995).

- Ra-226 and Po-210 are retained in the phosphogypsum; they do not enter the phosphoric acid stream to any significant degree (OCAS-TKBS-0002; Guimond, 1975, page 15; FIPR, 1995, pages 1-16).

- Uranium and thorium tend to favor the phosphoric acid phase (OCAS-TKBS-0002; Guimond, 1975; FIPR, 1995).

- Since Th-230 is present in the matrix with U-238, it is expected to go into solution along with the uranium when leached in sulfuric acid. Th-232, if occupying a different matrix in the rock, may not be as readily dissolved in sulfuric acid (Coppinger, 1959, page 20).

- Pb-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).

Uranium and other elements would be present at various stages in concentrations correlated with 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 maximizing doses from the various radionuclides that are present in the feed material.

NIOSH employed the following assumptions for isotopic ratios in the production of phosphoric acid from phosphate rock:

- Eighty-five percent of uranium resides in the phosphoric acid (Lopker, 1951; OCAS-TKBS-0002; Stoltz, 1958).

- Four percent of Ra-226 resides in the acid phase (Hull, 1996).

- Although several references indicate the thorium is likely to be somewhat lower than uranium, this evaluation assumes thorium partitions to acid in the same proportion as uranium. The assumption of equal recovery of thorium to uranium in the acid results in a higher source term for internal and external dose modeling (OCAS-TKBS-0002). If there were more thorium losses to the phosphogypsum stream, the doses would be lower.

- The radioactivity ratio of U-238 to Th-232 in the TCC phosphate rock is assumed to be 30:1, the same as for Blockson (OCAS-TKBS-0002). This ratio is considered to be a bounding ratio to allow for natural thorium and progeny based on reported U-238 and Th-232 concentrations in phosphate rock (ORAUT-OTIB-0043). Th-232 progeny are assumed to be in equilibrium. Although most of the Ra-228 would have been separated and removed with the phosphogypsum, it is assumed to be in equilibrium with Th-232 for dose-modeling purposes.

- Pb-210 is assumed to reside in the acid solution at 85%. Various references cite data indicating that lead follows the phosphogypsum, while other references report high percentages following to the phosphoric acid (OCAS-TKBS-0002). For modeling purposes, Bi-210 and Po-210 are assumed to be equal to Pb-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 in the same relative concentration as U-238 (the concentrate being the highest potential source for internal dose and source for external dose model) (OCAS-TKBS-0002).

Table 5-2 lists the relative radionuclide concentrations for the TCC Recovery Building.

Table 5-2: Recovery Building 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.
[1] Ratios given are for progeny without consideration of branching ratios, where applicable.

The following subsections discuss the relevant TCC source terms for the NIOSH-designated evaluation periods identified in Table 5-1.

5.2.1 Facility Construction-Only Period

This evaluation period extends from the petitioner-requested SEC class start date to the earliest plausible arrival of phosphate rock at the site. The AEC letter contract was signed on February 26, 1952, and operations did not begin until October 5, 1953. With construction on-going through 1952 and most of 1953, NIOSH concludes that January 1, 1953 is a reasonable date before which it would have been implausible for phosphate ore to have been received (i.e., nine months prior to the planned start of operations [October 1, 1953]). During this designated period, NIOSH concludes that TCC was only engaged in constructing the facility and making preparations for receipt of phosphate ore. The source term during this period is zero because no radioactive material was present on site for either fertilizer or uranium extraction operations.

5.2.2 Pre-Operational Period

This evaluation period extends from the earliest plausible arrival of phosphate rock (January 1, 1953) to onset of “intermittent shake-down operations” (October 4, 1953). The Pre-Operational Period would have included facility construction, but eventually would have included the receipt, unloading, and storage of phosphate rock. During this time period, workers are assumed to be exposed to naturally-occurring radioactive constituents present in the phosphate rock. This exposure resulted in inhalation uptakes, ingestion from contaminated surfaces, and external dose from the phosphate rock.

5.2.3 Operational Period

This evaluation period extends from the onset of “intermittent shake-down operations” (October 5, 1953) to the petitioner-requested SEC class end date (December 31, 1956). NIOSH has analyzed two exposure scenarios during the Operational Period:

1. Exposures inside the uranium recovery building
2. Exposures outside the uranium recovery building

The two exposure scenarios differ in their source terms, as discussed in the following subsections.

5.2.3.1 Operational Period Inside the Recovery Building

Workers inside the Recovery Building were subject to the following sources of potential exposure:

- The radioactive source term in the Recovery Building consisted of dried uranium concentrate. The uranium concentration of this material was likely similar to the product produced at Blockson, 40% to 60% uranium by mass. The relative ratios of other radioactive constituents assumed to be present in this product material are given in Table 5-2. Elevated airborne concentrations of this product material are assumed to be present in the Recovery Building.

- Surface contamination of this product material is assumed to be present inside the Recovery Building. Surface contamination resulted in ingested radioactive material and skin dose from personnel contamination.

- Although it appears that only 303 pounds (less than ½ of a 55-gallon drum) of product were produced at TCC, worker external doses are estimated under the assumption that workers were routinely exposed to full drums of uranium concentrate.

- Elevated radon concentrations are assumed to be present throughout the facility.

5.2.3.2 Operational Period Outside the Recovery Building

Workers outside the Recovery Building were subject to the following sources of potential exposure:

- The same potential exposures to NORM as during Pre-Operational Period (i.e., airborne naturally occurring radioactive constituents in phosphate rock, resulting from the receipt, unloading, and storage of phosphate ore). During the Operational Period however, air concentrations to the raw material could have significantly higher due to dust generating activities such as phosphate rock-crushing.

- Surface contamination resulted in ingested radioactive material.

- Elevated radon concentrations are assumed to be present throughout the facility.

- Radium in phosphogypsum and radium scale build-up in process equipment resulted in worker exposures

5.3 Radiological Exposure Sources from TCC Operations

There were several manufacturing plants in the 1950s that, like TCC, processed Florida phosphate rock to produce (among other products) uranium compounds from phosphoric acid solutions. The general sources of radiological exposure at each site were comparable.

The primary source of radiological exposure from operations performed at TCC from January 1, 1952 through December 31, 1956 was naturally-occurring radioactive constituents contained in phosphate rock, primarily uranium and thorium, and their associated progeny. 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 of phosphate rock
- Internal exposure from radon and radon progeny
- External photon dose from drums of uranium product
- External photon dose from radium
- External beta dose from direct exposure to uranium product material and from uranium skin contamination
- External neutron dose from drums of uranium product
- Internal and external dose from surface 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. The specific chemical processes used at TCC are not well-known; therefore, for the purposes of this evaluation, claimant-favorable assumptions have been made regarding the distributions of specific radionuclides throughout the TCC operation.

5.3.1 Alpha

Alpha exposure at TCC occurred 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, and uranium-235. 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).

Personnel exposures to alpha sources are discussed in Section 7.2.3.2 and include the following:

- Inhalation intakes of airborne dust from phosphate rock-handling operations in areas outside the uranium recovery building
- Inhalation intakes of airborne phosphogypsum dust, which contains radium and other radionuclides that do not enter the initial acid phase in the operation
- Inhalation intakes of airborne concentrated uranium product in the Recovery Building
- Inhalation of radon
- Ingestion resulting from surface contamination

5.3.2 Beta

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

- Shallow dose from exposure to open drums of uranium product during drum loading and sealing
- Shallow dose to skin contaminated with uranium product
- Skin dose from contact with contaminated work clothing
- Skin dose from direct contact with uranium concentrate (e.g., handling and cleaning uranium filter media)

5.3.3 Neutron

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. ORAUT-OTIB-0024 describes the expected neutron dose rates from various forms of uranium compounds.

5.3.4 Photon

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

NIOSH did not find any TCC personnel or workplace monitoring records for the period under evaluation.

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 would be 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 under evaluation. 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 7.5. 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 petition SEC-00088 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of TCC 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, representativeness, and sufficiency for determining the feasibility of dose reconstruction. The feasibility evaluation presupposes that data pedigree issues have been settled.

7.1.1 Internal Monitoring Data Review

NIOSH has been unable to find any record of uranium internal monitoring of TCC workers. Therefore, it is necessary to bound TCC intakes by: (1) relying on representative air monitoring data for workers handling ore concentrates at full-scale production AEC facilities; (2) applying 95^{th} percentile bounding doses to TCC uranium workers, where appropriate; and (3) using claimant-favorable assumptions regarding non-uranium radionuclides and potential intakes from dust in plant areas outside the TCC uranium recovery building. This methodology is discussed in Section 7.2.

7.1.2 External Monitoring Data Review

NIOSH has been unable to find any record of external dosimetry monitoring of TCC 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, by modeling external dose from bounding source term estimates, and by making claimant-favorable exposure time estimates, plausible and bounding dose estimates can be achieved. This methodology is discussed in Section 7.3.

7.2 Internal Radiation Doses at TCC

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 uranium product into containers for transfer to the AEC. Other sources of internal dose included: (1) contamination on building and equipment surfaces; and (2) radon and radon progeny that may have been present on site.

During the wet chemical processes used to concentrate uranium, contamination and dust exposures are minimal. 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 (NRC, 2002; Eidson, 1984; Personal Communication, 2002). Another dust-generating operation at TCC may have been the crushing of dry phosphate rock upon arrival at the TCC facility. However, the radioactivity concentration of the unprocessed rock was far lower than that of the final uranium product, as was the potential internal radiation dose from the inhalation of this dust.

There was a potential for internal radiation dose during the development phase of TCC's uranium extraction process, which included process development studies. The operational systems used for the process development studies were assumed by NIOSH to be similar to the production systems, although the exact configurations are not known. Laboratory work would have involved the same source of radioactive materials as those used in production, except on a much smaller scale and with intermittent operation for shorter periods of time. Therefore, the doses modeled for production workers are used to bound doses received by any workers performing process development studies.

7.2.1 Process-Related Internal Doses at TCC

As previously discussed, very limited information is currently available to NIOSH pertaining specifically to the TCC processes. This may be due to the apparent failure of the plant to efficiently recover uranium. According to available documentation, the TCC plant never reached full production status. The plant received its AEC contract(s) to build the plant in 1952. The plant was to be completed by October 1, 1953. All construction was to be performed at TCC's expense, with a fee based solely on the sale to the AEC of U_3O_8 on a dollars per pound basis. TCC went bankrupt in 1956. A paper by Wilkinson, *Uranium Recovery from Wet Process Phosphoric Acid: History & Present Status,* states:

> *... four Uranium recovery plants based on the solvent extraction process were constructed. Two of these plants, Texas City Chemicals, Inc., and Virginia-Carolina Chemical Corporation, were never successfully brought on stream due to complications both in the uranium recovery process and the basic phosphate plant.* (Wilkinson, 1976).

This statement may help explain the lack of uranium production data available for the TCC site. In any event, with the lack of definitive data to the contrary, this document assumes that the radiological conditions within the TCC Recovery Building during the Operational Period were comparable to the conditions at full-scale uranium production mills during that era, in facility areas where dry uranium concentrates were routinely handled.

The proposed SEC class period under evaluation for this petition is January 1, 1952 through December 31, 1956. TCC operations did not begin until October 5, 1953. From January 1, 1952 through December 31, 1952, it is assumed that no radiation exposures took place at TCC.

Since it is likely that TCC workers received and handled phosphate rock prior to the actual start of plant operations, NIOSH assumes that workers were potentially exposed to naturally-occurring radioactive materials associated with the raw phosphate rock from January 1, 1953 through October 4, 1953. To assess potential worker intakes during this Pre-Operational Period, NIOSH considered a dust-loading study by the U.S. Environmental Protection Agency (EPA). The EPA performed a thorough study of dust-loading and radionuclide concentrations in air throughout the phosphate ore process at an Idaho phosphate facility (EPA, 1978). The facility used the wet-process method to process phosphate rock, a process comparable to that used at TCC. Various air samples were taken at locations throughout the Idaho plant. The samples were analyzed for total dust-loading and airborne radioactivity concentrations were reported. The dust concentration reported for ore unloading and storage operations was 5.43 mg/m^3 (OCAS-TKBS-0002). Using this airborne dust concentration assumption, along with knowledge of the naturally-occurring radioactive constituents contained in Florida phosphate rock, potential worker intakes at TCC during the Pre-Operational Period may be bounded.

TCC operations began on October 5, 1953. According to the testimony of several former TCC employees, the plant shut down in early 1956 and reopened in late 1956 or early 1957 under different ownership (Personal Communication, 2007a; Worker Outreach Meeting Minutes, October 18, 2007). Uranium recovery was not pursued by the new owner, which operated the plant solely for fertilizer and feed production (Powers, 1979). For the purposes of this evaluation, the Operational Period is assumed to be continuous from October 5, 1953 through December 31, 1956. During the Operational

Period, as with the Pre-Operational Period, workers were potentially exposed to naturally-occurring radioactive materials in the raw phosphate rock. Since more active operations would have taken place during the Operational Period (e.g., rock-crushing), NIOSH recognizes the potential for higher dust-loading conditions during this period. In the EPA study mentioned above, the highest measured level of dust at the Idaho plant was in the area of the calciner, at 50.4 mg/m^3 (OCAS-TKBS-0002). Although a calciner was not used at TCC, these high calciner dust concentrations are assumed for workers outside the TCC Recovery Building in order to establish an upper-bound intake estimate from rock-crushing and other dust-generating operations.

At TCC, the operations associated with handling the dry uranium product inside the Recovery Building have been identified as having the highest worker exposure potential. During the 10-year period from 1948 through 1958, the Health and Safety Laboratory (HASL) of the U.S. Atomic Energy Commission conducted 60 complete evaluations of occupational hazards in seven uranium refining plants. These evaluations consisted of measurements of more than 20,000 individual dust samples. These data are summarized in a paper published in November 1960 by the American Academy of Occupational Medicine, entitled *The Industrial Hygiene of Uranium Refining* (Christofano, 1960). In this paper, data are presented for various uranium refining operations, including ore handling, ore sampling, uranium concentrate sampling, ore digestion, solvent extraction, denitration, oxide reduction, hydrofluorination, drum transfer operations, reduction to metal, recasting, fluorination, and scrap recovery. The uranium concentrate sampling operation described in this paper involved the routine handling of 1000-lb. samples of concentrate, 70% to 90% U_3O_8. Specific tasks associated with this operation included dumping the concentrate (during which airborne gross alpha concentrations ranged from 700 to 4800 dpm/m^3), delidding and lidding drums, and pipe sampling. The daily average concentration for this operation ranged from 90 to 190 dpm/m^3.

As discussed in Sections 5.1 and 5.2, production at TCC was minimal, producing only approximately 303 pounds of product over the lifetime of the operation (less than ½ of a 55-gallon drum). In contrast, the concentrate-handling operations described by Christofano involved routine handling of 1000 pound samples of 70% to 90% U_3O_8. The term “U_3O_8” was loosely used by the AEC for inventory purposes to include many uranium forms, not necessarily only U_3O_8. Exposure to workers handling these ore concentrates during full-scale production at AEC facilities are used to bound exposure to TCC workers in the Recovery Building during the Operational Period, a period of limited uranium production at TCC. For this evaluation, NIOSH assumes that workers were exposed to the maximum “daily average concentration” of 190 dpm/m^3 airborne alpha contamination. With regard to solvent extraction operations, a process used at TCC, the Christofano paper states: “The solvent extraction areas represent the lowest air contamination levels found in any refining operation” (Christofano, 1960).

7.2.2 Ambient Environmental Internal Radiation Doses at TCC

In this evaluation, all workers are assumed to be maximally exposed either to the conditions that potentially existed in the uranium recovery building, or to high dust concentrations outside of the Recovery Building. Ambient environmental dose is bounded by the assignment of this process-related dose.

7.2.3 Internal Dose Reconstruction

NIOSH evaluated the potential exposures from possible intakes of radioactive material at TCC based on representative air monitoring from other facilities that would bound intakes for TCC workers. Although some of the work at TCC may not have been directly related to uranium extraction, potential radiological exposures associated with all work at TCC have been evaluated because the TCC facility was originally designed and built with the intention of extracting uranium for use by the AEC.

7.2.3.1 TCC Uranium Exposures

NIOSH has found no TCC air sampling results with which to characterize airborne radioactivity concentrations. The greatest potential for internal uranium exposure in the TCC uranium recovery process was 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).

Although NIOSH has no TCC air sampling results, air sampling results from mills with similar activities have been published. For example, a study (Eidson, 1984) was performed relating to uranium aerosols generated during yellowcake packaging operations at four uranium mills.

Eidson and Damon's study described a sequence of steps common to all four uranium ore processing mills (Eidson, 1984):

- Step One - No Activity: The plant is shut down for maintenance, or all available yellowcake has been barreled. Worker exposure to airborne yellowcake is minimal in this step.
- Step Two - Barrel Loading: A barrel is placed under a hopper containing the dried yellowcake and 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.
- Step Three - Barrel Uncovering: 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.
- Step Four - Powder Sampling: A worker takes a sample of yellowcake for laboratory analysis.
- Step Five - Lid Sealing: A worker places a lid on the barrel and seals it.
- Step Six - Other Activities: Maintenance and cleaning.

This evaluation considers two different exposure scenarios for workers during the TCC Operational Period. One scenario considers exposures to workers in the uranium recovery building. This scenario represents the highest potential for exposure (e.g., operators who routinely handled and packaged dried uranium product). The second exposure scenario considers all those who worked outside the uranium recovery building. The intake rates for these workers are based on the assumption that they were exposed to high concentrations of airborne dust from the raw phosphate rock. Workers outside the Recovery Building are assumed to have been exposed to elevated levels of general area airborne radioactive contamination, ingestible surface contamination, and elevated external radiation levels on a continual basis. The airborne dust concentration outside the Recovery Building during the Operational Period is assumed to be higher than during the Pre-Operational Period due to activities such as rock-crushing that would presumably not have taken place prior to the start of operations.

7.2.3.2 TCC Radioactive Material Intakes

Material Absorption Types

The chemical composition of the uranium product produced at TCC is not well-known. A literature review indicates that there are a few compounds that should be considered Type S materials, UO_2 and U_3O_8 being the most commonly-found Type S compounds in the literature. A few other compounds are also reported and regarded as Type S material, such as UAl_x, UC_2, and UZr. (ICRP 66, 1979; DOE, 2000). U_3O_8 has been regarded as both Type M and Type S, depending on the extent of high heat treatment and formation of more stable forms of insoluble uranium.

The common indicator of Type S material in the literature is the presence of compounds that contain uranium in the +4 oxidation state, although some binary compounds with halogens are identified with uranium in the +4 state as having a Type M or Type F lung clearance rate. Compounds in the +6 state are all identified with either Type M or Type F material.

Uranium dioxide (UO_2) is identified as the highly-insoluble uranium component of yellowcake. It has been reported to result from processing at high heat, decomposing to UO_2 at temperatures above 1300 degrees C (Web Elements, 2007). The presence of a significant percentage of UO_2 oxides would indicate that the material would clear from the lungs more slowly than a Type M material.

Testimony from several individuals who worked at the TCC facility during the proposed SEC class period under evaluation indicates that a calciner, such as was used at Blockson, was not used at TCC (Personal Communication, 2007a; Worker Outreach Meetings; October 18, 2007). This evaluation assumes that uranium Type M or Type S materials could have been present in rock-handling areas prior to chemical processing (e.g., rock-crushing area). Although TCC used the solvent extraction method to recover uranium, the specifics of the TCC process are unknown; therefore, NIOSH assumes that the uranium product (or intermediate products) produced in the Recovery Building could have been of Type F, Type M, or Type S materials. Dose reconstructions can be bounded by assuming exposure to uranium dust that has a Type F, Type M, or Type S lung clearance rate, with the chosen absorption type being the one that results in the highest dose to the tissue of interest.

Inhalation Intakes

In this evaluation, radionuclide intake rates vary as a function of time period.

During the Facility Construction-Only Period (January 1, 1952 through December 31, 1952), intakes are presumed to be zero for all workers. During this period, there was not a radioactive source term present at the TCC site.

During the Pre-Operational Period (January 1, 1953 through October 4, 1953), workers are presumed to have been exposed to airborne contamination from the naturally-occurring radioactive constituents present in raw phosphate rock. Workers during this time period may have unloaded and staged phosphate rock in preparation for the start of operations. There are no records available to indicate when the first shipment of phosphate rock arrived at TCC. For the purpose of this evaluation, NIOSH assumes that rock would not have been shipped prior to January 1, 1953. This is a full nine months prior to the planned start of operations. Intakes for this Pre-Operational Period are based on a dust-loading study performed by the U.S. EPA at an Idaho Phosphate facility. From this study (see Section 7.2.1), the dust concentration reported for ore unloading and storage operations is estimated to be 5.43 mg/m^3 (OCAS-TKBS-0002). Bounding intakes were calculated based on a breathing rate of 1.2 m^3/hr and exposure to that high level of dust for 2000 hours per year. For these calculations, the uranium mass was assumed to be all U-238, as it represents over 99% of the uranium mass in natural uranium. U-234, Th-230, Ra-226, and other radionuclides in the U-238 chain are assumed to be in equilibrium with U-238. U-235 was not included because the method of calculating uranium activity bounds the small intake contribution from U-235. Additional parameters used include an assumed 0.014% uranium content in phosphate rock (Stoltz, 1958). Intakes of long-lived radionuclides that are significant to internal dose are listed in Table 7-1.

During the Operational Period, intake rates depend on whether the worker is located inside or outside the Recovery Building. During this period, workers were potentially exposed to airborne phosphate rock dust in areas outside the Recovery Building. NIOSH recognizes that during this time period dust levels could have been considerably higher than during the Pre-Operational Period. In EPA's Idaho phosphate facility study, the highest dust concentration reported was 50.4 mg/m^3, indicative of an operation with likely visible dust (OCAS-TKBS-0002). At the Idaho plant, this high dust concentration was found in the area of the calciner. Although a calciner was not used at TCC, these high calciner dust concentrations are assumed for workers outside the TCC Recovery Building in order to establish an upper-bound intake estimate from rock-crushing and other dust-generating operations. Intake quantities were calculated based on continuous exposure to an airborne dust loading of 50.4 mg/m^3. Bounding intakes were calculated based on a breathing rate of 1.2 m^3/hr and exposure to that high level of dust for 2000 hours per year. For these calculations, the uranium mass was assumed to be all U-238, as it represents over 99% of the uranium mass in natural uranium. U-234, Th-230, Ra-226, and other radionuclides in the U-238 chain are assumed to be in equilibrium with U-238 during dust-generating activities outside the Recovery Building (e.g., rock-crushing). U-235 was not included because the method of calculating uranium activity bounds the small intake contribution from U-235. Additional parameters used include an assumed 0.014% uranium content in phosphate rock (Stoltz, 1958).

Values calculated in the manner described above, and presented in Table 7-1 for workers outside the TCC Recovery Building, were taken from Table 3 of the Blockson TBD (OCAS-TKBS-0002), with the exception of Po-210. For Blockson, the Po-210 intake rate for workers outside the Blockson recovery building was 10 times higher than U-238 due to potential polonium boil-off during calciner operations. Since a calciner was not used at TCC, the Po-210 intake rate at TCC is assumed to be the same as for U-238.

As discussed in Section 7.2.1, worker exposures inside the TCC uranium recovery building are bounded by the assumption of an airborne gross alpha concentration of 190 dpm/m^3. This airborne concentration represents the maximum "daily average concentration" for workers handling ore concentrates at full-scale production at AEC facilities. For the purpose of this evaluation, the gross alpha activity represented by the 190 dpm/m^3 is assumed to be comprised of equal activity concentrations of U-238 and U-234. These activity fractions are then normalized to the assumed activity fractions for TCC uranium product using the values in Table 5-2. It should be noted that, when calculated in this manner, the resultant airborne activity has a total alpha activity greater than 190 dpm/m^3. This is because it is assumed that the TCC material has a higher specific activity due to the claimant-favorable assumptions on the disposition of uranium progeny within the TCC process. Bounding intake quantities were calculated based on continuous exposure with a breathing rate of 1.2 m^3/hr for 2000 hours per year.

With the exception of Ra-226, the bounding intakes given in Table 7-1 for workers outside of the TCC Recovery Building are lower than the intakes for workers inside the Recovery Building. Since workers may have worked in the Recovery Building and also in other facility locations, or their job assignment may not be well known, bounding internal doses should be selected based on the assumption that all workers were exposed at the intake levels for work inside the Recovery Building. (The slightly higher Ra-226 intake rate for workers outside the Recovery Building is insignificant when considering the much higher intake rates for all other radionuclides inside the Recovery Building.)

Table 7-1: Inhalation Rate for the TCC Site

Radionuclides	Workers Intake During Pre-operational Period (pCi/d)	Workers Intake Inside Recovery Building During Operations (pCi/d)	Workers Intake Outside Recovery Building During Operations (pCi/d) [1]
U-238, Th-230, U-234, Pb-210, Po-210	1.7	281	16
Th-231, Pa-231, Ac-227	0.079	13	0.73
Ra-226	1.7	13	16
Th-232, Ra-228, Th-228	0.056	9.3	0.52

Notes:
- Intake rates are normalized to units of calendar days.
- U-235 is accounted for in the U-238 and U-234 values. Values for U-235 progeny (Th-231, Pa-231, Ac-227) are presented.
- Absorption types are selected in a manner that ensures claimant-favorability. The choice may be Type F, M, or S, as applicable, based on ICRP 68 (ICRP 68, 1994).

[1] These values are from Blockson (OCAS-TKBS-0002, Table 3), modified with respect to worker intake of Po due to lack of a calciner at TCC.

Thorium-230 Considerations

This evaluation assumes that Th-230, Pb-210, and Po-210 follow the uranium isotopes through the chemical processes where they eventually become concentrated in the uranium product material at the same activity concentration as the uranium isotopes (i.e., concentrated by more than a factor of 3000). Although data specific to TCC are currently unavailable, data from other similar operations indicate that, in reality, most of the Th-230 likely remained with the uranium-free phosphoric acid, and most of the Pb-210 stayed in the phosphogypsum (Fukuma, 2000).

This evaluation assumes that U-238/Th-230 radioactivity equilibrium existed in the TCC phosphate rock feed material. It further assumes that Th-230 airborne radioactivity exposures are equal to U-238 airborne radioactivity exposures.

Chemical processing of phosphate rock alters the distribution of the various elements when the processed material splits into two or more streams. Since the degree of separation among uranium and thorium is not known for the TCC process, Th-230 is assumed to remain with U-238 throughout the process at the same relative radioactivity concentrations. The purpose of assuming no separation is to provide upper-bound intakes for thorium. The chemical behavior of natural thorium (i.e., Th-232 and Th-228) is considered to be equal to that of Th-230 once the radionuclides are in solution in the phosphoric acid.

Phosphogypsum is the solid waste resulting from the filtration of the phosphoric acid solution produced from dissolving phosphate rock in sulfuric acid. There are no known TCC analytical data on the percentages of Th-230 reporting to the phosphoric acid and the phosphogypsum. Elzerman reported that some separation of Th-230 and U-238 was likely to have occurred during phosphoric acid production at the Blockson facility (Elzerman, 2007). Due to similarities in the rock dissolution steps at TCC and Blockson, it is likely that a similar separation would have also occurred at TCC. As described below, the Th-230 exposures assigned to workers in the Recovery Building are likely much higher than exposures from phosphogypsum.

The TCC dry uranium concentrate output was likely 40%-60% uranium from an overall uranium recovery of 60%-70% (i.e., approximately 65% of the uranium present in the phosphate rock was recovered and packaged in drums for shipment to the AEC). This would be consistent with the output product from Blockson (Blockson, 1953). The product was reported as U_3O_8, which is about 85% uranium. Over 99% of natural uranium is U-238 on a mass basis. Thus, a 50% U_3O_8 concentration results in a U-238 mass concentration of about 42% in the product shipped to the AEC, which is equivalent to a U-238 concentration of about 1.42×10^5 pCi/g. Assuming that the U-238 and Th-230 concentrations in the product were equal, the TCC uranium product would contain Th-230 at a concentration of 1.42×10^5 pCi/g.

Analytical data on Th-230 in the TCC phosphogypsum piles are not available. There are a number of published studies on the fate of Th-230 at wet-process phosphate plants. Reviewed publications reported Th-230 concentrations in phosphogypsum of 13 pCi/g (Guimond, 1975); 2.4 pCi/g to 13.9 pCi/g and variable with the hydrate form of phosphogypsum produced (Hull, 1996; FIPR, 1995).

Comparing the assumed Th-230 concentration of 1.42 x 10^5 pCi/g in the TCC uranium product to the highest values referenced above for Th-230 (13.9 pCi/g) in phosphogypsum indicates that the modeled Th-230 concentration in the dried uranium in the Recovery Building is roughly 10,000 times more concentrated than what would be expected in phosphogypsum.

Much of the exposure to the phosphogypsum would be from handling it in wet form in the main fertilizer facility (phosphoric acid production). It was also slurried out to the large piles on the property as waste. Some exposures to dried phosphogypsum would be expected at various places in the facility. However, it is not credible that Th-230 exposure from phosphogypsum would approach the exposure that could have been received by handling the uranium product in a dry form for packaging in the Recovery Building. Therefore, NIOSH concluded that the assigned Recovery Building intake rates are significantly higher than one could have received from handling or being exposed to airborne phosphogypsum.

At a Brazilian phosphoric acid/uranium extraction facility that also used solvent extraction for uranium recovery, Th-228, Th-230, and Th-232 were reported to remain with the uranium-free phosphoric acid (Fukuma, 2000). At this facility, these thorium isotopes were then presumed to become part of the fertilizer subsequently produced. If this was also the fate of the thorium isotopes at TCC, where the relative mass of fertilizer produced was far greater than the mass of uranium product material produced, the potential airborne concentration of thorium resulting from airborne fertilizer would have been far less than what this evaluation assumes to be present in the uranium recovery building (1.42 x 10^5 pCi/g).

Ra-226 Considerations

As discussed in Section 5.2.1, most of the Ra-226 is retained in the phosphogypsum. For this reason, as indicated in Table 7-1, intakes of Ra-226 are bounded by exposures outside of the Recovery Building. The bounding Ra-226 intake presented in Table 7-1 for areas outside of the Recovery Building is based on inhalation of dust from phosphate rock at concentration of 50.4 mg/m^3. Concentrations of Ra-226 in phosphate rock are higher than that found in phosphogypsum (FIPR, 1998). The computations presented in this document for inhalation of dust from phosphate rock would, therefore, bound intakes from any gypsum-handling operations.

Ingestion Intakes

Due to contact with contaminated surfaces and/or from eating or drinking, workers also had the potential to ingest uranium and other associated radioactive material. 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. Ingestion intakes were calculated using the inhalation intake quantities from Table 7-1 and applying the methodology in OCAS-TIB-0009 (*Estimation of Ingestion Intakes*).

Table 7-2: Ingestion Rate for the TCC Site			
Radionuclide	**Workers Intake During Pre-Operational Period (pCi/d)**	**Workers Intake Inside Recovery Building During Operations (pCi/d)**	**Workers Intake Outside Recovery Building During Operations (pCi/d) [1]**
U-238, U-234, Th-230, Pb-210, Po-210	0.050	8.6	0.47
Th-231, Pa-231, Ac-227	0.0023	0.39	0.021
Ra-226	0.050	0.40	0.47
Th-232, Th-228, Ra-228	0.0017	0.28	0.016

Notes:
- Intake rates are normalized to units of calendar days.
- U-235 is accounted for in the U-238 and U-234 values. Values for U-235 progeny (Th-231, Pa-231, Ac-227) are presented.
- The fraction of ingested material passing through the gastrointestinal tract that is directly absorbed to body fluids (f1 value) should be selected in a manner consistent with the associated absorption types used for inhalation (see Table 7-1).

[1] These values are from Blockson (OCAS-TKBS-0002, Table 3), modified with respect to worker intake of Po due to lack of a calciner at TCC.

7.2.3.3 Process Development Studies

The purpose of TCC process development studies would likely have been to improve the process to meet contract obligations for uranium production. The uranium produced from work associated with these studies would likely have been at a much lower rate than the uranium produced during full-scale operations; furthermore, the developmental work may have only run intermittently. However, since full production may never have been achieved due to technical problems, it is possible that such studies were ongoing through much of the uranium recovery operations period. Since this work would have involved the same source of radioactive materials as production work (except on a smaller scale with shorter periods of operation), the doses modeled for the production workers are used to bound doses received by workers performing process development studies.

7.2.3.4 Radon Exposure

Radon exposures to workers from uranium extraction work at phosphate plants have been evaluated (ORAUT-OTIB-0043). For reconstructing lung doses, all TCC workers during the Pre-Operational and Operational Periods 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 7-3 lists doses from radon exposures.

Table 7-3: Radon Exposures During Recovery of Uranium from Phosphate Materials

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.
[1] Exposure and dose values are 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-011.

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) relying on representative air monitoring data for workers handling ore concentrates at full-scale production AEC facilities; (2) applying 95th percentile bounding exposure to radon; and (3) the use of claimant-favorable assumptions regarding other non-uranium radionuclides and potential intakes from dust in plant areas for workers outside the TCC Recovery Building.

7.3 External Radiation Doses at TCC

The principal source of external radiation doses for members of the proposed class was exposure to uranium, thorium, and their associated progeny. Because phosphate rock contains NORM, any work with this material potentially exposes workers to radioactivity. At TCC, uranium was extracted from phosphate rock and concentrated for use by the AEC. Employer-required medical X-ray examinations are another potential source of external radiation dose at TCC.

7.3.1 Process-Related External Radiation Doses at TCC

External dosimetry data are not known to exist for TCC workers. NIOSH data capture efforts have found no direct radiation survey results for TCC during the uranium extraction operational period. Therefore, source term information has been used to estimate external doses to workers involved in uranium extraction.

7.3.2 Ambient Environmental External Radiation Doses at TCC

In this evaluation, during the Operational Period, all workers are assumed to be maximally exposed to external radiological conditions that potentially existed in the uranium recovery building. During the Pre-Operational Period, doses are estimated using ORAUT-OTIB-0043, C*haracterization of Occupational Exposure to Radium and Radon Progeny During Recovery of Uranium from Phosphate Materials.* Ambient environmental dose is bounded by the assignment of this process-related dose.

7.3.3 TCC Occupational X-ray Examinations

Occupational X-ray exposure data for TCC workers are unavailable. Since occupational X-ray examinations were commonly required during the time period covered by this evaluation, potential dose from such practices are taken into account for TCC workers.

7.3.4 External Dose Reconstruction

As of October 23, 2007, 13 EEOICPA claims meeting the proposed class definition being evaluated in this report had been submitted to NIOSH. Of those 13 claims, NIOSH has completed dose reconstructions for two claims.

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

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

7.3.4.1 Photon Dose

TCC operations did not begin until October 5, 1953. The proposed SEC class period being considered in this evaluation begins January 1, 1952. From January 1, 1952 through December 31, 1952 there would not have been any sources of radiation exposure at the TCC site. For this early time period, worker external doses are assumed to be zero.

Although TCC operations had still not yet begun, for the Pre-Operational Period from January 1, 1953 through October 4, 1953, NIOSH assumes that phosphate rock was received at the site and that workers handling this material were potentially exposed. Photon dose to these workers can be estimated using ORAUT-OTIB-0043, C*haracterization of Occupational Exposure to Radium and Radon Progeny During Recovery of Uranium from Phosphate Materials.* This document considers potential worker dose to radiation sources such as radium concentrated in the phosphogypsum waste, and surface contamination (including radium scale build-up on equipment). Although these concentrated radiation sources would not yet have been present at TCC (since operations had not yet begun), worker doses estimated from these considerations may be used to bound any worker doses to the raw phosphate rock prior to start of operations. Using this methodology, the geometric mean value of 70 mrem/yr is assigned as a constant. Photon energies are assumed to be 50% 30-250 keV and 50% >250 keV.

The greatest potential source of photon dose to workers during the Operational Period would have been exposure to uranium product material inside the Recovery Building. For the purpose of this photon dose evaluation, the uranium product material is assumed to be yellowcake (U_3O_8). *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 (OCAS-TKBS-0002). This was later adjusted for actual source activity to compare actual dose rates. All radionuclide concentrations were calculated based on their respective ratios 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, 1996; OCAS-TKBS-0002). Results are provided in Table 7-4.

Table 7-4: Uranium Dose Rates from Drums of Yellowcake

Density of U_3O_8 (g/cm^{-3})	Activity of ^{nat}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	5.12E-03	4.08E-04	5.53E-03
2	1.248E-01	5.62E-03	4.39E-04	6.06E-03
4	2.497E-01	5.97E-03	4.54E-04	6.42E-03
6	3.745E-01	5.99E-03	4.38E-04	6.43E-03
6.7	4.182E-01	6.02E-03	4.52E-04	6.47E-03

Notes:
The data and information contained in this table are from Table 7 in OCAS-TKBS-0002.
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 (OCAS-TKBS-0002).

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. For skin, air kerma values were multiplied by an organ dose conversion factor of 1.0.

7.3.4.2 Electron Dose

The principal sources of beta exposure considered for workers inside the TCC Recovery Building include shallow dose from exposure to open drums of uranium product material, shallow dose from skin contaminated with uranium, skin dose from contact with contaminated work clothing, and skin dose from handling and cleaning filter media. Each potential source is discussed below. The dose for workers inside the Recovery Building bounds the dose for workers outside the Recovery Building.

Shallow Dose from Drums of Uranium Product Material

It is assumed that there was a potential for workers to receive a shallow dose from exposure to open drums of uranium product material during drum loading and sealing. For the purpose of this evaluation, the uranium product material is assumed to be yellowcake. The dose rate at one foot from the surface of aged yellowcake is between 1 and 2 mrem/hr. 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/hr. 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-bound shallow beta dose of 0.8 rem/yr with a geometric standard deviation of 2.7. The 0.8 rem/yr 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 (EPA, 1993). 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 7-5. The calculated beta dose has not been reduced to allow for doses to areas of the skin that are typically covered by clothing (which reduces beta dose to the skin) (OCAS-TKBS-0002).

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 the exposure to a drum of aged yellowcake (discussed above) and the estimated skin dose from contaminated clothing, as discussed below and shown in Table 7-5.

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 a level of 1.5 mrem/hr (AEC, 1958). The Mallinckrodt dose rate is used as a bounding condition for TCC 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/yr. Doses are applied as electrons > 15keV.

Direct Handling of Yellowcake Filter Media

Former Blockson workers stated that during filtering operations, their hands were directly exposed to filter cake containing uranium. For the purpose of this evaluation, it is assumed that similar exposures occurred at TCC. Blockson workers noted 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). Doses from filtering operations have been estimated for the hands and forearms.

Yellowcake concentration in the product delivered to the 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/yr, as indicated in Table 7-5. These doses are being applied as electrons > 15keV to all TCC workers.

Table 7-5: Shallow Dose for TCC Workers

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

Notes:
The data and information contained in this table are from Table 9 in OCAS-TKBS-0002.
[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 TCC. Technical Information Bulletin ORAUT-OTIB-0024 provides neutron dose rates from various forms of uranium compounds. In Table 5-5 of that document, the listed neutron dose rate at one foot from a source of natural uranium fluoride (UF_4) is 1.93E-9 rem/hr-gram. Due to the uncertainty of the chemical composition of the TCC product material, for the purposes of this evaluation, the dose rate value for UF_4 (with its high neutron yield) was assumed in order to ensure claimant favorability. For the purpose of estimating the maximum potential neutron dose, it was assumed that a uranium worker was exposed to a single drum containing 303 pounds of UF_4 (the estimated total quantity of uranium product recovered at TCC). An exposure time of 8 hrs/wk and 50 wks/yr at a distance of one foot from the source was also assumed. Under this scenario, the annual dose is estimated to be 0.106 rem. The dose for workers inside the Recovery Building bounds the dose for workers outside the Recovery Building. Neutron dose is only applicable to the Operational Period.

7.3.4.4 Unmonitored Individuals Working in Production Areas

NIOSH has no monitoring records for photon, electron, or neutron doses at TCC. 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. NIOSH considers the adequate reconstruction of medical dose for TCC workers to be feasible by using claimant-favorable assumptions as well as the applicable protocols in the complex-wide Technical Information Bulletin, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, ORAUT-OTIB-0006.

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-00088

The following assertions, made on behalf of petition SEC-00088 for the Texas City Chemicals, Inc., site, were evaluated. Information and affidavit statements provided by the petitioner are summarized in the italicized statements below; the comments that follow are from NIOSH.

Radiation monitoring records for members of the proposed class may have been lost, falsified, or destroyed.

NIOSH has been unable to obtain any radiation monitoring records for members of the proposed class. At this time, it is unclear whether radiation monitoring records ever existed. If they were generated, they appear to have been lost or destroyed. In the absence of these records, NIOSH has developed methodologies for estimating claimant-favorable worker doses at TCC based on process knowledge and data from similar uranium recovery facilities. These methodologies are described in Sections 7.2 and 7.3.

Information regarding monitoring from TCC is unavailable.

As mentioned above, NIOSH has not obtained any monitoring data. However, a bounding source term can be derived from available records. The uranium recovery processes used at TCC are sufficiently understood to develop reasonable claimant-favorable dose reconstruction methods. The methodologies developed are described in Sections 7.2 and 7.3.

7.5 Summary of Feasibility Findings for Petition SEC-00088

This report evaluates the feasibility for completing dose reconstructions for employees at the TCC from January 1, 1952 through December 31, 1956. NIOSH found that the process descriptions and source term data available are sufficient to complete dose reconstructions for the proposed class of employees.

Table 7-6 summarizes the results of the feasibility findings at TCC for each exposure source during the time period January 1, 1952 through December 31, 1956.

Table 7-6: Summary of Feasibility Findings for SEC-00088
January 1, 1952 through December 31, 1956

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	X	
- Occupational Medical X-ray	X	

As of October 23, 2007, a total of 13 claims have been submitted to NIOSH for individuals who worked at TCC and are covered by the proposed class definition evaluated in this report. Dose reconstructions have been completed for two individuals (~15%).

8.0 Evaluation of Health Endangerment for Petition SEC-00088

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.

NIOSH's 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-00088

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 workers who worked in any areas at Texas City Chemicals, Inc., from January 1, 1952 through December 31, 1956. In this evaluation, NIOSH considered exposures to all workers in order to bound the estimates of potential exposure for the petitioner's proposed class of "laborers." The class was modified because radiation monitoring records are unavailable for TCC workers for the specified period and all TCC employees were potentially exposed to radioactive materials as a result of AEC-related uranium extraction processes.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Database, for information relevant to SEC-00088. 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.

This page intentionally left blank

10.0 References

42 C.F.R. pt. 81, *Guidelines for Determining the Probability of Causation Under the Energy Employees Occupational Illness Compensation Program Act of 2000;* Final Rule, Federal Register/Vol. 67, No. 85/Thursday, p. 22,296; May 2, 2002; SRDB Ref ID: 19391

42 C.F.R. pt. 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 2, 2002; SRDB Ref ID: 19392

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*; Final Rule; May 28, 2004; SRDB Ref ID: 22001

42 U.S.C. §§ 7384-7385 [EEOICPA], *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended; OCAS website (http://www.cdc.gov/niosh/ocas)

Battelle-TBD-6001, *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium*, Rev. F0; December 13, 2006; SRDB Ref ID: 30673

Battelle-TBD-6001, App. BH, *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium, Appendix BH – International Minerals and Chemical Corporation*, Rev. 0; July 16, 2007; SRDB Ref ID: 35365

OCAS-IG-001, *External Dose Reconstruction Implementation Guideline*, Rev. 1; Office of Compensation Analysis and Support; Cincinnati, Ohio; August, 2002; SRDB Ref ID: 22401

OCAS-PR-004, *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, Rev. 0, National Institute for Occupational Safety and Health (NIOSH); Cincinnati, Ohio; September 23, 2004; SRDB Ref ID: 32022

OCAS-TIB-009, *Estimation of Ingestion Intakes*, Rev. 00, Rev. 0, National Institute for Occupational Safety and Health (NIOSH); Cincinnati, Ohio; April 13, 2004; SRDB Ref ID: 22397

OCAS-TIB-011, *Lung Dose Conversion Factor for Thoron WLM*, Rev. 02, Office of Compensation Analysis and Support (OCAS); Cincinnati, Ohio; January 13, 2006; SRDB Ref ID: 22409

OCAS-TKBS-0002, *Technical Basis Document for Atomic Energy Operations at Blockson Chemical, Joliet, Illinois*, Rev. 02, National Institute for Occupational Safety and Health (NIOSH); Cincinnati, Ohio; November 21, 2007; SRDB Ref ID: 36611

ORAUT-OTIB-0006, *Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, Rev. 03 PC-1; December 21, 2005; SRDB Ref ID: 20220

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

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

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

AEC, 1958, *Symposium on Occupational Health Experience and Practices in the Uranium Industry*; U.S. Atomic Energy Commission; October 15-17, 1958; SRDB Ref ID: 7886

AEC Contract, 1952, Letter Contract No. AT(49-1)-616 to Texas City Chemicals, Inc., from the Division of Raw Materials; U.S. Atomic Energy Commission; February 14, 1952; SRDB Ref ID: 14895

AEC Monthly, Dec. 1955, *Monthly Report on Activities of Domestic Production Phosphates, Division of Raw Materials During December 1955*; USAEC, Division of Raw Materials, Domestic Production Phosphates, Office of Domestic Procurement; December 1955; SRDB Ref ID: 22264

Affidavit, site and medical information from survivor of former TCC employee; received April 4, 2007; OSA document id: 103975

Andersson, 2002, *Radiation Dose Implications of Airborne Contaminant Deposition to Humans*, K. G. Andersson, et al; Health Physics 82(2), pp. 226-232; 2002; SRDB Ref ID: 33203

Christofano, 1960, *The Industrial Hygiene of Uranium Refining*; Emil Christofano and William B. Harris; Environmental Health (Official Publication for the American Academy of Occupational Medicine), Vol. 1, No. 5; November 1960; SRDB Ref ID: 15774

Coppinger, 1959, *Ionium (Thorium-230) for Radioisotope Preparation (Status Report)*; E. A. Coppinger; C. A. Rohrmann; Programming Operation, Hanford Laboratories Operation; December 15, 1959; SRDB Ref ID: 30884

DOE, 2000, *DOE Standard, Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities*; Department of Energy (DOE); Washington D.C.; August 2000; SRDB Ref ID: 4617

Eidson, 1984, *Predicted Deposition Rates of Uranium Yellowcake Aerosols Sampled in Uranium Mills*; Arthur F. Eidson and Edward G. Damon; *Health Physics*, Vol. 46, No. 1; January 1984; SRDB Ref ID: 32091

Elimination Report, 1986, *Elimination Report, Amoco Chemical Company (the Former Texas City Chemicals, Inc.), Texas City, Texas*; U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FUSRAP); 1986; SRDB Ref ID: 16646 (page 8 of 197)

Elzerman, 2007, *Report for Contract 5-15816*, Review of Blockson Chemical Co. uranium recovery process; Alan W. Elzerman; May 31, 2007; SRBD Ref ID 32738

EPA, 1978, *Radiological Surveys of Idaho Phosphate Ore Processing – The Wet Process Plant;* Environmental Protection Agency (EPA); April 1978, SRDB Ref ID 30886

EPA, 1993, *Federal Guidance Report No. 12: External Exposures to Radionuclides in Air, Water, and Soil*; K. F. Eckerman; J. C. Ryman; U.S. Environmental Protection Agency; Washington, D.C.; September, 1993; SRDB Ref ID: 11997

ERDA, 1976, *Summary of Available Data on Specified Division of Raw Materials Contractors*, memo and summary report from R. D. Nininger (Asst. Director for Raw Materials, Energy Research and Development Administration) to M. B. Biles (Director, Division of Safety, Standards and Compliance); October 5, 1976; SRDB Ref ID: 16441

FIPR, 1995, *Microbiology and Radiochemistry of Phosphogypsum*, Florida Institute of Phosphate Research (FIPR); May 1995, SRDB Ref ID 30136

FIPR, 1998, *Evaluation of Exposure to Technically Enhanced Naturally Occurring Radioactive Materials (TENORM) in the Phosphate Industry*, Florida Institute of Phosphate Research (FIPR); July 1998, SRDB Ref ID 18076

Florida Meeting, 1955, *Florida Production Meeting on Recovery of Uranium from Commercial Phosphoric Acid*, Florida meeting summary; Author unknown; April 25-26, 1955; SRDB Ref ID: 29518

Fogh, 1999, *Quantitative Measurement of Aerosol Deposition on Skin, Hair and Clothing for Dosimetric Assessment – Final Report*; C. L. Fogh, et al; June 1999; SRDB Ref ID: 14018

Fukuma, 2000, *Distribution of Natural Radionuclides During the Processing of Phosphate Rock from Itataia-Brazil for Production of Phosphoric Acid and Uranium Concentrate;* H. T. Fukuma, E. A. N. Fernandes, and A. L. Quinelato; Radiochimica Acta., Vol. 88, pp. 809-812; 2000; SRDB Ref ID: 30474

Greek, 1957, *Uranium Recovery from Wet Process Phosphoric Acid*; B. F. Greek; G. W. Allen; D. E. Tynan; Industrial Engineering Chemistry, Vol 49; 1957; SRDB Ref ID: 35734

Guimond, 1975, *Radioactivity Distribution in Phosphate Products, By-Products, Effluents, and Wastes*; Richard J. Guimond and Samuel T. Windham; August 1975; SRDB Ref ID: 13366

Hull, 1996, *Radiochemistry of Florida Phosphogypsum*; C. D. Hull and W. C. Burnett; Journal of Environmental Radioactivity, Vol. 32 (3) pp. 213-238; 1996; SRDB Ref ID: 32562

ICRP 30, *Limits for Intakes of Radionuclides by Workers*, International Commission on Radiological Protection (ICRP) Publication 30; Pergamon Press, Oxford; 1979; SRDB Ref ID: 29220

ICRP 66, *Human Respiratory Tract Model for Radiological Protection*, International Commission on Radiological Protection (ICRP) Publication 66; Annals of ICRP Vol. 24 (1-3); 1994; SRDB Ref ID: 22732; Commonly Available

ICRP 68, *Dose Coefficients for Intakes of Radionuclides by Workers*, International Commission on Radiological Protection (ICRP) Publication 68; Annals of ICRP Vol. 24 (4), 1994; SRDB Ref ID: 22731; Commonly Available

ICRP 74, *Conversion Coefficients for Use in Radiological Protection Against External Radiation*, International Commission on Radiological Protection (ICRP) Publication 74; Annals of ICRP Vol. 26 (3/4); 1996; SRDB Ref ID: 22730; Commonly Available

Johnson, 1953, Letter from Jesse C. Johnson (Director , AEC Division of Raw Materials) to Lewis L. Strauss (AEC Chairman); November 18, 1953; SRDB Ref ID: 16646 (page 24 of 197)

Lopker, 1951, Letter from E. B. Lopker (Director of Engineering, Blockson Chemical Co.) to Mr. Sheldon Wimpfen (Raw Materials Division, AEC); July 31, 1951; SRDB Ref. ID: 9558

NIOSH, 2007, *NIOSH Dose Reconstruction Project Worker Outreach Meeting with Former Workers from the Blockson Chemical Company*; meeting transcripts and minutes; January 24-25, 2007; available on OCAS website (http://www.cdc.gov/niosh/ocas)

NRC, 2002, *Health Physics Surveys in Uranium Recovery Facilities*, Regulatory Guide 8.30, Rev. 1; U.S. Nuclear Regulatory Commission (NRC); May 2002; SRDB Ref ID: 13982

Personal Communication, 2002, Communication regarding uranium program; various dates throughout 2002; [Name Redacted]; SRDB Ref. ID: 31328

Personal Communication, 2007a, *Personal Communication with Former TCC Employee*; Telephone Interview by ORAU Team; October 2, 2007; SRDB Ref ID: 35466

Personal Communication, 2007b, *Personal Communication with Survivor of Former TCC Employee*; Telephone Interview by ORAU Team; October 2, 2007; SRDB Ref ID: 35465

Petition Form B, SEC-00088, with supporting information; March 13, 2007, OSA Ref ID: 102669

Powers, 1979, *Letter regarding Lack of Uranium Recovery Activities*; Herman G. Powers; March 22, 1979; SRDB Ref ID: 16646, page 126

Proof of Relationship, affidavit of marriage and employment from survivor of former TCC employee; April 17, 2007; OSA document id: 102839

Robinson, 1955, *Florida Meeting on Recovery of Uranium from Phosphates*, memorandum to files; B. M. Robinson; May 2, 1955; SRDB Ref ID: 29526

Roessler, 1979, *Uranium and Radium-226 in Florida Phosphate Materials*; Health Physics, Vol. 37(3): 269-277; C. E. Roessler, et al.; February 1979; SRDB Ref ID: 13364

Stoltz, 1958, *Recovery of Uranium for Phosphate Ores*, Emil Stoltz, Jr.; July 24, 1958; SRDB Ref ID: 4026

Survey, 1980, *Preliminary Survey of Texas City Chemicals, Inc. (Borden Chemical Division of Borden, Inc.), Texas City, Texas*; Health and Safety Research Division; Oak Ridge National Laboratory; March 1980; SRDB Ref ID: 16646 (page 70 of 197)

Web Elements, 2007, http://www.webelements.com/webelements/compounds/text/U/O8U3-1344598.html; Sept. 27, 2007

Wilkinson, 1976, *Uranium Recovery from Wet Process Phosphoric Acid: History & Present Status*, Gerald E. G. Wilkinson; Gardinier, Inc.; May 17, 1976; SRDB Ref ID: 10897