SEC Petition Evaluation Report
Petition SEC-00216

Report Rev #:0 Report Submittal Date: January 29, 2015

Subject Expert(s):	Monica Harrison-Maples
Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Receipt Date	Qualification Date	DOE/AWE Facility Name
SEC-00216	83.13	June 12, 2014	August 5, 2014	Dow Chemical Company

Petitioner-Requested Class Definition

All employees in all areas who worked for Dow Chemical Co. in Pittsburg, CA (aka Walnut Creek, CA), from 1947-1957.

Class Evaluated by NIOSH

All employees who worked in any area of the Dow Chemical Company facility in Pittsburg, California, from January 1, 1947 through December 31, 1957.

NIOSH-Proposed Class to be Added to the SEC

All Atomic Weapons Employer employees who worked for Dow Chemical Company in Pittsburg, California, from October 1, 1947 through June 30, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
N/A	N/A	N/A	N/A

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
N/A	N/A

ORAU Lead Technical Evaluator: Monica Harrison-Maples

ORAU Peer Review Completed By: Daniel H. Stempfley

Peer Review Completed By:	[Signature on File] *Lara Hughes*	1/29/2015 *Date*
SEC Petition Evaluation Reviewed By:	[Signature on File] *J. W. Neton*	1/29/2015 *Date*
SEC Evaluation Approved By:	[Signature on File] *Stuart L. Hinnefeld*	1/30/2015 *Date*

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Evaluation Report Summary: SEC-00216, Dow Chemical Company

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-00216 was received on June 12, 2014, and qualified on August 5, 2014. The petitioner requested that NIOSH consider the following class: *All employees in all areas who worked for Dow Chemical Co. in Pittsburg, CA (aka Walnut Creek, CA), from 1947-1957.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. NIOSH evaluated the following class: All employees who worked in any area of the Dow Chemical Company facility in Pittsburg, California, from January 1, 1947 through December 31, 1957.

NIOSH-Proposed Class to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all Atomic Weapons Employer employees who worked for Dow Chemical Company in Pittsburg, California, from October 1, 1947 through June 30, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort. The class under evaluation was modified (see Section 3.0 below) because records of the contract and a memorandum documenting the conclusion of the work by Dow Chemical Company provide the start and end dates for the Atomic Energy Commission (AEC) work. The periods from January 1, 1947 through September 30, 1947, and from July 1, 1957 through December 31, 1957, have been excluded from the NIOSH-proposed class because covered work was not performed during these times.

Feasibility of Dose Reconstruction

Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it does not have 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. Information available from the site profile and additional resources is not 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.

The NIOSH dose reconstruction feasibility findings are based on the following:

- Principal sources of internal radiation for members of the proposed class included exposures to uranium contained in phosphate ores commercially processed to manufacture phosphate fertilizers and phosphate chemicals. The byproduct phosphatic acid derived from these manufacturing processes was used as a starting point for investigations into chemical recovery of the uranium naturally contained in the phosphate ores. NIOSH estimates between 17,000-26,500 gallons of solution were analyzed over the nine-and-one-half years of AEC research operations at Dow. The modes of potential exposure were inhalation and ingestion of uranium and its progeny during wet chemistry separation work, including evaporation and condensation operations to perform sample analyses.

- NIOSH has not located documentation giving any indication of a routine internal personnel exposure monitoring program for the period under evaluation. No internal monitoring or air sample data have been located by NIOSH. Without additional personnel radiation monitoring data representing the period from October 1, 1947 through June 30, 1957, NIOSH has insufficient information to appropriately characterize radioactive material intakes during Dow Chemical Company operations.

- Although the uranium content of the phosphate rock, from which this acid derived its uranium, was very low, the uranium concentration process developed at Dow resulted in refined uranium products. The concentration of uranium in the acids involved in the research at Dow Chemical Company labs is not documented in available reports for the period under evaluation. The documentation does not provide indication of the concentration or the total quantity of uranium in the purified products either. Without monitoring information or quantitative source term information, NIOSH cannot put an upper bounding estimate on potential exposures with any degree of confidence.

- Principal sources of external radiation for members of the proposed class included exposures to natural uranium and progeny during development of a wet-chemistry recovery process. Samples of uranium-bearing acids were treated and analyzed to develop procedures for the recovery of any uranium contained in these samples. Liquids were handled in hoods, using standard chemical protection methods and protective equipment.

- NIOSH has not located any indication of external personnel exposure monitoring for the period under evaluation. NIOSH's research indicates personnel monitoring for external exposure to radiological materials was not performed. No records or documentation of any program for external dose monitoring have been located.

- NIOSH does not have access to sufficient personnel monitoring, workplace monitoring, or source term data to estimate unmonitored external exposures for Dow Chemical Company workers exposed during the development of uranium-recovery operations from October 1, 1947 through June 30, 1957.

- Pursuant to 42 C.F.R. § 83.13(c)(1), NIOSH determined that there is insufficient information to either: (1) 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 (2) estimate the radiation doses of members of the class more precisely than a maximum dose estimate.

- Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Dow Chemical Company during the period from October 1, 1947 through June 30, 1957, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

- NIOSH finds that it is likely feasible to reconstruct occupational medical dose for Dow Chemical Company by using claimant-favorable assumptions and the *Technical Information Bulletin, Dose Reconstruction from Occupational Medical X-Ray Procedures* (ORAUT-OTIB-0006).

Health Endangerment Determination

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

NIOSH did not identify any evidence supplied by the petitioners or from other resources that would establish that the proposed class was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures. However, evidence indicates that some workers in the proposed class may have accumulated substantial chronic exposures through episodic intakes of radionuclides, combined with external exposures to gamma, beta, and neutron radiation. Consequently, NIOSH has determined that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under this employment or in combination with work days within the parameters established for one or more other SEC classes.

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SEC Petition Evaluation Report for SEC-00216

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 (ORAU) Team Lead Technical Evaluator: Monica Harrison-Maples, ORAU. 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 area of the Dow Chemical Company facility (often referred to as Dow in this report) in Pittsburg, California, from January 1, 1947 through December 31, 1957. 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 Division of Compensation Analysis and Support's (DCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, DCAS-PR-004.[1]

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.[2]

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 NIOSH to assume that any duration of unprotected exposure may have endangered the health of

[1] DCAS was formerly known as the Office of Compensation Analysis and Support (OCAS).
[2] 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.

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 one or more other SEC classes.

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 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.[3]

3.0 SEC-00216, Dow Chemical Company Class Definitions

The following subsections address the evolution of the class definition for SEC-00216, Dow Chemical Company. When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-requested class. If some portion of the petitioner-requested class is qualified, NIOSH will specify that class along with a justification for any modification of the petitioner's class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00216 was received on June 12, 2014, and qualified on August 5, 2014. The petitioner requested that NIOSH consider the following class: *All employees in all areas who worked for Dow Chemical Co. in Pittsburg, CA (aka Walnut Creek, CA), from 1947-1957.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Dow Chemical Company workers in question. NIOSH deemed the following Form B and affidavit statements sufficient to qualify SEC-00216 for evaluation:

- Records and information are inadequate to estimate radiation doses acquired by members of the proposed class of employees with sufficient accuracy.

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

- The DOL description states: The DOW operation involved process studies and experimentation investigations on different uranium ores and thorium-bearing ores, including pilot-scale solvent extraction from phosphoric acid.

Based on its Dow Chemical Company research and data capture efforts, NIOSH determined that it has access to process descriptions for many of the research operations that went on at Dow Chemical Company during the time period under evaluation. However, NIOSH also determined that no personnel, area, or air monitoring records exist for all time periods or for all radionuclides. NIOSH concluded that there is sufficient documentation to support, for at least part of the requested time period, the petition basis that radiation exposures and radiation doses were not adequately monitored at Dow Chemical Company, either through personal monitoring or area monitoring. 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 of this report.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class because of the lack of any monitoring records for the Dow Chemical Company facility in Pittsburg, California, for the period of AEC operations. Therefore, NIOSH defined the following class for further evaluation: All employees who worked in any area of the Dow Chemical Company facility in Pittsburg, California, from January 1, 1947 through December 31, 1957.

3.3 NIOSH-Proposed Class to be added to the SEC

Based on its research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all Atomic Weapons Employer employees who worked for Dow Chemical Company in Pittsburg, California, from October 1, 1947 through June 30, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

The NIOSH-proposed class was modified from the NIOSH-evaluated class because during its evaluation NIOSH found documentation regarding the start and end dates for the AEC work; the initiation of the contract with AEC began on October 1, 1947, while the contract was completed June 30, 1957 (Contract AT-30-1-GEN-236; Johnson, 1957). The periods from January 1, 1947 through September 30, 1947, and from July 1, 1957 through December 31, 1957, have been excluded from the NIOSH-proposed class because covered work was not performed during these times. The scope of workers included in the class was not modified from the petitioner-requested class description of “all workers”. Though a former worker indicated that it was not the custom for individuals to enter labs they were not working in, it seems there were no access controls to prevent it. With no administrative or engineered controls to prevent access to the source terms at Dow Chemical Company, and no monitoring program to detect possible exposures, NIOSH cannot differentiate the potentially-exposed worker population from workers with no potential for exposure, based on available documentation.

NIOSH also investigated the description of the site location provided as part of the petition. Information NIOSH gathered indicates that the Walnut Creek facility was not built until after the covered period of AEC operations. Because the Walnut Creek location was not in existence during the AEC operations, any operations at that location are excluded as they are not EEOICPA-covered activities. Therefore, the NIOSH-proposed class indicates only Pittsburg, California, and no further investigations into work at the Walnut Creek facility are reported herein.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

As is standard practice, NIOSH completed an extensive database and Internet search for information regarding Dow Chemical Company. The database search included the DOE Legacy Management Considered Sites database, the DOE Office of Scientific and Technical Information (OSTI) database, the Energy Citations database, and the Hanford Declassified Document Retrieval System. In addition to general Internet searches, the NIOSH Internet search included OSTI OpenNet Advanced searches, OSTI Information Bridge Fielded searches, Nuclear Regulatory Commission (NRC) Agency-wide Documents Access and Management (ADAMS) web searches, the DOE Office of Human Radiation Experiments website, and the DOE-National Nuclear Security Administration-Nevada Site Office-search. Attachment One contains a summary of Dow Chemical Company documents. The summary specifically identifies data capture details and general descriptions of the documents retrieved.

In addition to the database and Internet searches listed above, NIOSH identified and reviewed numerous data sources to determine information relevant to determining the feasibility of dose reconstruction for the class of employees under evaluation. 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. While a Site Profile document was not developed for the Dow Chemical Company site, NIOSH examined the following TBD for insights into Dow Chemical Company operations or related topics/operations at other sites:

- *Technical Basis Document for Atomic Energy Operations at Blockson Chemical Company, Joliet, Illinois*, DCAS-TKBS-0002; Rev. 03; November 21, 2007; SRDB Ref ID: 91205

4.2 ORAU Technical Information Bulletins (OTIBs)

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

- *OTIB: Dose Reconstruction from Occupational Medical X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 4; June 20, 2011; SRDB Ref ID: 98147

- *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: Guidance on Assigning Occupational X-Ray Dose Under EEOICPA for X-Rays Administered Off Site*, ORAUT-OTIB-0079, Rev. 00; January 3, 2011; SRDB Ref ID: 89563

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed three former Dow Chemical Company employees. NIOSH tried to locate additional former employees, but all that were identified to NIOSH as associated with this work that occurred over 50 years ago are deceased. NIOSH's objective was to gather information on specific radioactive material operations at the Dow Chemical Company facility in Pittsburg, California, to clearly determine the location of the radiation work conducted and to identify any radiological monitoring performed during operations. Interviews were performed by telephone with a minimum of one NIOSH and two ORAU Team personnel in attendance. NIOSH also contacted a former worker associated with the Formerly Utilized Sites Remedial Action Program (FUSRAP) elimination survey for the site. That individual declined to be interviewed.

- Personal Communication, 2014a, *Personal Communication with Former Dow Chemical Company Employee* ; Telephone Interview by ORAU Team and NIOSH; August 29, 2014; SRDB Ref ID: 135915

- Personal Communication, 2014b, *Personal Communication with Former Dow Chemical Company Employee*; Telephone Interview by ORAU Team and NIOSH; September 2, 2014; SRDB Ref ID: 135930

- Personal Communication, 2014c, *Personal Communication with Former Dow Chemical Company Employee*; Telephone Interview by ORAU Team and NIOSH; September 11, 2014; SRDB Ref ID: 136594

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH DCAS Claims Tracking System (referred to as 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 7, 2015)

Table 4-1: No. of Dow Chemical Company Claims Submitted Under the Dose Reconstruction Rule	
Description	**Totals**
Total number of claims submitted for dose reconstruction	1
Total number of claims submitted for energy employees who worked during the period under evaluation (January 1, 1947 through December 31, 1957)	1
Number of dose reconstructions completed for energy employees who worked during the period under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	1
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	0
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	0

NIOSH reviewed the single claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. No personal monitoring records were located for the claim and a maximizing approach was applied to over-estimate the possible exposure this individual could have received. No indications of any discrete incidents were located.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. One hundred sixty-six documents in this database were identified as pertaining to Dow Chemical Company. These documents were evaluated for their relevance to this petition. The documents include historical background on the development of chemical processes investigated and assessed by Dow Chemical Company for the recovery of uranium as a byproduct of the commercial phosphate processing industry. Information on process materials and process descriptions were included.

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*, June 11, 2014 (DSA Ref ID: 120003);
- Newspaper article, Exhibit Building was Center of Most Attention at Fair, *The Antioch Ledger*; August 13, 1951 (DSA Ref ID: 120083, PDF p. 4);
- Handout, *Information about the Displays: Gamma the Glutton A Dipper Bird*, a handout for use in explaining specific exhibits (DSA Ref ID: 120083, PDF pp. 6-9); and
- Affidavit from Survivor, indicating that records and information are inadequate to estimate the radiation doses acquired by members of the proposed class with sufficient accuracy; June 30, 2014 (DSA Ref ID: 120083, PDF pp. 2-3).

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at the Dow Chemical Company from January 1, 1947 through December 31, 1957, and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered descriptive information regarding the uranium source of concern, and information describing 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 Dow Chemical Company Plant and Process Descriptions

The AEC, in an effort to ensure domestic production of uranium, pursued options to adapt the processes for recovering uranium from pitchblende and carnotite ores to the problem of recovering uranium from phosphate ores. The goal was to develop large, low-grade deposits of shales, phosphates, and lignites into economical sources of uranium. Emphasis was placed on phosphate rock (Greek, 1957, PDF p. 3), which contains about 0.01% U_3O_8 (Bailes, 1951, PDF p. 5). The uranium is evenly distributed through the phosphate rock and consequently cannot be concentrated by mechanical methods.

Phosphate ores, already in use at the time to manufacture phosphate fertilizers and phosphate chemicals, offered an economic advantage because the mining itself was not a cost to the government. The phosphate ore deposits were being mined for these commercial products and the uranium would be extracted as a byproduct operation. *Uranium Recovery from Wet Process Phosphoric Acid* (Greek, 1957, PDF p. 3) estimates a ton of phosphate rock generally contains 0.1 to 0.4 pounds of uranium. Occasionally a deposit was found with uranium content up to 1 pound per ton of phosphate rock.

On February 17, 1948, the AEC initiated Contract No. AT-30-1-GEN-236 with Dow Chemical Company to "conduct certain studies and experimental investigations on uranium and thorium-bearing ores designated by the Commission…" (Contract AT-30-1-GEN-236, PDF p.4). The contract was effective October 1, 1947, and extended annually to June 30, 1957, by Supplement 12 (DOE, unknown, PDF p. 13). The contract called for process studies and pilot-scale solvent extraction of uranium from phosphoric acid with Supplement 2 adding studies on liquid waste disposal. The studies during the nine-and-a-half years of work pertained to uranium recovery from a variety of raw materials and improving concentrates to yield specification-grade uranium compounds. Precipitation, ion exchange, and solvent extraction were investigated as potential methods. Investigations were carried out by Dow Chemical Company into uranium recovery from phosphates, superphosphates, low-content leached zone phosphates, sulfuric acid leach solutions (from the Colorado Plateau mills), carbonate leach liquors, Mallinckrodt uranium refinery nitrate raffinates and carbonate scrub solutions, phosphate ores by direct-solvent uranium extraction (without prior aqueous leaching), and from other miscellaneous materials. Numerous original contributions to uranium-ore metallurgy came from this work. Most of the work for the last year of the contract was concerned with methods for the production of specification-grade UF_4 products at the mill site. Reduced uranium could be extracted. UF_4 products of high purity were obtained by precipitation that approached the chemical specifications

(Bailes, 1957, PDF p. 14). The studies suggested that integration of raw material and feed material production in the mills producing crude concentrate was feasible, at a considerable cost savings.

Dow Chemical Company was located in Pittsburg, California, on a multi-acre site. Although NIOSH does not have documentation providing the dimensions of the physical site during the period under evaluation, the current Dow Chemical Company site in Pittsburg, California, encompasses 513 acres, 472 of which are wetlands preserve, leaving 41 acres available for operational use. The uranium-recovery work was located in the Research Laboratory building, along with other research groups. The building was a two-story building with approximately 7-8 offices for supervisors and clerical personnel as well as meeting rooms at one end. It also contained a storeroom and a library. The top floor had 7-8 laboratories, including the analytical laboratory, which supported all the projects in the Research Laboratory building, including sample analysis for the AEC work. The AEC uranium work was carried out on the top floor. The first floor was principally devoted to Dow's fiber project, which was a Dow commercial project that is not associated with work for the AEC and was not associated with radiological materials (Personal Communication, 2014 a,b,c).

The amount of space within the building allotted to the AEC work varied from a minimum of a single 600-square-foot laboratory up to a maximum of 7 labs (2.5 laboratory rooms for research, 2 for pilot-plant work, and 2.5 for analytical work) spread over 4,200 square feet (Bailes, 1957). For the period evaluated by NIOSH, the Dow Chemical Company workforce consisted of approximately 100 workers. A total of 22 research chemists and chemical engineers were engaged in the laboratory and pilot plant investigations, six of whom worked on the project for the greater part of the contract. Eight technicians assisted in the laboratory work and four operators worked in the pilot plant operations. The analytical staff members were assisted by 53 analysts during the Atomic Weapons Employer (AWE) operational period. Intermittently, additional chemical engineers were needed for cost estimation and plant design; their assistance was arranged from the Dow Research Engineering group as needed. Five such engineers worked on the AEC project for some period. The AEC engineer group had access to the regular library, stockroom, purchasing, glass-blowing, and machine shop facilities of the Dow Research Department. Including librarians, warehouse or stockroom employees, purchasing, etc., NIOSH estimates 100 workers were directly involved in the work.

Phosphoric acid was chosen as the starting material for the recovery investigations at Dow Chemical Company. Since the uranium in phosphate rock is dissolved in the acid solution when the rock is converted to phosphoric acid, the acid solution appeared to be the most promising starting material for recovery (Bailes, 1957). Commercial phosphoric acids were obtained for testing from a large number of plants. These acids came from Florida phosphate mining or processing operations and phosphate mining operations in the western United States (i.e., Montana-Anaconda Copper Mining Company Plant in Anaconda, Montana) (Bailes, 1957, PDF p. 9). The *Topical Report DOW-162*, which summarizes the research work performed for the AEC, states that 248,463 uranium analyses and 78,081 other analyses were made at the Dow Research Laboratory (Bailes, 1957, PDF p. 16). The Dow Spectrographic Laboratory at Midland, Michigan, made 44 analyses of purified products for trace impurities (Bailes, 1957, PDF p. 16). Assuming, based on interview statements, that the samples to be analyzed were on the order of 200-300 ml each, this would suggest a quantity of approximately 65-100 kilolitres or 17,000-26,500 gallons of solution over the nine-and-a-half years. This estimate is quite imprecise and cannot be used to base any definite conclusions on. It is simply provided to roughly demonstrate the scale of the facility's work.

Precipitation Method

The precipitation method was the first successful method in recovering uranium at Dow. The first process was known as the fluoride process and consisted of passing the acid through a column packed with iron to reduce all the uranium to the +4 state. This step consumed about 1 gram of iron per liter of acid. Then CaO and hydrofluoric acid (HF) were added, which precipitated the uranium in a 0.3% U_3O_8 cake. The uranium was then leached from the precipitate with Na_2CO_3 or dilute acids. The uranium products were processed from the leach by standard chemical methods (Bailes, 1951, PDF pp. 7-8). According to a Progress Report for January 1949 (Bailes, Feb1949), fluoride precipitations were carried out on a 2- or 5-liter scale, with the next goal being to progress to batch processing 5-10 gallons of acid at a time. Several precipitations were made using the raw phosphate rock as a source of calcium. A Progress Report for February 1949 (Bailes, Mar1949, p. 3) describes the construction and operation of a test plant for uranium reduction and precipitation from 50-100 pound batches of 35% phosphoric acid (H_3PO_4) in 4 hours. The report includes a picture of the test plant, which would easily have been housed in one of the Dow labs. The report also describes work with precipitate cakes and samples (Bailes, Mar1949, p. 15). The Progress Report for February 1949 mentions quantities on the order of 50 grams of precipitate, over 50 grams of residue, and 400-500 ml of leach. These were handled and/or analyzed for content. A table of results is provided (Bailes, Mar1949, p. 16). Hydrochloric acid leaching experiments in 600 ml beakers are also described (Bailes, Mar1949, p. 16). The precipitate was ground to 30-mesh size, presumably onsite.

Another process proved to be more efficient. It used Sb_2O_3 as a precipitant, which left the uranium in an ammonium-phosphate solution. When the solution was heated the uranium precipitated out and gave a 13% U_3O_8 cake.

The HF used to precipitate the calcium in the first process was too expensive to be an economical choice so that path of investigation ended. The antimony process, which used Sb_2O_3 as a precipitant, was abandoned because estimates indicated ion exchange would be less expensive.

Some investigations looked into uranium recovery during the manufacture of ammonium phosphates by neutralization of phosphoric acid. These preliminary laboratory investigations at Dow Chemical Company led to the development of a process involving the oxidation of the uranium in the acid with chlorine, neutralization, filtration, and then precipitation of uranium as uranous phosphate.

The Progress Report for July 1949 (Bailes, Jul1949) specifically reported on tests into the effect of time and temperature on related parts of the processes. Precipitation process samples would have undergone physical handling to include heating, stirring, agitation, filtration, pouring, pipetting, drying, crushing, and grinding during uranium recovery or analysis.

Ion Exchange

The original ion-exchange process was developed by Dow, with work continuing over the AEC operational period to refine the uranium recovery process so that it was economical and efficient. Concurrently with the development of the precipitation processes, Dow began to investigate the use of ion-exchange resins. It was found that uranium as an anion could be adsorbed from phosphoric acids by anion-exchange resins. The preliminary work on the phosphoric acid-ion exchange process was done with acid from Montana. This acid contained vanadium and uranium. The process included adsorption of both metals and separation by selective elution. The vanadium was eluted first by

reduction with sulfur dioxide, and then the uranium was eluted with dilute sodium-chloride solution. Investigations into the effect of different exchange resins, the oxidation state with respect to resin efficiency, impurities in the acid, resin mesh size, column diameter, flow rate, and temperature were conducted (Bailes, Aug1949). A Progress Report for November 1949 (Bailes, Nov1949) indicates that "to avoid excessive use of manpower and to obtain resin-life data in the shortest possible time, an automatic ion exchange column operator was designed and constructed which operates an ion exchange column through a complex cycle on a 24-hour basis with no attention." Page 59 of the November 1949 Progress Report describes operation of the automatic controller and an incident where a sintered glass disk holding the resin bed broke through after 80 cycles and the resin was lost. Each cycle used 500 ml of commercial phosphoric acid, so some loss of uranium was possible (Bailes, Nov1949).

A laboratory-scale pilot plant was operated initially at the Pittsburg laboratory, and the process was tested for several months (Bailes, 1957, PDF p. 18). A Dow report, *Recovery of Uranium and Vanadium from Phosphoric Acid Solution by Ion Exchange*, dated March 22, 1951 (Bailes, 1951, PDF p. 15), describes the laboratory-scale pilot plant as consisting of a 4-column unit of 2-inch diameter columns containing about 1.5 liters of wet-settled resin each. The columns were constructed of Pyrex glass pipe with jackets for heating or cooling. Solutions were fed into the columns with pumps or pressurized vessels and controlled by means of a series of stopcocks. They could be operated individually or in series.

The pilot investigations were successful, a larger pilot plant was designed and a cost estimate to build it was developed in April 1950. The March 1951 report indicates that a pilot plant with a capacity of 1,000 gallons per day of 30% H_3PO_4 for both vanadium and uranium recovery was designed and built, but the report does not specify the location (Bailes, 1951, PDF p. 43). NIOSH has found reference to a large-scale pilot plant that was built at East Tampa, Florida, by the U.S. Phosphoric Products Corporation, with two Dow engineers deployed there for several months to assist in the engineering and operation of this plant (Bailes, 1957, PDF p. 9; Wilkinson, 1976, PDF p. 11). These pilot plant investigations identified a number of problems which could not have been determined in the previous laboratory work. For the low-uranium-content Florida phosphoric acid, the process was too expensive and was abandoned and deemed economically impractical. This was because none of the available resins had the specific affinity for uranium; the resin load would be made up of calcium, iron, aluminum, and vanadium ions with very little uranium. These findings, coupled with the increased discoveries of uranium in the Rock Mountain basin area, made this process economically unattractive. In view of these findings, Dow developed a solvent-extraction process based on organic, phosphate esters.

Solvent Extraction

The ion-exchange process was abandoned for the solvent-extraction method. Alkyl pyrophosphoric acid solvent was found to extract uranium from phosphoric acid. Later, additional work was carried out to show how alkyl orthophosphates could be used to extract uranium from most any leach liquor. Alkyl pyrophosphate extracts the uranium from the phosphoric acid forming a complex compound with bonding similar to a chelate or a true chemical bond as in ion exchange. After separation, the organic complex in a diluent has removed as much of other ions as possible by precipitation with sulfuric acid. The uranium is then recovered from the complex by reacting it with hydrofluoric acid. Recovered uranium, as uranium tetrafluoride (UF_4), in a complex salt was dried and shipped to AEC

installations for further processing. Alkyl pyrophosphates with chain lengths from 4 to 17 carbon atoms were investigated to find the extracting power increases with the chain length up to 17 carbon atoms. The physical properties of the alkyl pyrophosphates were also investigated (Greek, 1957). An application (Patent Number 2859092A) was filed on February 5, 1953, for the solvent-extraction method for the recovery of metals from phosphoric acid. Three pilot-plant operations were implemented to confirm the solvent-extraction method; one at International Minerals and Chemical Company under a contract dated April 26, 1951, which was shut down in 1959; one at Armour Fertilizer Works on the W.R. Grace Co. property operating from late November to late December 1954; and one at U.S. Phosphoric Products Company in East Tampa, Florida (Unknown, 2001, PDF p. 28). Some pilot plant research into solvent extraction was also being researched at the U.S. Bureau of Mines plant in Salt Lake City. Reports mention a problem of large losses of solvent through entrainment in the heavy slurry systems at the Salt Lake City pilot plant (Bailes, Nov1955). While larger-scale work was ongoing at pilot plants, the research to resolve this and other problems encountered was performed at Dow Chemical Company. At Dow, slurry and organic feed rates were 100 ml/min at the lab mixer.

Additional pilot plants were later built to test the solvent-extraction process. These included one built by Mathieson Chemical Company, Pasadena, Texas; one by U.S. Phosphoric Products Company, Tampa, Florida; and one by International Mineral and Chemical Company, near Bartow, Florida. These plants were not staffed by Dow employees, although one employee did make several visits to the Mathieson pilot plant in Texas and assisted in its operation (Bailes, 1957, PDF p. 10).

Based on this pilot-plant work, four solvent-extraction recovery plants were built, one each at Texas City Chemicals, Inc. in Texas City, Texas; Virginia-Carolina Chemical Corp. in Nichols, Florida; International Minerals and Chemicals in Bonnie, Florida; and U.S. Phosphoric Products Company in Tampa, Florida.

Neither the Texas City Chemicals nor the Virginia-Carolina Chemical plants ever achieved production capacity. International Minerals and Chemical Company and U.S. Phosphoric Products began production in 1955. U.S. Phosphoric Products signed a contract (AT(49-6)-912) with the AEC in December 1954, to construct and operate a byproduct uranium-recovery plant with an estimated production of 60 tons of U_3O_8 per year. Operations at this plant were discontinued in 1960 when U.S. Phosphoric Products and the AEC came to a mutual agreement to terminate the contract (Unknown, post-Nov1980, PDF p. 65).

Uranium Extraction from Phosphate Rock

Although recovery research primarily used commercial phosphoric acids from the various industrial plants as the initial sample material (Bailes, 1957, PDF p. 7), a laboratory study was also performed regarding the manufacture of phosphoric acid from phosphate rock. The purpose of the study was to determine the best conditions for uranium dissolution in the acid, from which the uranium could later be recovered.

Direct Solvent Leaching of Uranium Ores with Alkyl Phosphates (Magner, 1957) describes direct ore leaching with organic solvents in detail. The report describes a result based on 100 pounds of sulfuric acid per ton of ore (Magner, 1957, p. 8). This, superficially, indicates they worked with a ton of ore to achieve the results, but no detail is provided on whether this was done at Dow or at one of the other

pilot plants. It also doesn't provide clear evidence that the work involved this quantity, as the results may have been scaled to provide comparable units. The description of work (Magner, 1957, p. 9) also indicates that data on the effects of variables were based on work with small batch samples and the ratios of volume-to-weight of ore were known and varied to determine the quantity of extractant required. The amount of acid was equivalent to 48 pounds per ton of ore in 2 series of tests. A sample of the ore as received was screened and separated into fractions according to mesh size (Magner, 1957, p. 27). Dow found the uranium recovery did not increase enough to justify the cost of grinding operations. Investigations were conducted into percolation leaching (Magner, 1957, p. 35), the application of acidified solvent to the ore, and removal after short contact time. This involved a continuous counter-current system with ore carried on a moving belt while dripping solvent onto the surface, percolating through the ore to leach materials directly. Dow also investigated columnar percolation leaching with the acid percolated through ore in a column configuration to leach products from the ore.

African Ore

Topical Report Dow-162, Table I (Bailes, 1957, PDF pp. 19-20) contains a list of research subjects and provides the status and related topical and progress reports containing those subjects. One subject in the table, "U from Miscellaneous African MgX ore" has raised concern that Dow might have performed work with African ores. The table indicates that progress reports 35-38 and 40 contain reference to this topic, and the code letter for the subject is W. Table II of *Topical Report Dow-162* lists these same reports (35-38 and 40) with dates ranging from September 1950 through December 1950. *Topical Report Dow-162* lists South African project reports and states that the reports summarize work in South Africa on a project to introduce uranium recovery by ion exchange in gold mills there (Bailes, 1957, PDF 28). This work was presumably under the Dow contract, and at least one Dow employee may have received exposure at the South African mills. However, this project would not likely have introduced African ores to the Dow Chemical Company site.

Waste Phosphatic Materials

Dow investigated processes to recover uranium from low-grade phosphate materials, which are considered waste materials from a commercial perspective (Stoltz, 1958). These materials, also called leach-zone materials in the phosphate industry, contain from three to five times more uranium than the phosphate ores recovered as products of the Florida mining operations (Stoltz, 1958, PDF p. 3). The leach zone overlies the calcium phosphate rock matrix and because it contains only 10-12% P_2O_5, it is generally discarded as waste material by the phosphate mining industry. This leach-zone ore was investigated by Dow Chemical Company for possible methods for recovering the uranium it contained, none of which proved to be economically self-sufficient. Dow Chemical Company's laboratory work indicated the possibility of producing alumina, tri-sodium phosphate, ammonium phosphates, ammonium sulfate, and other products from so-called leached-zone ores. International Minerals and Chemical Company conducted extensive pilot plant testing on leached zone phosphates and prepared engineering estimates on plants capable of producing from 100 to 500 tons of uranium per year. These estimates showed none of these processes could economically produce uranium at the time of the investigations.

5.2 Radiological Exposure Sources from Dow Chemical Company Operations

Available reports indicate that research at Dow Chemical Company involved uranium-bearing materials, and what is described in the FUSRAP documentation of the contract language as "thorium bearing ores." However, the documentation does not provide sufficient information on specific quantities, or forms of the source materials used at any given time during the period under evaluation. Given this lack of information, NIOSH is unable to make supported assumptions about source terms, concentrations, or radiological equilibrium conditions at the Dow Chemical Company facility for the period from October 1, 1947 through June 30, 1957.

Considerable detail regarding the chemistry processes under investigation is found in the Dow Progress Reports and Research Reports. These reports provide descriptions of the processes and chemical interactions investigated, but do not provide the level of quantitative information that NIOSH looks for during evaluation of facility exposure potential. The reports describe samples and test runs as larger- and smaller-scale, but without providing any quantitative information to define what is considered large or small. The scale of the processes and the work is completely absent from these reports. This information has been reviewed and considered in this evaluation by NIOSH, but has not been provided in depth in this report. The following subsections provide a summary of the limited internal and external exposure source documentation available to NIOSH for the Dow Chemical Company class under evaluation.

5.2.1 Internal Radiological Exposure Sources from Dow Chemical Company Operations

Research at Dow Chemical Company involved natural uranium-bearing phosphatic solutions received from commercial sources. These materials were sources of potential radiological exposure at the site.

5.2.1.1 Uranium

The primary source of internal radiological exposure was inhalation and/or ingestion of natural uranium, which generally is defined to include approximately 0.7% U-235, 99.3% U-238, and a very small residual amount of U-234, by weight. In terms of radioactivity, natural uranium contains approximately equal percentages of U-238 (48.6%) and U-234 (49.2%). These radionuclides emit alpha particles with primary emission energies of 4.20 MeV and 4.15 MeV (U-238), and 4.77 MeV and 4.72 MeV (U-234) (Rad Handbook, 1970). The radioactivity contribution from U-235 is much smaller (approximately 2.2%) relative to U-238 or U-234. U-235 emits alpha particles with energies of 4.40 MeV and 4.37 MeV. Other alpha-emitting radionuclides, including radon and progeny, occur naturally as part of the U-238 decay process.

5.2.1.2 Thorium

There have been indications in the contract and FUSRAP reports of work that used thorium-bearing ores at Dow Chemical Company. NIOSH has not found clear documentation of specific research work focusing on thorium.

5.2.2 External Radiological Exposure Sources from Dow Chemical Company Operations

Based on information and documentation available to NIOSH, the potential for external radiation doses from uranium and uranium-decay products existed at the Dow Chemical Company site. The uranium was naturally-occurring, derived from phosphate rock, with natural isotopic abundance. The following subsections provide an overview of the external exposure sources.

Natural uranium emits both beta particles (electrons) and photons (X-ray and gamma photons), as shown in Table 5-1. The two primary components of natural uranium are U-238 and U-235.

5.2.2.1 Photon

External exposures to photon radiation would have resulted from the immediate daughter radionuclides in the uranium decay chain. The uranium progeny that result in the most significant photon exposures include Th-234 and Pa-234m (Rad Handbook, 1970). Note that these isotopes have relatively short half-lives and can be assumed to be in equilibrium with the parent U-238. Because of their short half-lives, the exposure potential from these isotopes would travel with the parent and will not be considered separately. Photon emissions from uranium during the period under evaluation would include emissions from uranium progeny (mainly Ra-226 and radium progeny).

The majority of the photons from natural uranium isotopes are in the 30-250 keV energy range (ORAUT-OTIB-0004).

5.2.2.2 Beta

Any beta radiation fields at Dow Chemical Company would have been the result of contributions from uranium progeny radionuclides following the uranium during the acid leaching at the mining facilities. For example, nearly the entire beta radiation field from U-238 comes from the daughter radionuclide Pa-234m, and to a lesser extent from Th-234. Operations at Dow Chemical Company were not known to concentrate progeny elements specifically, but there is potential for such concentration, especially in the resin ion-exchange process and the precipitation-recovery process investigations.

Table 5-1 shows the beta emitters and their energies for the uranium and thorium natural decay series that might have been present in the phosphatic acid at Dow Chemical Company. There are a significant number of high-energy beta radiations that represent a shallow dose exposure concern for Dow Chemical Company workers in close proximity to the solutions that were being researched. Workers handling the bench-level experiments on the uranium- and thorium-bearing solutions would have received shallow dose exposures, primarily to the hands and forearms, and to a lesser extent, exposures to the neck and face.

Chemical processing (e.g., phosphoric acid production) may alter the relative concentrations of uranium, thorium, radium, or other radionuclides from those found in the phosphatic-rock raw material. The various radioisotopes will fractionate according to chemical properties (Burnett, 1995). The distribution of specific uranium and thorium decay chain radionuclides within phosphate source material and within the various products and waste streams produced by the phosphate ore processing industry has been the subject of various studies. In general:

- Radiological equilibrium in the uranium chain appears to be maintained in rock that has not been chemically processed (Roessler, 1979; Burnett, 1995); thus the phosphatic rock raw material is assumed to have been in equilibrium at the start of processing.

- Ra-226 and Po-210 are retained in the phosphogypsum (i.e., do not enter the phosphoric acid stream to any significant degree) (Guimond, 1975, PDF p. 15; Burnett, 1995, PDF pp. 1-16).

- Uranium and thorium tend to favor the phosphoric acid phase (Guimond, 1975; Burnett, 1995).

Table 5-1: Beta and Gamma Emissions of Primary Interest
Table 5-1 spans three pages.

Radionuclide	Beta Energy (MeV, max.)	Gamma Energy (MeV)
Uranium-238	None	None
Thorium-234	0.10 (19%) 0.193 (79%)	0.063 (3.5%) 0.093 (4%)
Protactinium-234m	2.28 (99%)	0.766 (0.2%) 1.00 (0.6%)
Uranium-234	None	0.053 (0.1%)
Thorium-230	None	0.0667 (0.37%) 0.142 (0.07%) 0.144 (0.045%)
Radium-226*	None	0.186 (3.28%)
Radon-222	None	0.510 (0.078%)
Polonium-218	0.33 (0.02%)	0.837 (0.0011%)
Lead-214	0.67 (48%) 0.73 (42.5%) 1.03 (6.3 %)	0.2419 (7.5%) 0.295 (19.2%) 0.352 (37.1%)
Bismuth-214	1.42 (8.3%) 1.505 (17.6%) 1.54 (17.9%) 3.27 (17.7%)	0.609 (46.1%) 1.12 (15.0%) 1.765 (15.9%) 2.204 (5.0%)
Polonium-214	None	0.7997 (0.010%)
Lead-210	0.016 (80%) 0.063 (20%)	0.0465 (4%)
Bismuth-210	1.161 (~100%)	None
Polonium-210*	None	0.802 (0.0011%)
Uranium-235	None	0.144 (11%) 0.163 (5%) 0.186 (54%) 0.205 (5%)
Thorium-231	0.205 (15%) 0.287 (49%) 0.304 (35%)	0.026 (15%) 0.084 (6.5%)

Table 5-1: Beta and Gamma Emissions of Primary Interest *Table 5-1 spans three pages.*		
Radionuclide	**Beta Energy (MeV, max.)**	**Gamma Energy (MeV)**
Protactinium-231	None	0.027 (6%) 0.29 (6%)
Actinium-227	0.043 (99%)	0.070 (0.08%)
Thorium-227	None	0.050 (8%) 0.237 (15%) 0.31 (8%)
Francium-223	1.15 (100%)	0.050 (40%) 0.080 (13%) 0.234 (4%)
Radium-223	None	0.149 (10%) 0.270 (10%) 0.33 (6%)
Radon-219	None	0.272 (9%) 0.401 (5%)
Polonium-215	0.74 (~.00023%)	None
Lead-211	0.29 (1.4%) 0.56 (9.4%) 1.39 (87.5%)	0.405 (3.4%) 0.427 (1.8%) 0.832 (3.4%)
Bismuth-211	0.60 (0.28%)	0.351 (14%)
Thallium-207	1.44 (99.8%)	0.897 (0.16%)
Thorium-232	None	0.059 (0.19%) 0.126 (0.04%)
Radium-228	0.0389 (100%)	0.0067 (6 x 10^{-5}%)
Actinium-228	0.983 (7%) 1.014 (6.6%) 1.115 (3.4%) 1.17 (32%) 1.74 (12%) 2.08 (8%) (+33 more βs)	0.338 (11.4%) 0.911 (27.7%) 0.969 (16.6%) 1.588 (3.5%)
Thorium-228	None	0.084 (1.19%) 0.132 (0.11%) 0.166 (0.08%) 0.216 (0.27%)
Radium-224	None	0.241 (3.7%)
Radon-220	None	0.55 (0.07%)
Lead-212	0.346 (81%) 0.586 (14%)	0.239 (47%) 0.300 (3.2%)
Bismuth-212	1.59 (8%) 2.246 (48.4%)	0.040 (1%) 0.727 (11.8%) 1.620 (2.75%)

Table 5-1: Beta and Gamma Emissions of Primary Interest *Table 5-1 spans three pages.*		
Radionuclide	**Beta Energy (MeV, max.)**	**Gamma Energy (MeV)**
Thallium-208	1.28 (25%) 1.52 (21%) 1.80 (50%)	0.511 (23%) 0.583 (86%) 0.860 (12%) 2.614 (100%)

Note:
*Included for completeness but shown to separate into the gypsum phase and not an external exposure source at Dow Chemical Company.

5.2.2.3 Neutron

Uranium compounds can be a source of neutrons from spontaneous fission occurring in the isotopes of uranium and from alpha-neutron reactions with low atomic number materials such as oxides and impurities. Low-atomic-number elements (such as fluorine) emit neutrons of approximately 2 MeV energy when struck by alpha particles (referred to as alpha-neutron ["α-n"] reactions). The intensity of the radiation field from these reactions increases as a function of the enrichment. *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds* (ORAUT-OTIB-0024) describes the expected neutron dose rates from various forms of uranium compounds. Because only uranium-bearing byproducts with a natural isotopic ratio were researched at Dow Chemical Company, the neutron radiation field was significantly lower than the gamma component; therefore, neutrons are not considered a significant exposure concern and are not addressed further in this evaluation.

6.0 Summary of Available Monitoring Data for the Class Evaluated by NIOSH

The following subsections provide an overview of the state of the available internal and external monitoring data for the Dow Chemical Company class under evaluation.

6.1 Available Dow Chemical Company Internal Monitoring Data

The primary data used for determining internal exposures are derived from personal monitoring data, such as urinalyses, fecal samples, and whole-body counting results. If these are unavailable, the air monitoring data from breathing zone and general area monitoring are used to estimate the potential internal exposure. If personal monitoring and breathing zone area monitoring are unavailable, internal exposures can sometimes be estimated using more general area monitoring, process information, and information characterizing and quantifying the source term.

NIOSH has found no indication that a routine uranium or thorium urinalysis program was in place during the Dow Chemical Company's AEC operational period. No documentation of medical surveillance of any kind for the site has been located.

NIOSH has not located any documentation indicating that Dow conducted a routine air sampling program for uranium or thorium during AEC operations.

6.2 Available Dow Chemical Company External Monitoring Data

NIOSH has located no indication of external dosimetry or other radiation exposure monitoring records for the period from January 1, 1947 through December 31, 1957 at Dow Chemical Company. No records or documentation of surface-contamination survey results obtained during or associated with the AEC research operations have been located.

Minimal information has been located on the materials handled on site. These materials may have included phosphatic ores containing natural uranium and its associated daughters and thorium-bearing ores, but no documentation providing details on such has been located. Processing information and reports on the research conducted allow NIOSH to infer an estimate of the quantities handled; however, no information specific to the quantity of these materials that could confirm these estimates has been located.

The NOCTS database was reviewed for claimants whose work history included Dow Chemical Company during part or all of the covered period (1947-1957). One such claimant was identified. The files for this claimant were thoroughly reviewed and no external monitoring data were found.

NIOSH has no record of any medical X-ray occupational exposure information.

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

The feasibility determination for the class of employees under evaluation in this report are 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. 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. This approach is discussed in DCAS'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-00216 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Dow Chemical Company Data

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

As discussed in Section 6.1, NIOSH has not located any documentation indicating the existence of routine air sampling or internal monitoring programs for uranium or thorium during the operation of the Dow Chemical Company research facility. The statements made by former workers during interviews indicate that air sampling, area monitoring, urinalysis, or *in vitro* monitoring was not performed at this facility. Therefore, an internal monitoring data pedigree evaluation is not possible for the internal monitoring data type.

7.1.2 External Monitoring Data Pedigree Review

NIOSH has not located any personnel external dosimetry data for the period under evaluation. Therefore, a data sufficiency and pedigree evaluation is not possible for this data type for this period.

7.2 Evaluation of Bounding Internal Radiation Doses at Dow Chemical Company

The principal source of internal radiation doses for members of the class under evaluation was the natural uranium that Dow was attempting to recover from the phosphatic material derived from processing phosphate rock into commercial products (i.e., fertilizer) (Bailes, 1957). The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction.

7.2.1 Evaluation of Bounding Process-Related Internal Doses

NIOSH interviewed three former workers and researched historical documentation on the research operations at Dow Chemical Company. The three former workers were specifically asked about a bioassay program associated with the AEC work at Dow and the three were consistent in reporting

that there was not such a program (Personal Communication, 2014,a,b,c). This is also consistent with the lack of information on any bioassay monitoring in documents reviewed by NIOSH.

Dow Chemical Company workers were potentially exposed to acidic solutions containing uranium and uranium progeny. NIOSH has found no indications that bioassay measurements were collected for the period under evaluation. NIOSH has also been unable to locate any records indicating that breathing zone or area air sampling was conducted during any of the Dow Chemical Company research, pilot operations, or sample analyses activities. Although former workers indicated that it was not common practice to enter laboratory space from other operations or areas of the facility, there were no physical or administrative access controls that would limit workers from entering these spaces, or generate a record of their presence in an area of potential exposure. The labs designated for the AEC work were not physically isolated from the rest of the research lab building, and there is no information indicating that there were any engineering controls to segregate the HVAC of these labs from any other in the building. Thus, NIOSH has no data to determine which employees were likely to be exposed.

The following subsections summarize the extent and limitations of information available for reconstructing the process-related internal doses of members of the class under evaluation.

7.2.1.1 Urinalysis Information and Available Data

NIOSH has not found any uranium urinalysis information for Dow Chemical Company workers.

7.2.1.2 Lung Counting Information and Available Data

NIOSH has not found any information regarding lung counting for Dow Chemical Company workers.

7.2.1.3 Other Types of Bioassay

NIOSH has not found any other bioassay information for Dow Chemical Company workers.

7.2.1.4 Airborne Levels

There was some potential for airborne levels of uranium resulting from the chemical processes associated with uranium recovery activities at Dow Chemical Company. The physical handling of the uranium-bearing phosphatic solutions was generally carried out in hoods, which should have helped to contain any airborne radiological materials. Because there are no air monitoring records for the breathing zones or for the general laboratory area, NIOSH cannot directly quantify the airborne radiological conditions within the labs during the activities associated with uranium recovery. With specific information on the uranium concentration in solution and the volume of solution analyzed at any given time, NIOSH could estimate the source term available for suspension into the atmosphere of the laboratory. However, NIOSH does not have this level of detailed information for any of the different processes investigated at Dow Chemical Company.

7.2.2 Evaluation of Bounding Residual Period Internal Doses

Dow Chemical Company does not have a designated residual period.

7.2.3 Methods for Bounding Internal Dose at Dow Chemical Company

NIOSH has determined that the available data are inadequate to reconstruct worker exposures to uranium, thorium, and uranium daughter products resulting from wet-chemical separation activities and analyses performed during the Dow Chemical Company operational period under evaluation.

There are no measured air concentration data that can be used to bound radiological internal exposures during the operational period. While the materials were primarily handled in solution, there was also the likelihood that a relatively small quantity of raw phosphate ore and solid precipitate were handled at the site as part of the investigations into uranium recovery. Both the ore and the dried precipitate may have been ground to differing specifications to study the effect of particle size and to increase the efficiency of uranium recovery. The physical state of the uranium in an acidic solution would have limited the distribution of uranium into the air somewhat, but any grinding of phosphate ore or dried precipitate cake could have contributed to the airborne spread of uranium. These laboratory-scale investigations, as described in the Dow Progress Reports, documented neither the quantity of phosphate ore nor the quantity of dried precipitate cake processed for the recovery research. Without air monitoring data to represent the air concentrations encountered by the maximally-exposed individual, NIOSH cannot presume to know what the bounding condition was at the site. NIOSH does not have access to any personal dosimetry records to support bounding assumptions.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

NIOSH has evaluated the available information on the activities and materials of concern at Dow Chemical Company and has determined that there are insufficient data for estimating internal exposures.

NIOSH has not found documentation that describes any sampling or bioassay program at Dow Chemical Company. NIOSH has insufficient personnel monitoring data to appropriately characterize internal radiation intakes during Dow operations.

In addition to the absence of adequate internal dose monitoring criteria and adequate personnel monitoring data, NIOSH has not found general area air sampling, breathing zone air sampling, site survey, or source term information to allow it to bound potential exposures, or to demonstrate that workers were adequately monitored for potential exposures to radioactive materials at Dow during the period being evaluated. NIOSH has determined that reconstruction of the total internal doses received from exposures to uranium, thorium, and uranium progeny is not feasible using the information available to NIOSH for the period under evaluation from October 1, 1947 through June 30, 1957. The periods from January 1, 1947 through September 30, 1947, and from July 1, 1957 through December 31, 1957, have been excluded from the NIOSH-proposed class because covered work was not performed during these times.

Although NIOSH found that it is not possible to completely reconstruct internal radiation doses for the period from October 1, 1947 through June 30, 1957, NIOSH intends to use any internal monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at Dow Chemical Company during the period from October 1, 1947 through June 30, 1957, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.3 Evaluation of Bounding External Radiation Doses at Dow Chemical Company

The principal source of external radiation doses for members of the evaluated class was exposure to beta and gamma radiation emanating from uranium-bearing and thorium-bearing materials. The following subsections address the ability to bound external doses, methods for bounding doses, and the feasibility of external dose reconstruction.

7.3.1 Evaluation of Bounding Process-Related External Doses

NIOSH has not identified any personal dosimetry data, radiation surveys, or general area surveys for research activities involving radiological material handling during the operational period at the Dow Chemical Company facility. No inventory information or shipping records have been located to support any conclusions regarding specific quantities of uranium- or thorium-bearing materials that were handled at any given time on the site.

NIOSH has not identified documentation to define and quantify the total external source term for Dow Chemical Company during the period under evaluation. Without additional documentation, NIOSH cannot make supported assumptions about the relative amounts of materials that could have been encountered at the site during the period of AEC operations.

7.3.2 Dow Chemical Company Occupational X-Ray Examinations

No site-specific records have been located, documenting whether the employer held any requirement for occupational X-ray examinations at the Dow Chemical Company site, either in the claimant records or in the SRDB holdings for the Dow site. EEOICPA requires that external dose from medical X-ray examinations performed and required as a condition of employment be included in dose reconstruction efforts. If there is doubt about where the X-ray exposure occurred, NIOSH defaults to assume the dose was received at a covered facility. Per ORAUT-OTIB-0079, *Guidance on Assigning Occupational X-Ray Dose Under EEOICPA for X-Rays Administered Off Site,* NIOSH has determined that it is applicable to reconstruct occupational medical X-ray exposures for Dow Chemical Company workers during the period from October 1, 1947 through June 30, 1957.

7.3.3 Methods for Bounding External Dose at Dow Chemical Company

NIOSH has not identified any external monitoring records or personal dosimetry data associated with the uranium handling conducted during the period under evaluation. This was a unique project for which there were no operational logs, only technical summary descriptions of activities contained in topical reports, and no corresponding radiological data. NIOSH has not located any information documenting or describing a regular workplace monitoring program. No records of any routine monitoring or area survey program have been located.

NIOSH has determined that it lacks sufficient personnel monitoring data, area monitoring data, or source term data needed to bound external photon, beta, or neutron doses that Dow Chemical Company workers potentially received from natural uranium, thorium, or uranium progeny.

Therefore, NIOSH has not identified a method for bounding external doses at Dow Chemical Company for the period from October 1, 1947 through June 30, 1957.

Medical X-ray Dose

NIOSH will perform reconstruction of medical dose using the claimant-favorable assumptions described in the Technical Information Bulletin, *Dose Reconstruction from Occupational Medical X-Ray Procedures* (ORAUT-OTIB-0006), including assuming posterior-anterior (PA) projection, pre- and post-employment screening X-rays, and annual X-ray exposures.

7.3.4 External Dose Reconstruction Feasibility Conclusion

NIOSH does not have access to sufficient personnel monitoring, workplace monitoring, or source term data to estimate potential external exposures to uranium, thorium, or uranium progeny during the period of process investigations at Dow Chemical Company. Therefore, NIOSH finds that it is infeasible to completely reconstruct external doses from October 1, 1947 through June 30, 1957, due to insufficient monitoring data. The periods from January 1, 1947 through September 30, 1947, and from July 1, 1957 through December 31, 1957, have been excluded from the NIOSH-proposed class because covered work was not performed during these times.

Although NIOSH found that it is not possible to completely reconstruct external radiation doses for the period from October 1, 1947 through June 30, 1957, NIOSH intends to use any external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at Dow Chemical Company during the period from October 1, 1947 through June 30, 1957, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.4 Evaluation of Petition Basis for SEC-00216

The following subsections evaluate the assertions made on behalf of petition SEC-00216 for Dow Chemical Company.

7.4.1 Inadequate Records

Assertion: *Records and information are inadequate to estimate the radiation doses acquired by members of the proposed class of employees with sufficient accuracy.*

Response: Neither personnel monitoring nor bioassay data for Dow Chemical Company workers have been found. NIOSH has not located air monitoring data or area monitoring data for the site. NIOSH's review indicates that, in the absence of personnel monitoring data, area monitoring data, or adequate source term data, it is not possible to bound potential radiation doses received during the AWE period under evaluation. In this evaluation report, NIOSH has proposed an SEC class for the period from October 1, 1947 through June 30, 1957.

7.4.2 Surrogate Data

Assertion: Texas City Chemicals was used to perform dose reconstruction for Dow Chemical Company employee(s). The data for Texas City Chemicals was from the mid-1950s, but Dow Chemical Company began their work in 1947.

Response: The methods used to recover uranium from the phosphatic acid byproduct of the phosphate work at Texas City Chemicals were based on the investigations at Dow. The difference in the period that the work was performed is minor and not significant to the potential for exposure in this case. The evaluation report for Texas City Chemicals was reviewed and it was found that the data being applied in the Texas City Chemicals Evaluation Report are surrogate data. The source term for operations at Texas City Chemicals comes from phosphate rock from central Florida that reacted with sulfuric acid to produce phosphoric acid. The rock contained naturally occurring radioactive material, primarily uranium and potentially some thorium, plus associated progeny. Dow initiated investigations with the phosphatic acid that was produced commercially at other sites. The distribution of radionuclides in the phosphatic acid is specific to the process by which it is produced, but generally the uranium and thorium tend to favor the acid phase, while radium-226 and polonium-210 are retained in the phosphogypsum stream. Since the phosphogypsum was not delivered to Dow, these isotopes contributed to exposure at Texas City Chemicals but not at Dow.

There are uncertainties with chemical recoveries and potential losses of some elements in some of the chemical steps; thus, assumptions for isotopic ratios in the production of phosphatic acid have to be applied. The concentration of the product (uranium concentrate) at Dow would have varied for each of the methods under investigation (though there were not enough runs of each method to establish a routine concentration for any particular method). The radioactivity concentrations in Table 5-4 of the Texas City Chemicals Evaluation Report could be applied to Dow for investigations of Florida phosphates, but not for investigations on phosphates from the western United States.

7.4.3 DOE Radiological Survey

Assertion: The question of *where* the December 8, 1977 "Walnut Creek" radiological survey was performed may be important. DOE documents explicitly point out 2800 Mitchell Drive, which could not have been the only location of work. At this precise time the EPA was investigating Dow's Midland plant operations and in December 1977, Dow refused to provide access to the plant, setting off an aerial surveillance by EPA that was the focus of *Dow Chemical Company V. United States*.

Response: Please see the response to the facility location issue below in Section 7.5. The facility designation is indicative of the conflation of these two facilities in the available documentation. However, it seems clear, based on the investigations of the petition representative and NIOSH, that the radiological research operations being evaluated were conducted at the Pittsburg, California location.

The DOE survey was conducted based on consultation with the Radiation Safety Officer (RSO) at the time. This RSO also happened to have been directly involved with the AEC contract work, and would have had personal knowledge of the Research Building facilities used for this research. Since this individual identified the work location to the DOE personnel, it is highly improbable that the survey was performed in the wrong location. It is much more likely that the administrative mailing address was used, incorrectly, to identify the physical location of the survey in the follow-on documentation.

The DOE survey was part of the FUSRAP efforts and would have been unrelated to the EPA investigation of Dow Midland.

7.5 Other Potential SEC Issues Relevant to the Petition Identified During the Evaluation

During the feasibility evaluation for SEC-00216, a number of issues were identified that needed further analysis and resolution. The issues and their current status are:

- ISSUE: The designation for this facility by the Office of Environment, Health, Safety and Security indicates the location as Walnut Creek, California. The "Also Known As" section lists Pittsburg, California. These are two physical locations approximately 13 miles (direct line) separating them. The names and locations have been used interchangeably in the documentation.

  RESPONSE: The Pittsburg location is currently a manufacturing facility and employs over 300 people. The Walnut Creek location still exists as a DOE genomic facility.

  A memo, documenting a DOE survey (Bauer, 1977) refers to Walnut Creek, but identifies four rooms in the Research Building. The *FUSRAP Considered Sites* listing lists the 2800 Mitchell Dr. address for Walnut Creek. During interviews with former workers, information was given that this Walnut Creek location was built after the AEC uranium recovery work had ended at Dow. NIOSH investigated and located additional information indicating that the Walnut Creek facility was not built until 1961, after the covered period of AEC operations. The Elimination/Site Summary Report (Aerospace, 1987, PDF p. 5**)** refers to the DOE survey as a basis for removing Walnut Creek from FUSRAP consideration. DOE identifies the building in FUSRAP references as 'Walnut Creek', but the letter to Dow in 1987 notifying them they were not a FUSRAP site was sent to the Environmental Control Dept. in Pittsburg, California. Other letters to Dow also bear a PO Box address in Pittsburg, California. NIOSH considered all of this information and concludes that all AEC-contracted activities occurred at the Dow-Pittsburg location.

- ISSUE: There is no mention of any dosimetry or monitoring program for the Dow facility in reports or correspondence currently available to NIOSH.

  RESPONSE: NIOSH has not located any reference to a monitoring program. Requests for any records or evidence of a monitoring program at Dow Chemical Company were made to both Dow Chemical Company in Pittsburg and Landauer Inc. Landauer reported they did not locate any evidence that they or their affiliates had provided film badge services to Dow's California operations during the period from 1947 to 1957.

  NIOSH's interviews included a focus on any monitoring programs or efforts. One interviewee reported only vague memories of wearing a film badge, but included the caveat that such monitoring was unlikely to be productive, given the nature of the materials investigated and the lack of external radiation hazard. NIOSH agrees that it is likely Dow did not perform personnel dosimetry monitoring.

- ISSUE: To date, no actual documentation of the radiological source term experimented with at Dow Chemical Company has been identified. The contractual agreements spoke to investigations on the extraction of uranium from phosphate ores, yet the FUSRAP elimination description of work at the site alluded to thorium-bearing ores. There may have been work with raw-uranium ores as well.

  RESPONSE: All of the topical reports and other documentation reviewed for Dow Chemical Company indicate that work was with phosphoric-acid solutions that were provided from various commercial phosphate facilities. No indications of the delivery of actual ores at the Dow site were found. Interviews with former employees also indicated that Dow's laboratory research work focused on uranium-bearing solutions. There were no indications found of any effort to investigate thorium recovery at Dow Chemical Company, nor were there any reports located that had indications of other work specifically related to thorium-bearing ores.

  NIOSH also attempted to locate information related to the possibility of work with African ores. Reports of work on uranium from miscellaneous African MgX ore seem to be related to work in South Africa on a project to introduce uranium recovery by ion exchange in gold mills. This work was presumably under the Dow contract and at least one Dow employee may have received exposure at the South African mills, but this project would not likely have introduced African ores to the Dow Chemical Company site.

- ISSUE: Several references to pilot plant operations have occurred throughout the evaluation of Dow Chemical Company research activities. The nature of these operations and the exposure arising from these activities to Dow personnel is not well understood. Some indications are that there were significant pilot-plant operations and source term that may have generated exposure potential onsite, while other references imply that the pilot-plant activities were on a laboratory-scale with an industrial-scale pilot plant located at other locations.

  RESPONSE: Section 5.1 of this report details various investigations and research activities conducted at Dow Chemical Company. As Dow worked to develop and assess the various methods to recover uranium from phosphatic acids, the laboratory results progressed from 'bench-top' investigations to pilot-plant studies. Knowledge of the nature and location of these pilot-plant operations is vital to the understanding of the radiation exposure hazard delivered by these operations to the Dow Chemical Company employees. NIOSH has attempted to document, as clearly as possible, the processes that did in fact proceed to the pilot-plant stage of development and the scale of those pilot-plant activities. NIOSH concludes that there were small-scale to mid-scale pilot-plant activities at the Dow Chemical Company location, with large-scale pilot plants having been built and run at remote locations, closer to the sources of the phosphate rock. Dow Chemical Company engineers were sometimes deployed to assist in establishing and operating pilot plants at these remote sites.

7.6 Summary of Feasibility Findings for Petition SEC-00216

This report evaluates the feasibility for completing dose reconstructions for employees at Dow Chemical Company from January 1, 1947 through December 31, 1957. NIOSH found that the available monitoring records, process descriptions and source term data available are not sufficient to

complete dose reconstructions for the evaluated class of employees. Although NIOSH did evaluate the entire period from January 1, 1947 through December 31, 1957, the periods from January 1, 1947 through September 30, 1947, and from July 1, 1957 through December 31, 1957, have been excluded from the NIOSH-proposed class because covered work was not performed during these times.

Table 7-1 summarizes the results of the feasibility findings at Dow Chemical Company for each exposure source during the time period from October 1, 1947 through June 30, 1957.

Table 7-1: Summary of Feasibility Findings for SEC-00216
October 1, 1947 through June 30, 1957

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal		**X**
- Uranium		X
External		**X**
- Gamma		X
- Beta		X
- Neutron		X
- Occupational Medical X-ray	X	

As of January 7, 2015, a total of 1 claim has been submitted to NIOSH for an individual who worked at Dow Chemical Company during the period under evaluation in this report. Dose reconstructions have been completed for 1 individual (100%).

Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Dow Chemical Company during the period from October 1, 1947 through June 30, 1957, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

8.0 Evaluation of Health Endangerment for Petition SEC-00216

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 not feasible to estimate radiation dose for members of the NIOSH-evaluated class for the time period from October 1, 1947 through June 30, 1957, with sufficient accuracy based on the sum of information available from available resources. Therefore, the resulting NIOSH-proposed SEC class must include a minimum required employment period as a basis for specifying that health was endangered. Although NIOSH did evaluate the entire period from January 1, 1947 through December 31, 1957, the periods from January 1, 1947 through September 30, 1947, and from July 1, 1957 through December 31, 1957, have been excluded from the NIOSH-proposed class because covered work was not performed during these times.

9.0 Class Conclusion for Petition SEC-00216

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all Atomic Weapons Employer employees who worked for Dow Chemical Company in Pittsburg, California, from October 1, 1947 through June 30, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

As stated in Section 3.3 of this report, the NIOSH-proposed class was modified from the NIOSH-evaluated class because during its evaluation NIOSH found documentation regarding the start and end dates for the AEC work at Dow Chemical Company. The initiation of the contract with AEC began on October 1, 1947, while the contract was completed June 30, 1957 (Contract AT-30-1-GEN-236; Johnson, 1957). Thus, the periods from January 1, 1947 through September 30, 1947, and from July 1, 1957 through December 31, 1957, have been excluded from the NIOSH-proposed class because covered work was not performed during these times.

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 (SRDB), for information relevant to SEC-00216. 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 the feasibility or infeasibility of reconstructing dose for the class under evaluation.

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

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Bailes, Mar1949, *Progress Report for February 1949*, DOW-12; R. H. Bailes; March 10, 1949; SRDB Ref ID: ECI 137966

Bailes, Jul1949, *Progress Report for July 1949*, DOW-17; R. H. Bailes; July 28, 1949; SRDB Ref ID: ECI 137973

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DCAS-TKBS-0002, *Technical Basis Document for Atomic Energy Operations at Blockson Chemical Company, Joliet, Illinois*, Rev. 03; National Institute for Occupational Safety and Health (NIOSH); Cincinnati, Ohio; November 21, 2007; SRDB Ref ID: 91205

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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

Johnson, 1957, *Conclusion of Dow Chemical Company Research Work*, correspondence to the Dow Research Department; Jesse C. Johnson; July 9, 1957; SRDB Ref ID: 61492

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ORAUT-OTIB-0004, *Estimating the Maximum Plausible Dose to Workers at Atomic Weapons Employer Facilities*, Rev. 03 PC-2; ORAU Team Dose Reconstruction Project for NIOSH; December 6, 2006; SRDB Ref ID: 36191

ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures*, Rev. 4; ORAU Team Dose Reconstruction Project for NIOSH; effective June 20, 2011; SRDB Ref ID: 98147

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Attachment One: Data Capture Synopsis

Table A1-1: Summary of Holdings in the SRDB for Dow Chemical Company			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Primary Site/Company Name: Dow Chemical Company AWE 1947-1957 Alternate Site Names: Pittsburg, CA Physical Size of the Site: The site encompasses 513 acres, of which 472 are wetlands, leaving 41 acres for operational use. The building where the work occurred was 4,200 square feet. Site Population: The current site population is approximately 300. During the covered period the site population was approximately 100.	Documented communications with former Dow employees. The ORAU Team was informed by the Dow Chemical Corporate Office that old records have been retired to the Midland (MI) County Historical Society.	10/09/2014	2
State Contacted: California Department of Public Health, Radiologic Health Branch	The U.S. Nuclear Regulatory Commission turned over responsibility for Dow Chemical Company to the State of California in 1997. A search of the California Department of Public Health, Radiologic Health Branch website for Dow, Walnut Creek, and Pittsburg did not yield any relevant documents. A Public Records Request submitted to the Radiologic Health Branch identified no Walnut Creek documents and only sealed source inspections dating back to 1977 at the Pittsburg location. As such, no records were requested.	11/17/2014	0
DOE Germantown	Uranium recovery from phosphoric acid, U-233 processing, and search procedures for the DOE Oak Ridge Operations Records Holding Area.	03/07/2011	3
DOE Legacy Management - Grand Junction Office	A solvent extraction report, the conclusion of research at Dow, a radiological survey and descriptions of radiological conditions and problems, and a 1942 Metallurgical Project bulletin.	06/07/2011	6
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Correspondence from National Lead of Ohio regarding the recovery of magnesium from contaminated magnesium fluoride.	02/21/2008	1
DOE Oak Ridge Operations Office	FOIA requests and Savannah River Site responses to FOIA requests.	11/09/2007	5
DOE Office of Scientific and Technical Information (OSTI)	Progress and technical reports.	12/04/2014	31
Federal Records Center (FRC) - Lee's Summit	Film badge reports from 1954 to 1956.	10/16/2008	3

Table A1-1: Summary of Holdings in the SRDB for Dow Chemical Company			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Federal Records Center (FRC) - San Bruno	The Lawrence Berkeley National Laboratory isotope receiving log, 1949-1960.	07/26/2012	1
Florida Institute of Phosphate Research	Reports regarding the characterization of and doses from aerosols generated by phosphate processing.	10/26/2007	6
General Atomics	Reports of no radiation dose received by General Atomics employees who visited Dow.	01/10/2006	1
Hanford	A 1956 letter granting authority to declassify raw materials program documents.	03/20/2013	1
Interlibrary Loan	A 1958 report on uranium ore processing.	02/22/2007	1
Internet - Defense Technical Information Center (DTIC)	No relevant documents identified.	08/15/2014	0
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	No relevant documents identified.	08/15/2014	0
Internet - DOE Legacy Management Considered Sites	Elimination of Dow Chemical Walnut Creek from consideration as a FUSRAP site.	07/22/2014	1
Internet - DOE National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant documents identified.	08/15/2014	0
Internet - DOE OpenNet	Manufacturing statements for weapons production schedule of transfers and the June 1953 index to the AEC Fourteenth Semiannual Report to Congress.	07/24/2014	3
Internet - DOE OSTI Energy Citations	The final report on Contract AT-30-1-GEN-236.	02/17/2010	1
Internet - DOE OSTI Information Bridge	A 1950 report on the definition of the roentgen at high gamma energies. Dow is included on distribution.	08/16/2012	1
Internet - DOE OSTI SciTech Connect	No relevant documents identified.	07/30/2014	0
Internet - Energy Employees Claimant Assistance Project (EECAP)	No relevant documents identified.	08/15/2014	0
Internet - Google	Lists of nuclear sites and FUSRAP sites, Nuclear News articles, the DOE/union data tracking meeting, residual radioactivity reports, an Oak Ridge National Laboratory isotopes and radiation technology report, Glenn Seaborg's journal, photos of the Walnut Creek site, and the turnover of the site from the U.S. Nuclear Regulatory Commission to the State of California in 1997.	07/29/2014	15
Internet - Health Physics Journal	No relevant documents identified.	08/15/2014	0
Internet - Journal of Occupational and Environmental Hygiene	No relevant documents identified.	08/15/2014	0
Internet - National Academies Press (NAP)	No relevant documents identified.	07/30/2014	0

Table A1-1: Summary of Holdings in the SRDB for Dow Chemical Company			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Internet - National Institute for Occupational Safety and Health (NIOSH)	Reports on residual radioactive and beryllium contamination at atomic weapons employer facilities.	08/31/2011	3
Internet - NRC Agencywide Document Access and Management (ADAMS)	Staff evaluations of radiological sites identified in a USA Today article, a FOIA for thorium licenses at Dow, a petitioner's motion to transfer rulemaking from the NRC to District Court, and a list of FOIA requests received by the NRC from 01/01/2005 to 02/08/2008.	03/28/2013	6
Internet - Oak Ridge National Laboratory (ORNL)	A 1953 report on uranium extraction and a 1950 operations report mentioning magnesium irradiations to be performed for Dow.	03/09/2012	2
Internet - US Army Corps of Engineers (USACE)	No relevant documents identified.	07/30/2014	0
Internet - US Environmental Protection Agency NEPIS	No relevant documents identified.	07/30/2014	0
Internet - US Transuranium and Uranium Registries	No relevant documents identified.	07/30/2014	0
Midland (MI) County Historical Society	Attempts to reach the Midland County Historical Society Archivist are continuing.	12/04/2014	0
National Archives and Records Administration (NARA) - Atlanta	A report on uranium recovery from phosphoric acid.	07/09/2004	1
National Archives and Records Administration (NARA) - College Park	A report on a 1951 thorium meeting at Battelle where Dow's phosphate extraction process was discussed.	07/13/2010	1
National Archives and Records Administration (NARA) - Kansas City	Dow's contract number AT-30-1-GEN-236, a description of uranium from phosphate contracts, and the Certification Docket for Gilman Hall which identifies Dow as a California FUSRAP site.	03/30/2005	3
National Institute for Occupational Safety and Health (NIOSH)	AEC semiannual reports to Congress, general exposure calculations, a 1948 waste disposal report, the history of the AEC 1947-1952, and Dow progress reports.	09/23/2014	13
Nuclear Regulatory Commission Public Document Room	Dow's corporate source material license and associated correspondence, compliance inspections, and thorium residue storage.	01/29/2007	19
Oak Ridge National Laboratory (ORNL)	An isotopes development newsletter and source and special nuclear materials accountability reports referencing Dow inventories.	03/19/2014	7
ORAU Team	Documented communications with former Dow employees.	09/02/2014	2
Public Library	A 1957 report on recovery of uranium from wet process phosphoric acid.	10/16/2007	1
R. S. Landauer	Confirmation that Landauer or its affiliates did not provide film badge services to Dow's California operations.	10/10/2014	1
S. Cohen & Associates (SC&A)	Irradiations in Idaho National Laboratory's Materials Testing Reactor and interest in recovering plutonium from unirradiated scrap.	04/07/2011	2

Table A1-1: Summary of Holdings in the SRDB for Dow Chemical Company			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Sandia National Laboratory - CA	September 1965 film badge results.	03/28/2007	1
Savannah River Site	Savannah River Site dosimetry visitors cards, a FOIA request, and a FOIA response.	08/26/2008	4
Southern Illinois University, Edwardsville, IL	Response to a FOIA for NRC's Dow records, a review of thorium activities at the Dow Madison plant, and transcripts of Advisory Board Radiation Worker Health meetings.	11/01/2008	7
Unknown	Early AEC monthly progress reports, a Project spreadsheet, identification of Dow Walnut Creek as a California FUSRAP site, identification of Dow Walnut Creek as a raw materials site, and FUSRAP elimination reports and summaries.	09/11/2002	10
Washington University Library	A 1951 report on the fluorimetric determination of uranium in phosphoric acid.	04/23/2007	1
Total			**166**

Table A1-2: Database Searches for Dow Chemical Company			
Database/Source	**Keywords**	**Hits**	**Uploaded into SRDB**
NOTE: Database search terms employed for each of the databases listed below are available in the Excel file called “Data Capture Synopsis for Dow Chemical Corporation –Walnut Creek Rev 01.”			
Defense Technical Information Center (DTIC) https://www.dtic.mil/ COMPLETED 08/15/2014	See Note above	12,651	0
DOE CEDR https://www.orau.gov/cedr COMPLETED 08/15/2014	See Note above	0	0
DOE Legacy Management Considered Sites http://www.lm.doe.gov/considered_Sites/ COMPLETED 07/30/2014	See Note above	119	1
DOE NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 08/15/2014	See Note above	0	0
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp	See Note above	179	6

Table A1-2: Database Searches for Dow Chemical Company			
Database/Source	**Keywords**	**Hits**	**Uploaded into SRDB**
COMPLETED 07/30/2014			
DOE OSTI SciTech Connect http://www.osti.gov/scitech COMPLETED 07/30/2014	See Note above	174	0
Energy Employees Claimant Assistance Project (EECAP) http://www.eecap.org COMPLETED 08/15/2014	See Note above	0	0
Google http://www.google.com COMPLETED 07/30/2014	See Note above	4,190,700	21
HP Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 08/15/2014	See Note above	7	0
Journal of Occupational and Environmental Health http://www.ijoeh.com/index.php/ijoeh COMPLETED 08/15/2014	See Note above	6	0
National Academies Press http://www.nap.edu/ COMPLETED 07/30/2014	See Note above	2	0
NEPIS http://nepis.epa.gov/ COMPLETED 07/30/2014	See Note above	1,624	0
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 07/30/2014	See Note above	144	0
United States Army Corps of Engineers (USACE) http://www.usace.army.mil/ COMPLETED 07/30/2014	See Note above	0	0
United States Army Corps of Engineers (USACE) - Sacramento District http://www.spk.usace.army.mil/ COMPLETED 07/30/2014	See Note above	0	0
United States Army Corps of Engineers (USACE) -	See Note above	1	0

Table A1-2: Database Searches for Dow Chemical Company			
Database/Source	**Keywords**	**Hits**	**Uploaded into SRDB**
San Francisco District http://www.spn.usace.army.mil/ COMPLETED 07/30/2014			
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 07/30/2014	See Note above	6	0

Table A1-3: Interlibrary Loan Documents Requested			
Document Number	**Document Title**	**Date Requested**	**Date Received**
AECU-3071	Recent Developments in the Processing of Uranium Ores and Their Significance in the Extractive Metallurgy of Metals	10/22/2014	

Table A1-4: OSTI Documents Requested (All OSTI-requested documents are awaiting sensitivity review)			
Document Number	**Document Title**	**Date Requested**	**Date Received**
DOW-140 Ref ID: 137982	Research Report: Recovery of Uranium from Plateau Ores by Solvent Extraction with Di-OPA	10/27/2014	12/03/2014
DOW-146 Ref ID: 137957	Research Report; Entrainment of Solvent in Extraction of Uranium from Heavy Slurries	10/27/2014	12/03/2014
AECU-3071 Ref ID: 137954	Recent Developments in the Processing of Uranium Ores and Their Significance in the Extractive Metallurgy of Metals	10/27/2014	12/03/2014
DOW-156 Ref ID: 137965	Direct Solvent Leaching of Uranium Ores with Alkyl Phosphates	10/27/2014	12/03/2014
DOW-159 Ref ID: 137968	New Methods for the Production of High-Purity Uranium Salts	10/27/2014	12/03/2014
DOW-8 Ref ID: 137956	Dow Progress Report 8 for October 1948	10/27/2014	12/03/2014
DOW-9 Ref ID: 137961	Dow Progress Report 9 for November 1948	10/27/2014	12/03/2014
DOW-10 Ref ID: 137963	Dow Progress Report 10 for December 1948	10/27/2014	12/03/2014

Table A1-4: OSTI Documents Requested (All OSTI-requested documents are awaiting sensitivity review)			
Document Number	**Document Title**	**Date Requested**	**Date Received**
DOW-11 Ref ID: 137964	Dow Progress Report 11 for January 1949	10/27/2014	12/03/2014
DOW-12 Ref ID: 137966	Dow Progress Report 12 for February 1949	10/27/2014	12/03/2014
DOW-13 Ref ID: 137969	Dow Progress Report 13 for March 1949	10/27/2014	12/03/2014
DOW-14 Ref ID: 137970	Dow Progress Report 14 for April 1949	10/27/2014	12/03/2014
DOW-15 Ref ID: 137971	Dow Progress Report 15 for May 1949	10/27/2014	12/03/2014
DOW-16 Ref ID: 137972	Dow Progress Report 16 for June 1949	10/27/2014	12/03/2014
DOW-17 Ref ID: 137973	Dow Progress Report 17 for July 1949	10/27/2014	12/03/2014
DOW-18 Ref ID: 137974	Dow Progress Report 18 for August 1949	10/27/2014	12/03/2014
DOW-19 Ref ID: 137975	Dow Progress Report 19 for September 1949	10/27/2014	12/03/2014
DOW-20 Ref ID: 137976	Dow Progress Report 20 for October 1949	10/27/2014	12/03/2014
DOW-21 Ref ID: 137977	Dow Progress Report 21 for November 1949	10/27/2014	12/03/2014
DOW-22 Ref ID: 137978	Dow Progress Report 22 for December 1949	10/27/2014	12/03/2014
DOW-134 Ref ID: 137979	July-August 1955 Progress Report	10/27/2014	12/03/2014
DOW-136 Ref ID: 137980	September-October 1955 Progress Report	10/27/2014	12/03/2014
DOW-141 Ref ID: 137952	January-February 1956 Progress Report	10/27/2014	12/03/2014
DOW-143 Ref ID: 137953	March -April 1956 Progress Report	10/27/2014	12/03/2014
DOW-145 Ref ID: 137955	May-June 1956 Progress Report	10/27/2014	12/03/2014
DOW-147 Ref ID: 137958	July-August 1956 Progress Report	10/27/2014	12/03/2014

Table A1-4: OSTI Documents Requested (All OSTI-requested documents are awaiting sensitivity review)			
Document Number	**Document Title**	**Date Requested**	**Date Received**
DOW-149 Ref ID: 137959	September-October 1956 Progress Report	10/27/2014	12/03/2014
DOW-138 Ref ID: 137981	November-December 1956 Progress Report	10/27/2014	12/03/2014
DOW-152 Ref ID: 137960	November-December 1956 Progress Report	10/27/2014	12/03/2014
DOW-154 Ref ID: 137962	January-February 1957 Progress Report	10/27/2014	12/03/2014
DOW-157 Ref ID: 137967	April 1957 Progress Report	10/27/2014	12/03/2014