SEC Petition Evaluation Report
Petition SEC-00105

Report Rev #: _0_ Report Submittal Date: October 3, 2008

Subject Expert(s):	Louise Buker, Ray Clark, Mike Domal, and Joe Guido
Site Expert(s):	NA

Petition Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition Qualification Date	DOE/AWE Facility Name
SEC-00105	83.13	May 15, 2008	General Steel Industries

Petitioner Class Definition
All individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through December 31, 1966, and/or during the residual period from January 1, 1967 through December 31, 1992.

Class Evaluated by NIOSH
All individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through June 30, 1966, and/or during the residual radiation period from July 1, 1966 through December 31, 1992.

NIOSH-Proposed Class(es) to be Added to the SEC
None

Related Petition Summary Information			
SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
NA	NA	NA	NA

Related Evaluation Report Information	
Report Title	DOE/AWE Facility Name
NA	NA

ORAU Lead Technical Evaluator: Mike Domal	**ORAU Review Completed By:** Dan Stempfley

Peer Review Completed By:	[Signature on file] *Dave Allen*	10/03/2008 *Date*
SEC Petition Evaluation Reviewed By:	[Signature on file] *J. W. Neton*	10/03/2008 *Date*
SEC Evaluation Approved By:	[Signature on file] *Larry Elliott*	10/03/2008 *Date*

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Evaluation Report Summary: SEC-00105, General Steel Industries

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-00105, qualified on May 15, 2008, requested that NIOSH consider the following class: *All individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through December 31, 1966, and/or during the residual period from January 1, 1967 through December 31, 1992.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH modified the petitioner-requested class. NIOSH evaluated the following class: All individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through June 30, 1966, and/or during the residual period from July 1, 1966 through December 31, 1992.

NIOSH-Proposed Class(es) to be Added to the SEC

Based on its complete research of the class under evaluation, NIOSH has assessed Battelle-TBD-6000, Battelle-TBD-6000 Appendix BB, the most recently discovered personnel external monitoring data, monitoring data bounding operations from other similar sites, and modeling data associated with evaluation of the source term at General Steel Industries. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

Feasibility of Dose Reconstruction

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

Health Endangerment Determination

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

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SEC Petition Evaluation Report for SEC-00105

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through June 30, 1966, and/or during the residual period from July 1, 1966 through December 31, 1992. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

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

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

2.0 Introduction

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

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

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, then NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the

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

class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

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

3.0 SEC-00105 General Steel Industries Class Definitions

The following subsections address the evolution of the class definition for SEC-00105, General Steel Industries. When a petition is submitted by a claimant, the requested class definition is evaluated as submitted. If the available site information and data justify a change in the petitioner's class definition, NIOSH will specify a modified class to be fully evaluated. After a complete analysis, 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-00105, qualified on May 15, 2008, requested that NIOSH consider the following class for addition to the SEC: *All individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through December 31, 1966, and/or during the residual period from January 1, 1967 through December 31, 1992.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the General Steel Industries workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00105 for evaluation:

> The petition indicates that radiation exposures and radiation doses potentially incurred by members of the petitioner-requested class were not monitored either through personal monitoring or through area monitoring. Certain identified individuals did not wear, nor were they offered, radiation monitoring of any kind. The petition further states that no radiation monitoring of any kind was performed at the site.
>
> Some of the affidavit statements made in the petition include the following:

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

- *We were never given any type of badge or monitoring device to measure our exposure to radiation.*
- *We were not monitored but were asked to leave certain areas prior to X-ray operations.*
- *Not many precautions were taken in regard to protecting the workers at General Steel industries.*

Concerns were also expressed about unmonitored employees working in and/or around the #10 Building, which was near the New Betatron building.

Based on its research and data capture efforts related to General Steel Industries, NIOSH determined that it has access to film badge data for radiographers who worked at General Steel Industries during the time period under evaluation. However, NIOSH also determined that personnel internal and external monitoring records are not complete for all time periods or for all radiation energies. NIOSH concluded that there is sufficient documentation to support, for at least part of the proposed time period, the petition basis that internal and external radiation exposures were not monitored at General Steel Industries, 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.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH modified the petitioner-proposed class. The date for the end of the Atomic Energy Commission (AEC) work was based on the last Mallinckrodt purchase order requisition dated July 7, 1965 (Purchase Order, 1965), and is also relayed in the Formerly Utilized Sites Remedial Action Program (FUSRAP) Authority Determination from the Department of Energy (GSI, 1991). The associated purchase order covers services for the period from July 1, 1965 through June 30, 1966, for the end of the operational period, for performing X-rays on uranium ingots. This end date is supported by the end of AEC-related operations in the St. Louis area (including the Mallinckrodt and Weldon Spring sites). The AEC Completion Report for the St. Louis area indicates that the AEC announced its plans to terminate St. Louis-area uranium production activities in April 1966, with the subsequent shutdown of Uranium Division operations and placing the Weldon Spring site in a standby condition, which was followed by the termination of the AEC contract in early June 1967 (Mallinckrodt, 1967). Therefore, NIOSH defined the following class for further evaluation: all individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through June 30, 1966, and/or during the residual period from July 1, 1966 through December 31, 1992.

3.3 NIOSH-Proposed Class(es) to be Added to the SEC

Based on its research, NIOSH has obtained sufficient data to determine the facility layout, available source terms, site operations, and likely exposure scenarios. NIOSH also obtained film badge data for radiographers who worked at General Steel Industries from 1963 through 1974. Airborne monitoring data analyses compiled from other uranium metal handling facilities were also available (Battelle-TBD-6000). Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

NIOSH identified and reviewed 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 personnel 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 provides process history information, information on personnel and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. As part of NIOSH's evaluation detailed herein, it examined the following Site Profiles for insights into General Steel Industries operations or related topics/operations at other sites:

- *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals*, Battelle-TBD-6000 PNWD-3738; Rev. FO; December 13, 2006; SRDB Ref ID: 30671 (Battelle-TBD-6000)

- *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals - Appendix BB General Steel Industries,* Battelle-TBD-6000 Appendix BB; Rev. 0; June 25, 2007; SRDB Ref ID: 47713 (Battelle-TBD-6000 Appendix BB)

4.2 Technical Information Bulletins (TIBs)

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

- *Battelle-TIB-5000*: *Default Assumptions and Methods for Atomic Weapons Employer Dose Reconstructions*, Battelle-TIB-5000 PNWD-3741, Rev. 00; April 2, 2007; SRDB Ref ID: 32016 (Battelle-TIB-5000)

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

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

4.3 Facility Employees and Experts

To obtain additional information, Sanford Cohen & Associates (SC&A) interviewed former employees of General Steel Industries on October 9, 2007. The meeting was arranged by SC&A and a spokesperson for former workers from General Steel Industries. The purpose of the meeting was to gather information for use in reviewing Battelle-TBD-6000 Appendix BB. In addition to the October 9th meeting, one worker outreach meeting and two affidavit testimony meetings have been conducted with former employees of General Steel Industries:

- August 21-22, 2006, General Steel Industries meeting in Collinsville, Illinois (Transcript, August 21, 2006; Transcript, August 22, 2006; McKeel, 2006)
- August 11, 2006, General Steel Industries affidavit testimony meeting held in East Alton, Illinois (Transcript, August 11, 2006)
- July 7, 2006, General Steel Industries affidavit testimony meeting held in East Alton, Illinois (Transcript, July 7, 2006)

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH OCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of July 17, 2008)

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

Description	Totals
Total number of claims submitted for dose reconstruction	238
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (January 1, 1953 through June 30, 1966, and/or during the residual period from July 1, 1966 through December 31, 1992)	238
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	208
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	11

Note:
* OCAS identified 11 claimants with dosimetry records. A review of the records indicated Battelle-TBD-6000 Appendix BB was favorable in each case.

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. Most dose reconstructions performed to date were completed prior to the availability of personnel monitoring records. Bounding external doses were estimated based on modeled external exposure pathways derived from interview data, site operations, estimated exposure rates, and calculated exposure rates. Bounding internal doses were estimated based on airborne radioactivity data compiled from other uranium metal handling facilities (Battelle-TBD-6000). External monitoring records are now available for some of the claimants, the results of which are much lower than the bounding estimates listed in Battelle-TBD-6000 Appendix BB (discussed further in Section 7.3).

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the evaluation of the proposed class. Seventy-eight documents in this database were identified as pertaining to General Steel Industries. These documents were evaluated for their relevance to this petition. The documents include historical background on purchase orders, levels of operation, film badge monitoring, survey reports, and equipment manuals.

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 – 83.13*, [Name One Redacted]; June 19, 2008; OSA Ref ID: 105333 (Name One, 2008)

- *Affidavit from [Name Two Redacted];* (no date); OSA Ref ID: 105333, p. 15 (Name Two, unknown date)

- *Affidavit from [Name Three Redacted]*; February 9, 2008; OSA Ref ID: 105333, pp. 10-12 (Name Three, 2008)

- *Letter from [Name Three Redacted]*; (no date); OSA Ref ID: 105333, pp. 13-14 (Name Three, unknown date)

- *Cleanup Criteria Information page*; March 3, 2005; DOE; OSA Ref ID: 105333, p. 16 (DOE, 2005)

- *Article: GSI's Castings Division*; (no author identified); (no date); OSA Ref ID: 105333, p. 17 (Unknown author, unknown date-a)

- *Drawing: GSI map*; (no author identified); (no date); OSA Ref ID: 105333, p. 18 (Unknown author, unknown date-b)

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at General Steel Industries from January 1, 1953 through June 30, 1966, as well as the potential radioactive material exposures during the residual period from July 1, 1966 through December 31, 1992, and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing 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 General Steel Industries Plant and Process Descriptions

ATTRIBUTION: Section 5.1 was completed by Ray Clark, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationale for all conclusions in this document are explained in the associated text.

The General Steel Castings Corporation was incorporated in Delaware in December 1928, and was originally owned by the Baldwin Locomotive Works and American Steel Foundries. A bond issue was floated on June 21, 1929 to enable the company to acquire the Commonwealth Steel Corporation in Granite City, Illinois. Commonwealth Steel Corporation was consolidated with General Steel Castings in November 1929, becoming the Commonwealth Division of General Steel Castings. The company went through various acquisitions and expansions until 1961, when General Steel Castings formally changed its name to General Steel Industries, Inc. The General Steel Industries facility is located at 1417 State Street in southwest Granite City, Illinois, northeast of St. Louis, Missouri, and east of the Mississippi River. All of General Steel Industries' operations were consolidated in Granite City in 1963, and operations continued there until the plant closed in 1973. For the purpose of this evaluation report, the name "General Steel Industries" (abbreviated as General Steel) is used to represent the Granite City, Illinois site (located at 1417 State Street) over the entire EEOICPA covered period for the purpose of evaluating radiological exposures and the ability to reconstruct radiological dose under this program (DOE, 2007).

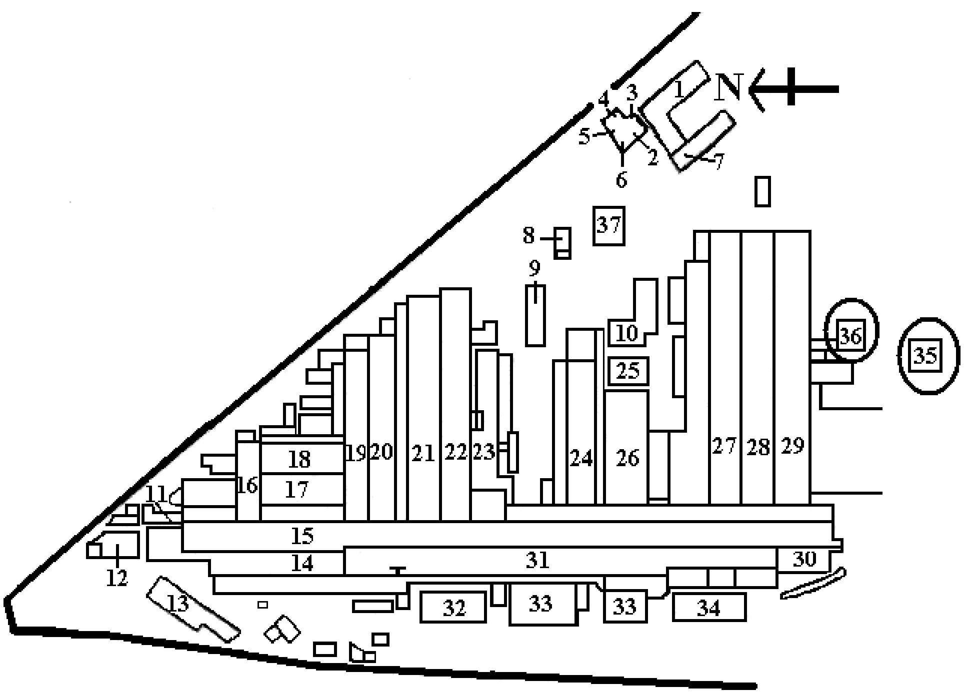
General Steel Industries, in Granite City, Illinois, performed quality control work for the AEC during the 1950s and 1960s. Based on available information, the site primarily supported AEC-related activities at the Mallinckrodt Chemical Company site from 1958 through 1966, but may have supported the AEC as early as 1953 (Unknown author, 1991, p. 5; Battelle-TBD-6000 Appendix BB; GSI, 1991). Utilizing two betatron machines, it performed X-rays on uranium ingots to detect metallurgical flaws in support of AEC-related activities at the Mallinckrodt Chemical Company (DOE, September 1992, p. 5). This work was performed in areas of the facility which were part of what was later known as the South Plant. The uranium ingots that were X-rayed at the site were cylindrical, 18 to 20 inches in diameter, approximately 18 inches long, and weighed up to 3,000 pounds. At least some of the work was performed on Betatron slices, each of which was an approximately four-inch-thick slice taken from an ingot. Wherever this document refers to ingots, it is intended to mean ingots or betatron slices. In addition to AEC operations, the betatrons were also used commercially to detect flaws in metal castings (Battelle-TBD-6000 Appendix BB) during the same period of time (1953-1966).

The X-ray quality control work on uranium ingots was performed on an as-needed basis, as indicated by Mallinckrodt Chemical Company purchase orders and associated cost limits, with no indication of the frequency or duration (DOE, September 1992, p. 5; Unknown author, 1991). Reasonable estimates regarding the time that the betatrons were in service for both AEC and commercial operations each year can be made based on purchase orders and the associated securing of St. Louis-area activities by the AEC, information/documentation available to NIOSH (in its Site Research Database) regarding the use of the betatrons at the site, and information obtained from interviews with former General Steel Industries operators who worked at the site during the time period evaluated in this report (DOE, September 1992, p. 5; Unknown author, 1991; Mallinckrodt, 1967).

Figure 5-1 depicts the overall General Steel Industries layout. The betatrons were located at the south end of the plant (identified as location numbers 35 and 36 in Figure 5-1).

Figure 5-1: General Steel Industries Plant Layout

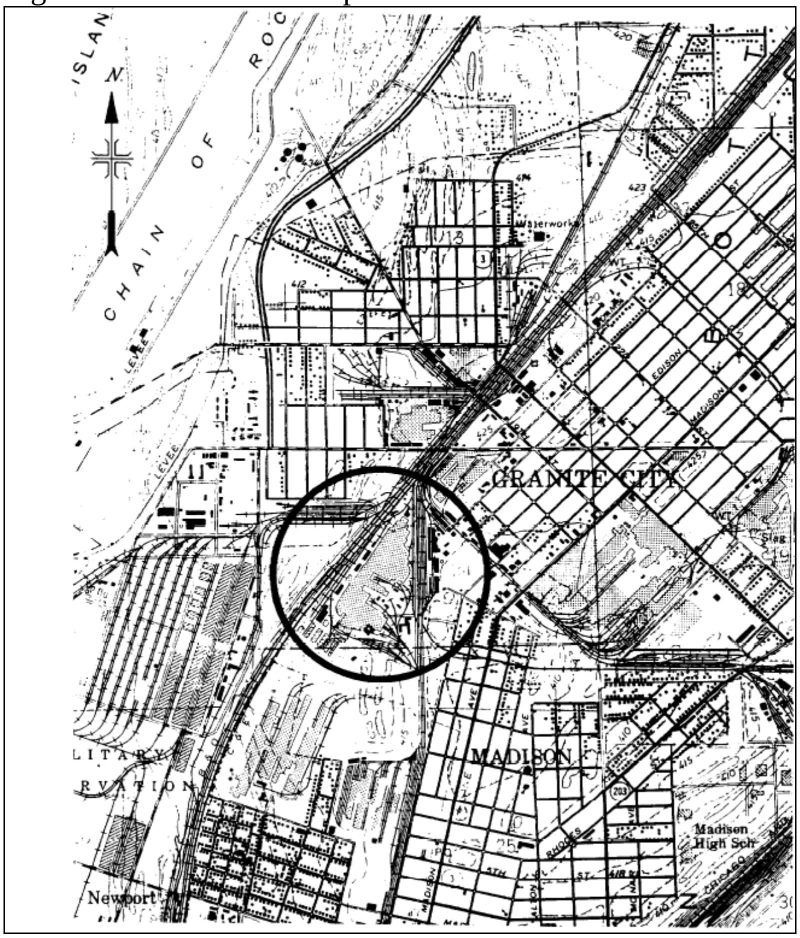
1-General Office	14-Open Hearth	27-No. 8 Building
2-Plant Office	15-No. 1 Foundry	28-No. 9 Building
3-Guard Office	16-No. 1 Building	29-No. 10 Building
4-Personnel Office	17-No. 2 Building	30-Heat Treat
5-Safety Office	18-No. 3 Building	31-Core Room
6-Dispensary	19-No. 4 Building	32-Mechanical Repair
7-Locker Room	20-No. 5 Building	33-Patt. Storage
8-Test Laboratory	21-No. 6 Building	34-Patt. Shop
9-Storeroom	22-No. 7 Building	35-Gov. Betatron
10-Cafeteria	23-Seed System	36-Betatron
11-Storeroom	24-No. 2 Foundry	37-Research Laboratory
12-Blacksmith	25-Carpenter Shop	
13-Power House	26-No. 12 Building	



Source: Reformatted from McKeel, 2006, p. 42

Figure 5-2 provides an aerial site map of General Steel Industries.

Figure 5-2: Aerial Site Map of General Steel Industries



Source: Murray, 1992, p. 21

5.2 Radiological Exposure Sources from General Steel Industries Operations

<u>ATTRIBUTION</u>: Section 5.2 and its related subsections were completed by Mike Domal, MJW Corporation. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationale for all conclusions in this document are explained in the associated text.

The following subsections provide an overview of the internal and external exposure sources for the General Steel Industries class under evaluation.

5.2.1 Internal Radiological Exposure Sources from General Steel Operations

General Steel Industries performed quality-control work on uranium ingots for the Mallinckrodt Chemical Company, which involved X-raying uranium ingots to determine if metallurgical flaws existed. The quality-control work did not include any cutting, machining, or abrading of the uranium ingots; therefore, there was a low probability of producing elevated air concentrations of uranium.

The primary source of airborne contamination was from oxidation and dust particles on the surface of the ingots that became airborne by forces such as air currents and handling activities. Internal radiological exposure could occur by means of inhalation and/or ingestion of radioactive materials.

5.2.1.1 Uranium

The AEC quality-control X-ray activities performed by General Steel Industries only involved uranium ingots. Therefore the primary radionuclide of concern for internal radiological exposure is uranium. Uranium oxides form in a variety of ways in metal working plants, including scale formation on hot surfaces and oxidation enhanced by the presence of water (Battelle-TBD-6000). Uranium particles could have been removed from the surface and become airborne during handling operations and subsequently inhaled or ingested. Until 1953, most uranium handled in AWE metal-working sites was natural uranium (Battelle-TBD-6000). Details regarding the relative concentrations of uranium isotopes in the ingots supplied by Mallinckrodt Chemical Company were not available; however, it is reasonable to assume that the ingots consisted of natural uranium given the source of the uranium metal ingots (or dingots) (ORAUT-TKBS-0005; Mallinckrodt, 1967).

5.2.1.2 Recycled Uranium

It is possible that uranium processed in refineries after 1953 was recycled or contained recycled uranium. Therefore, for the timeframe evaluated in this report and in the absence of definitive information about the origin of the processed uranium, it is assumed that the uranium contained the following contaminants: plutonium-239, neptunium-237, technetium-99, thorium-232, and thorium-228 (Battelle-TBD-6000). The relative fractions of recycled uranium products are assumed to be those stated in Table 3.2 of Battelle-TBD-6000.

5.2.1.3 Fission Products

Internal exposure to fission products is considered in this evaluation because it was possible for fission products created on the surface of the uranium ingot during betatron operations to be removed from the surface and become airborne (Battelle-TBD-6000).

5.2.1.4 Activation Products

Internal exposure to activation products from the surface of the uranium ingots was considered in this evaluation because it was possible for some uranium to become dislodged during handling operations. Internal exposure from steel activation products was considered because during non-AEC work, metals were X-rayed and the flaws ground out. The grinding activities of activated steel presented a pathway for internal exposure (Battelle-TBD-6000 Appendix BB).

Additionally, according to SC&A, 2008, the inhalation of dust from activated steel did not constitute a significant exposure pathway.

5.2.2 External Radiological Exposure Sources from General Steel Operations

External radiological exposures from AEC operations at General Steel Industries resulted from the processes involved in taking X-rays of uranium ingots. External radiological exposures from non-

AEC operations resulted from activities associated with taking X-rays of steel castings and then handling or grinding the castings to remove any flaws afterwards. External exposure source scenarios are divided into three scenarios: X-ray set-up, X-ray operations, and post-X-ray activities. Each scenario has specific sources to consider.

During X-ray set-up activities for uranium ingots, the primary external exposure source was the uranium ingot itself. Employees involved in positioning the uranium ingots for X-ray exposures received deep and shallow external doses from the external surface of the uranium ingot. Time and distance from the surface of the ingot determined the amount of exposure employees received. During X-ray set-up activities for steel castings, there was no radiological exposure because the steel was not activated.

During X-ray operations involving uranium ingots and steel castings, employees were potentially exposed to two sources of radiation: penetration of the shield wall and skyshine. The betatrons were operated from a control room outside of the primary shield wall for protection against being exposed to the primary X-ray beam. The betatrons were housed inside of a building with a ten-foot-thick shield wall to protect employees from the X-ray beam (Murray, 1992). Additionally, there was a loud speaker system and lights along with an interlock system that would prevent the betatron from operating if the door was opened (Unknown author, unknown date-c). Discussions with former operators indicated that X-rays lasted about one hour , during which time employees who were in rooms near the betatron had the potential for external radiological exposure (Meeting Minutes, October 9, 2007). A small fraction of the radiation penetrated the shield wall; thus, the closer an individual was to the external surface of the shield wall, the higher the exposure rate. External exposure was also indirectly possible from skyshine, which consisted of photons that were scattered upward out of the building, then downward to ground level, thus bypassing the shield wall. Skyshine can be a significant exposure source at facilities which have particle accelerators (depending on the energy and flux of resultant radiations). For the General Steel facility, scattered photons were determined by calculation to contribute to the external dose of employees. The areas outside of the betatron buildings that had the highest calculated dose rates from skyshine were considered in dose estimates.

The post-X-ray operations included two external radiation sources: ingots and activation of the betatron components. The ingot itself included short-lived activation products from photon-neutron reactions that occurred during X-ray operations. Fission products were also present in the uranium ingot due to the photo-fission reaction that occurred during betatron operations (Battelle-TBD-6000 Appendix BB). Exposure to activation products and fission products from the uranium ingots was in addition to radiation normally emitted from un-irradiated uranium ingots. The exposure rates from the irradiated ingots were highest immediately after the betatron was shut down; exposure rates dropped exponentially with time (Battelle-TBD-6000 Appendix BB).

The second external radiation source during post-X-ray operations was from activation of the betatron apparatus itself (Battelle-TBD-6000 Appendix BB). The external exposure hazard from activation of the betatron became minimal after about 30 minutes.

Additional sources of external radiation include sealed radiography sources and a portable X-ray unit. The radiography source and portable X-ray units were used for X-raying components at the facility.

5.2.2.1 Photon

There were a number of photon radiation sources that contributed to the overall external exposures associated with performing quality-control X-rays on uranium ingots. The external photon radiation exposure sources included photons from the uranium (ingots), X-rays from the betatron operations (through the shielding and from skyshine), and activation of the uranium and betatron components (post-uranium X-ray operations).

Photons resulting from the operation of the betatron also contributed to external radiation exposure. These photons resulted in personnel exposure through penetration of the primary shield wall or through scattering as a result of skyshine. Photons from skyshine were scattered out of the betatron building and then back down to ground level, bypassing the primary shield wall. The areas outside of the betatron buildings that had the highest calculated dose rates from skyshine were considered in dose estimates.

The activation of uranium and betatron components also resulted in post-X-ray photon sources. In uranium, photons resulted from short-lived neutron activation products that were produced from photo-neutron reactions while the betatron was in operation; photons also resulted from fission products which were produced from photo-fission reactions. Activation of the betatron apparatus also resulted in short-term, post-operation photon exposures. The exposure rates from activation of the betatron apparatus dropped quickly (Name Four, 2007).

5.2.2.2 Beta

The dominant beta radiation source was from the surface of the uranium ingots. In the uranium-238 decay scheme, there is a short-lived isotope, protactinium-234m. This isotope decays by emitting an energetic 2.28 MeV beta particle. It is this beta particle that accounts for shallow-dose hazard associated with handling the uranium metal. Beta radiation from the uranium ingot surface is considered during X-ray set-up activities and post-X-ray operations since both activities required handling the uranium ingot. Beta radiation was also present after X-ray operations from fission and activation products present in uranium ingots, and in activation products present in steel following non-AEC X-ray operations.

5.2.2.3 Neutron

As discussed in ORAUT-OTIB-0004, neutron doses from exposure to natural uranium, including uranium metals, are considered negligible (ORAUT-OTIB-0004). During X-ray operations, potential neutron exposures were possible from photo-neutron interactions and delayed neutrons from photo-fission interactions; however, this did not result in a significant exposure source because neutrons resulted from secondary radiations from the X-ray interactions with matter in the X-ray area. This issue is further assessed in Section 7.3 of this report.

5.2.3 Incidents

A review of General Steel Industries' records did not uncover any radiological incidents that were associated with AEC operations, or that could not be accounted for using the information and documentation available to NIOSH.

5.2.4 Residual Radioactivity Period at the General Steel Industries Site

Based on the purchase orders for Mallinckrodt to X-ray uranium, the AEC-related radiological operations at General Steel Industries were completed in 1966. For the purposes of this evaluation report, NIOSH has defined the end-date of radiological operations as June 30, 1966. Therefore, the start date of the residual period is considered to be July 1, 1966. The residual period ends in 1992. Again, for the purposes of this evaluation report, NIOSH has defined the date as December 31, 1992 (based on the start of the DOE site remediation under FUSRAP, which occurred in 1993). During the period of residual contamination, as designated by NIOSH and as noted in the dates above, employees of subsequent owners and operators of this facility are also covered under EEOICPA.

During the residual contamination period (i.e., after AEC operations ended), internal exposure could have resulted from resuspension of settled uranium dust or particles. The potential airborne concentrations from resuspended contamination are considered to be significantly less than the airborne concentrations that could have occurred during AEC operations.

In 1989, DOE conducted a radiological survey to establish the current radiological conditions in and around the building in which the X-ray equipment was housed. Survey results showed that small amounts of residual radioactivity from former operations remained in several discrete areas in the X-ray building at the Granite City facility. Uranium-238 was found in elevated concentrations in debris from an industrial vacuum cleaner, and in dust and debris in several small locations throughout the building. This information, coupled with the radiological exposure sources discussed above for the operational period at the site, can be used to evaluate the radiological exposure sources during the residual radioactivity period at the General Steel Industries site.

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

ATTRIBUTION: Section 6.0 and its related subsections were completed by Louise Buker, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following subsections provide an overview of the state of the available internal and external monitoring data for the General Steel Industries class under evaluation.

6.1 Available General Steel Industries Internal Monitoring Data

As of the date of this evaluation, NIOSH has been unable to find any records of internal monitoring data for General Steel Industry employees; this includes its search for bioassay data and air monitoring data. Therefore, NIOSH developed a bounding internal dose estimation method based on air monitoring data from other AEC uranium-handling facilities. The estimated employee intakes were reasonably bounded because the assumed airborne activities were derived from AEC uranium-handling facilities that used a "slug production" process. The air monitoring data from the slug production process provides a basis to bound internal dose estimates since this process includes uranium machining activities, which resulted in airborne uranium dust production. General Steel operations did not include uranium machining; therefore, the assumed airborne activity levels would be considered conservatively bounding for the proposed worker class being evaluated in this report. This methodology is discussed in Section 7.2.

6.2 Available General Steel Industries External Monitoring Data

As of the date of this evaluation, NIOSH has been unable to find any records of external monitoring data prior to 1964 for General Steel employees. However, personnel monitoring data (film badges from the film badge vendor Landauer) for the years 1964 through 1973 are available to NIOSH and are used in the evaluation of bounding external doses (as discussed in Section 7.2 of this report) (Landauer, 1964; Landauer, 1965; Landauer, 1966; Landauer, 1967; Landauer, 1968; Landauer, 1969; Landauer, 1970; Landauer, 1971; Landauer, 1972; Landauer, 1973). Although 1966 was the end of the operational period, monitoring data are available during the residual period up to 1973. The available monitoring data provided in the Landauer reports include only photon dose data. Based on a review of the information available to NIOSH, including the available purchase order requisitions and personnel interviews, NIOSH determined that the potential for exposure during 1964 was higher than in any previous year during the operational period at General Steel Industries. This determination was based on the estimated betatron operational times for both AEC and non-AEC uses. Therefore, the dosimetry data are considered sufficiently representative for all other years during the operational period. In addition, based on the evaluation and assessment of the dose reconstruction approach presented in Battelle-TBD-6000 and Battelle-TBD-6000 Appendix BB as performed in this report, the dosimetry data also support the conclusion that Battelle-TBD-6000 provides a bounding estimate of external doses for the proposed class of workers evaluated in this report.

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

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class. 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 ensure 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 OCAS's SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00105 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of General Steel Industries Data

ATTRIBUTION: Section 7.1 and its related subsections were completed by Louise Buker, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

This subsection considers questions that need to be addressed 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 basis 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

NIOSH has been unable to find records of uranium internal monitoring for uranium for General Steel Industries employees. General Steel Industries' data, such as bioassay results and air sampling results, are not available. However, Battelle-TBD-6000 includes air sampling data collected from other AWE facilities that handled uranium. The data identified in Battelle-TBD-6000 are considered representative measurements for most of the processes that took place at metal-working AWE sites, as the results are typical for the state of technology in the late 1950s. The air sample data were categorized and presented in Battelle-TBD-6000 based on common uranium metal working processes. The air sample results from the uranium metal-working process, known as slug production, were used to reasonably bound the airborne radioactivity concentrations that could have existed at the General Steel Industries site. The slug production process involved handling uranium slugs as well as abrasive activities such as brushing and filing (Battelle-TBD-6000). The activities at General Steel Industries also involved handling uranium metal, but did not include abrasive activities. It is therefore reasonable to assume that the air sample data used were credible and reasonable for estimating internal doses to General Steel employees.

7.1.2 External Monitoring Data Pedigree Review

NIOSH was able to find external dosimetry monitoring records for General Steel employees for the years 1964 through 1973, which includes results for the last two years of site operations (Landauer, 1964; Landauer, 1965; Landauer, 1966; Landauer, 1967; Landauer, 1968; Landauer, 1969; Landauer, 1970; Landauer, 1971; Landauer, 1972; Landauer, 1973). The data were in the form of film badge results and came directly from the paper records provided by Landauer, the external dosimetry vendor. The names of several radiographers at General Steel Industries were confirmed to be included in the data. The Landauer data appear to include all radiographers at General Steel Industries and some support personnel. These data are significant because radiographers were considered to be the highest exposed workers at the site. Therefore, these data provide a clear indication of the actual external doses of the highest exposed workers at General Steel Industries. However, to form the basis for bounding external doses for the site, the methodology in Battelle-TBD-6000 Appendix BB was used. This methodology incorporates exposure scenarios based on input from former operators and source term modeling and calculations using Monte Carlo N-Particle transport code.

7.2 Evaluation of Bounding Internal Radiation Doses at General Steel Industries

ATTRIBUTION: Section 7.2 and its related subsections were completed by Louise Buker, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The principal sources of internal radiation doses for members of the proposed class include inhalation and ingestion of uranium dust from handling uranium metal, fission and activation products from handling and examining the uranium following X-ray operations, and activation products from steel castings handled and examined following X-ray operations. The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction at General Steel Industries, located on 1417 State Street, Granite City, Illinois, during the operational period from January 1, 1953 through June 30, 1966, and during the residual period from July 1, 1966 through December 31, 1992.

7.2.1 Evaluation of Bounding Process-Related Internal Doses

As of the date of this evaluation, NIOSH has not found any internal dosimetry data for General Steel employees or any air monitoring data associated with General Steel operations. However, since no cutting, machining, or abrading of uranium was done, there was a low potential for producing elevated air concentrations of uranium at the General Steel site. As reviewed and evaluated in Battelle-TBD-6000 and Battelle-TBD-6000 Appendix BB, General Steel's uranium work process is reasonably similar to the "Slug Production" process. They are similar in that the work at General Steel and the slug production process both involve the handling of solid uranium metals. They are dissimilar in that the slug production process also included abrasive uranium metal-work activities, whereas no uranium metal-working took place at General Steel. Therefore, representative air sampling data associated with uranium slug production at AEC facilities form a basis to reasonably bound internal exposures for members of the proposed worker class evaluated in this report. A specific assessment of this methodology is included in Section 7.2.3 of this report.

General Steel also X-rayed steel castings to detect internal flaws in the castings; these were non-AEC operations that occurred at the same time AEC operations took place. The steel castings could potentially be ground out soon after the X-rays were performed, while the steel was still activated, thus resulting in radioactive dust being inhaled by the employee grinding the casting. As reviewed and evaluated in Battelle-TBD-6000 and Battelle-TBD-6000 Appendix BB, an internal exposure scenario based on centerless grinding provides a bounding estimate of the airborne exposure involving inhalation of steel activation products. For the purpose of evaluating the exposure scenario, since the grinding could not occur until after the film was processed, it is assumed that grinding did not start until 30 minutes after the X-ray exposure ended. As assessed in Battelle-TBD-6000, the bounding exposure scenario assumes that grinding would start on a freshly X-rayed piece of steel every 2 hours (with grinding performed on each piece until the activity was completely decayed away). Employees were assumed to inhale iron-53 (steel activation product) every two hours for 2,400 hours per year. This intake was calculated to yield an annual dose of less than 1 mrem for all organs. Based on this assessment, further evaluation of this internal dose pathway is not included in Section 7.2.3 of this report.

7.2.2 Evaluation of Bounding Residual Period Internal Doses

Internal dose from the residual contamination period is limited to contamination left behind following the operational period. An internal dose pathway is possible if the settled contamination is re-suspended into the air. Dose estimates from inhalation and ingestion of re-suspended contamination were calculated using a resuspension model. The methodology used in the calculation is described in Section 7.2.3.2.

7.2.3 Methods for Bounding Internal Dose at General Steel

NIOSH evaluated the potential exposures from possible intakes of radioactive material at General Steel Industries based on air monitoring data from other facilities for the operational period. Internal exposures from the residual period were estimated by modeling the resuspension of surface contamination levels to determine airborne levels that would bound intakes for General Steel employees.

7.2.3.1 Methods for Bounding Operational Period Internal Dose

General Steel Industries' internal dose is bounded by using air sampling measurement data from other AEC facilities that conducted uranium slug production operations. Since slug production included machining uranium and General Steel did not machine uranium, these values are considered bounding. The only airborne potential for General Steel Industries uranium work was from handling and moving uranium metal. Slug production inherently includes handling and moving the uranium metal, as well as uranium machining.

Uranium may have also contained fission and activation products produced from photonuclear reactions from the high-energy X-rays of the betatron. The physics associated with producing these products is well-known and can be modeled. Several scenarios have been modeled and have shown that internal dose from activation products is negligible (SC&A, 2008). However, to account for potential doses from fission products, as noted below, the claimant-favorable assumption was made to increase the estimated uranium intake by 1%.

In order to bound the internal dose due to fission products, the overestimating methodology of increasing the uranium intake by 1% to account for the differences in biokinetic models between uranium and the fission products was applied. This was based on assuming a worst-case 2:1 decay energy ratio of uranium-to-fission products, meaning the energy associated with the decay of uranium was assumed to be twice as high as the energy associated with the decay of fission products. Given this ratio, the dose delivered by fission products over the first year after inhalation is approximately 0.005% that of the dose delivered by uranium. Therefore, it is bounding, for several reasons, to estimate the internal dose from fission products by assuming the uranium intake is 1% higher than that listed in Tables 7.8 and 7.9 of Battelle-TBD-6000 Appendix BB. First, the energy ratio is actually a conservative assumption. Second, uranium will continue to deliver dose long after the first year following intake due to its retention in the body while fission products will continue to decrease due to elimination from the body and radioactive decay. Finally, the radiation-weighting factor for alpha radiation resulting from uranium is 20 times higher than that of beta- and gamma-emitting fission products (Battelle-TBD-6000 Appendix BB, Section 5.1).

According to Battelle-TBD-6000 Appendix BB, internal dose estimates from iron-53 (steel activation product from photo-neutron reactions) were considered and found to be negligible.

7.2.3.2 Methods for Bounding Residual Period Internal Dose

Internal dose estimates for the residual period were based on resuspension of settled contamination. The air sample values collected during operations inherently include airborne uranium caused by resuspension (as well as directly from the operation itself). This implies that the intakes from the residual period can be bounded if the intakes during the operational period are bounded. For General Steel Industries, the internal dose received during the residual contamination period was bounded by estimating a surface contamination value created during the operational period, and in turn estimating a resuspended air concentration of uranium (Battelle-TBD-6000 Appendix BB).

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

This evaluation concludes that internal dose reconstruction for personnel working during the operations period at the General Steel Industries site is feasible based on using a bounding estimate of uranium intakes from air sampling data at other AWE uranium handling facilities. The estimate is bounding due to the fact that air sampling data from facilities involved in uranium slug production were used. Activities at uranium slug production facilities included brushing and filing uranium; therefore, the slug production facilities produced higher airborne uranium concentrations than what was possible at General Steel Industries, which did not brush and file uranium. Internal doses from non-AEC operations that occurred during the AEC operational period were conservatively evaluated and found to be negligible (SC&A, 2008; Battelle-TBD-6000 Appendix BB). In addition, this evaluation supports the ability to bound residual period doses based on a calculated maximum surface contamination and an associated airborne radioactivity exposure scenario. Based on the assessment of these doses, NIOSH concludes that the methods described in Battelle-TBD-6000 and Battelle-TBD-6000 Appendix BB provide reasonable approaches to conservatively bound internal doses for all members of the class under evaluation.

7.3 Evaluation of Bounding External Radiation Doses at General Steel Industries

ATTRIBUTION: Section 7.3 and its related subsections were completed by Louise Buker, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationale for all conclusions in this document are explained in the associated text.

The principal source of external radiation doses for members of the proposed class was from activities associated with the betatron machines. During set-up activities in preparation for X-raying uranium ingots, there was the potential for exposure directly from the uranium ingots. While in operation, there was the potential for exposure from radiation escaping the shielded area (such as skyshine or by directly penetrating the shield wall). Following X-ray operations, there was the potential for exposure to irradiated steel alloys that were activated by photo-neutron interactions caused by the high-energy X-rays, and to the uranium metal (which also included fission and activation products caused by photo-neutron interactions).

Additional sources of external radiation include sealed radiography sources and a portable X-ray unit.

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

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

7.3.1.1 Personnel Dosimetry Data

NIOSH has obtained film badge data from Landauer that appear to include records for all workers employed as radiographers at General Steel Industries between 1964 and 1973. The radiographers are considered to be the maximally-exposed group of workers based on the potential sources for external radiation. These included skyshine during operations, exposure to uranium ingots before and/or after X-ray operations, and exposure to activated steel after X-ray operations. The time period from 1964 to 1966 (monitored time period) is considered to be the time period that had the highest potential annual site exposures, because a new higher-energy betatron was received in 1963 from the Eddystone plant. When the new betatron was upgraded and put into operation, the site then had two operational betatrons. The two betatrons were not in close enough proximity to have overlapping exposure potentials. Nonetheless, with the ability to use two betatrons came the potential for higher site exposures. As expected, X-ray operations increased during this timeframe (Transcript, August 21, 2006, p. 41). Although there are only two years of dosimetry data for the operational timeframe (1964-1966), the data are representative of the highest doses the radiographers may have received.

Photon

Radiographers

The available radiographer film badge data from 1964 through 1966 can be used to provide a bounding estimate of the radiation doses received by radiographers over any period of time at the site. One reason for this is that the period of available monitoring includes a period where two betatrons were operational at General Steel Industries. Therefore, X-ray operations increased concurrent with the potential for higher radiographer and site-employee doses.

General Steel operators indicated that the new betatron had an output of 250 R/minute, while the old betatron had an output of 100 R/minute (Transcript, August 21, 2006, p. 45). This appears credible based on an interview with a former Allis Chalmers employee (Name Four, 2007) who indicated that there were lower outputs in the early 1950s. The new betatron was reportedly upgraded in 1963 when it was moved from the Eddystone Plant to Granite City (SC&A, 2008). Operators also discussed the difference in the amount of betatron work before and after 1963. Operators indicated that the betatrons were operated almost continuously starting in 1963, when the Eddystone Plant was closed. Prior to that, the betatron work occurred at a slower pace (Transcript, August 21, 2006, p. 41; Meeting Minutes, October 9, 2007). Thus, NIOSH assumes that the dose received by operators after 1963 would bound any dose received prior to 1963, and the available film badge data can be used to estimate pre-1964 dose.

There were also sealed sources used for radiography at General Steel Industries, as well as a portable X-ray unit. These sources were used infrequently in the plant. When they were used, they were operated by the radiographers which is the same group that operated the betatrons. The external dose to the radiographers is conservatively bounded by assuming they received the same dose as betatron operators, the maximally-exposed work group.

Other employees (non-radiographers)
While radiographers wore film badges starting in 1963, most other General Steel employees did not. Some of these unmonitored employees worked in, or with, materials recently X-rayed in the Betatron building. Two models (SC&A, 2008; Battelle-TBD-6000 Appendix BB) determined that the dose to the unmonitored employees would be bounded by assuming that they received the same dose as the betatron operators.

For other unmonitored employees, potential exposure to external photon radiation can be broken down into three categories.

- Radiation received from the Betatron building by employees working in elevated locations above the height of the Betatron building shield wall;
- Radiation received from the Betatron building by employees working in close proximity to the Betatron building but at ground level; or
- Radiation received while in close proximity to a sealed-source radiography unit used in other portions of the facility.

For the first category, two scenarios have been developed (SC&A, 2008). The first is based on statements by a former General Steel employee indicating that he performed maintenance on the roof fans of the Betatron building twice per year for approximately 20 minutes per fan (Meeting Minutes, October 9, 2007). Dose rates at the fans directly above the shooting area of the betatron have been modeled to be as high as 208.5 mrem/hour during an X-ray exposure. There are three fans above the shooting room in the New Betatron building. The total maintenance time for three fans is estimated to be one hour (20 minutes/fan). If fan maintenance was performed twice per year, the total annual maintenance time is estimated to be two hours, and the annual dose equal to 417 mrem/year. A usage factor (fraction of time the machine is emitting radiation) has been estimated as 0.414 (SC&A, 2008) and 0.5 (Battelle-TBD-6000 Appendix BB). However, if no usage factor is applied, the annual dose is estimated to be 417 mrem/year. Therefore this dose estimate can be considered bounding for employees included in this scenario, and the bounding dose is not implausibly high.

The second scenario pertains only to the new betatron since it was in close proximity to Building #10; it applies to the period from 1963 through 1966 and to individuals working on the roof of Building #10. Based on pictures of the facility combined with scale drawings of the New Betatron building, NIOSH estimated approximate distances and heights of these buildings. Using simple geometry, it is apparent that for an X-ray taken with the betatron in the center of the shooting area, the unshielded beam would be at least 10 feet above the roof line of Building #10. At head height, the beam passes through at least one foot of concrete. At the edge of the roof, the beam would pass through the entire 10 feet of shielding. Based on an unshielded dose rate calculated for the roof of 208.5 mrem/hour (SC&A, 2008), the increased distance alone would reduce this to approximately 11.2 mrem/hour. However, the 10 feet of shielding will further reduce this to a level that is well below the dose rates received in the control room. Therefore, NIOSH estimates that the radiographers in the control room would receive a higher dose; thus, radiographer dose estimates would bound this dose scenario.

It is also possible that employees not associated with radiography could have been exposed while outside the Betatron buildings at ground level. Both models (SC&A, 2008; Battelle-TBD-6000 Appendix BB) used claimant-favorable assumptions when calculating the dose rates at various locations outside the Betatron buildings. Dose rates in one model were calculated both assuming the betatron was located in the center of the shooting area and again assuming it was located near the entrance of the building pointed at the railroad tracks. This last position could only occur if the betatron head is “flipped” (SC&A, 2008, Meeting Minutes, October 9, 2007). However, operators indicated this was not done until after a particular supervisor left the company (Meeting Minutes, October 9, 2007) after the AEC contract period ended. This indicates that this scenario only occurred in the residual contamination period. Since only the radiation from residual contamination of AEC-related material can be accounted for during that period (OCAS-IG-003), it is not applicable to dose reconstructions under the EEOICPA. Dose rates determined for the center shot include 0.3 mrem/hour in the control room, 1.5 mrem/hour in a restroom, and 2.4 mrem/hour outside the building. The last two areas are not normal work areas and thus would not represent an area where someone would be exposed 100% of the workday. Occupancy factors for restrooms and other low-occupancy areas vary from 1/8 to 1/40 (Cossairt, 2008; NCRP, 2003; Liu, 2007). If the highest occupancy factor (1/8) is used, the highest dose rate outside the shield (2.4 mrem/hour) would be effectively reduced to 0.3 mrem/hour, which is the same as the control room dose rate. This implies that employees outside the Betatron building at ground level would be exposed to the same level of radiation as the betatron operators during the X-ray examination. Betatron operators would of course receive additional radiation dose while the machine is off, and they are exposed to the irradiated material in the shooting area. Therefore, the dose to employees outside of the betatron (at ground level) can be bounded by the radiographers’ estimated dose. This indicates that General Steel employee dose from this scenario can be plausibly bounded.

The last source of external radiation exposure at General Steel Industries was exposure caused by the use of sealed sources or a portable X-ray unit. Operators indicated that these sources were not used often, and the large cobalt-60 source (80 Ci) was always used in the New Betatron building. There was also a smaller cobalt-60 source used in a cinderblock room within Building #6. Indications are that all sources and the portable X-ray machine were used by radiographers and that all radiographers wore film badges (from 1964 to 1973). The radiographers themselves would likely be the most exposed individuals from these sources, since they would always be near the source during an exposure while other employees would only infrequently be exposed as they walked by the area. Thus, the radiographer film badges can be used as a bounding estimate that is not implausible. There is one additional scenario related to this third category. The cinderblock room had no ceiling. Therefore, someone working on the 40-foot-high roof of Building #6 (above this cinderblock room) could be exposed to radiation without the benefit of the minimal shielding afforded by the cinderblock. Since the source is a point source, the dose rate decreases simply with the inverse of the square of the distance from the source. The dose rate outside of the room was modeled as 18 mrem/hour, one meter from the wall (SC&A, 2008). A distance of approximately 27 feet is necessary to reduce the unshielded dose rate to18 mrem/hour. Therefore, the dose to employees working above the room more than 27 feet from the source can still be bounded with the radiographer film badge readings.

Beta

Beta dose can be reasonably bounded by using the dose methodology described in Battelle-TBD-6000 Appendix BB. This methodology assumes the operators received beta dose exposures from handling the uranium ingots both before and after X-ray operations. The beta dose estimate was bounded by overestimating the exposure time after X-ray operations to be 30 minutes. The operators were assumed to spend 15 minutes within one foot of the ingot and 15 minutes within one meter of the ingot (Battelle-TBD-6000 Appendix BB). The total exposure included radiation from uranium as well as the fission and activation products. The time period and exposure rates were conservative enough to bound any beta dose from steel-handling operations as well.

Neutron

Neutron dose was considerably smaller than photon doses but still contributed to the overall external exposures. As with other facilities, neutron doses can be determined using the photon-to-neutron ratio.

7.3.2 Evaluation of Bounding Residual Period External Doses

External dose during the residual contamination period at General Steel Industries is limited to the radiation emitted from residual uranium contamination (OCAS-IG-003). With no mechanical manipulation of the uranium (i.e., cutting, grinding, or machining) and no high-temperature applications, no significant large potential for producing large “flakes” of uranium existed. Therefore, surface contamination can be modeled from airborne concentration values. As indicated in Section 7.2, the airborne uranium is bounded by operations with uranium metal that involve mechanically disturbing the metal. In addition, the 1989 pre-remediation survey provides information associated with an industrial vacuum cleaner which had a dose rate higher than that calculated from the assumed contamination level caused by the residual surface contamination. Therefore, the contact dose rate from the vacuum cleaner can be used as a basis to calculate external dose from residual contamination

(Battelle-TBD-6000 Appendix BB). Based on this information, a bounding external dose estimate can be established for the proposed worker class for the residual period evaluated in this report.

7.3.3 General Steel Occupational X-Ray Examinations

Dose from occupationally-required medical X-rays has also been considered and assumed to have occurred, although exposure data were unavailable. Since occupational X-ray examinations were commonly required during the time period covered by this evaluation, potential dose from such practices are taken into account for General Steel employees.

NIOSH considers it feasible to bound the medical dose for General Steel workers by using claimant-favorable assumptions as well as the applicable protocols in the complex-wide Technical Information Bulletin *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procures* (ORAUT-OTIB-0006).

7.3.4 Methods for Bounding External Dose at General Steel

By July 17, 2008, 238 EEOICPA claims meeting the class definition being evaluated in this report had been submitted to NIOSH. Of those 238 claims, NIOSH has completed dose reconstructions for 208 claims.

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

- Photon Dose
- Beta Dose
- Neutron Dose
- Medical X-ray Dose

7.3.4.1 Methods for Bounding Operational Period External Dose

Photon Dose

As previously indicated, NIOSH has obtained Landauer film badge reports from 1964 through 1973. The film badge data include weekly readings with a recording limit of 10 mrem. Through the week of June 27, 1966, which would cover the operational period, there were 6,999 individual readings. Of these readings, only 22 indicated 10 mrem or greater. Therefore, approximately 99.7% of the readings indicated exposure below 10 mrem. Also, no individual had more than one reading above the 10 mrem recording limit during this timeframe.

The values resulting in exposure of less than 10 mrem were recorded as “M” (monitored). Since 99.7% of the readings were below this value, the 95th percentile is clearly less than 10 mrem per week or 500 mrem per year for a 50-week work year. This technically accounts for the 22 readings that were greater than the recording limit, since those readings are included in the set and they are all above the 95th percentile. However, the readings can represent unusual occurrences, and with the limited number of recorded readings, an attempt was made to account more favorably for such occurrences. There were 89 individuals monitored for varying periods of time during this timeframe.

If 10 mrem is substituted for each "M" and added to any recorded values, a weekly average can be determined for each individual that accounts for the recorded values as well as those recorded as less than 10 mrem. This results in 89 individual weekly averages. This dataset has an average of 10.35 mrem with a standard deviation of 2.75 mrem for a resulting 95th percentile of 14.87 mrem. If a 50-week work year is assumed, this results in an annual exposure of 743.6 mrem. This is clearly bounding since it represents the 95th percentile of the data, in which 10 mr was substituted for the 99.7% of the values recorded as less than 10 mrem.

As discussed in Section 7.3.1, these data confirm that the Battelle-TBD-6000 Appendix BB method for assigning external dose can be considered bounding for all employees.

Beta Dose

The two sources of external beta dose at General Steel Industries are beta dose from the uranium X-rayed in the Betatron buildings and beta dose from activation of X-rayed steel castings. Beta dose can be reasonably bounded by using the dose methodology described in Battelle-TBD-6000 Appendix BB. This methodology assumes the operators received beta dose exposures from handling the uranium ingots both before and after X-ray operations. The beta dose estimate was bounded by overestimating the exposure time after X-ray operations to be 30 minutes. The operators were assumed to spend 15 minutes within one foot of the ingot and 15 minutes within one meter of the ingot (Battelle-TBD-6000 Appendix BB). The total exposure included radiation from uranium as well as the fission and activation products. The time period and exposure rates were sufficiently conservative enough to bound any beta dose from steel handling operations as well.

Neutron Dose

Neutrons can be produced while material is being X-rayed, as can delayed neutrons from fission products produced in uranium. Both effects have been modeled (SC&A, 2008) and always found to be less than the photon dose. Neutron dose was considerably smaller than photon doses but still contributed to the overall external exposures. A study is in place to determine the photon-to-neutron ratio.

Medical X-ray Dose

Dose from occupationally-required medical X-rays has also been considered and assumed to have occurred. NIOSH considers the adequate reconstruction of medical dose for General Steel employees to be feasible by using claimant-favorable assumptions as well as the applicable protocols in ORAUT-OTIB-0006.

7.3.4.2 Methods for Bounding Residual Period External Doses

External dose during the residual contamination period at General Steel Industries is limited to the radiation emitted from residual uranium contamination (OCAS-IG-003). In a survey conducted in 1989 of the General Steel Industries facility, the highest surface contamination level was determined to be 540 dpm/100 cm^2 (Battelle-TBD-6000 Appendix BB). Radiation level surveys indicated near-background levels throughout the facility. The only exception to the very low readings was on the surface of an industrial vacuum cleaner; where the reading was 90 µR/hour (Battelle-TBD-6000

Appendix BB). Rather than use the highest surface contamination level and apply an external dose conversion factor, external doses for the residual period were overestimated by assuming an external exposure rate of 90 µR/hour throughout the residual period. This methodology reasonably bounds potential external exposures during the residual period.

As discussed in Section 7.3.1, these data confirm that the Battelle-TBD-6000 Appendix BB method for assigning external dose can be considered bounding for all employees.

7.3.5 External Dose Reconstruction Feasibility Conclusion

This evaluation concludes that external dose reconstruction for personnel working during the operations period at the General Steel Industries site is feasible. By modeling external dose from radiographer film badge data, dose estimates are plausible and bounding. In addition, this evaluation supports the ability to bound residual period doses based on a maximum surface contamination and an associated pre-remediation survey exposure scenario. This scenario applies the highest potential surface contamination levels (those associated with the operations period). Based on its assessment of these doses, NIOSH concludes that the methods described in Battelle-TBD-6000 and Battelle-TBD-6000 Appendix BB provides reasonable approaches to conservatively bound external doses for all members of the class under evaluation.

7.4 Evaluation of Petition Basis for SEC-00105

ATTRIBUTION: Section 7.4 and all related subsections were completed by Louise Buker, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following subsections evaluate the assertions made on behalf of petition SEC-00105 for General Steel Industries.

7.4.1 Lack of Monitoring Data

SEC-00105: It was asserted that there was no personnel or area monitoring performed at the General Steel site.

Response: Personnel monitoring data from Landauer have been obtained by NIOSH for the years 1964 through 1973. NIOSH has compared is in the process of comparing the dosimetry data to the modeled estimates provided by both Battelle-TBD-6000 Appendix BB and the SC&A analysis. Based on a this preliminary assessment of the comparison, the dosimetry data support the finding that the dose reconstruction approach in Battelle-TBD-6000 presents a bounding approach for the workers at the General Steel Industries site, which includes the proposed worker class dose that is evaluated in this report.

7.4.2 Underestimated External Dose Modeling

SEC-00105: It was asserted that external dose modeling may have been underestimated if only one betatron was assumed to be in use.

Response: Although not extensively documented, the presence of a second betatron was accounted for in the preparation of Battelle-TBD-6000 Appendix BB. The presence of a second betatron likely would not change the modeled exposure because of the large distance between both betatrons and any one worker (i.e., a worker could only be in proximity to only one betatron at a time, from a significant external dose perspective). However, NIOSH has obtained film badge results for the betatron operators and has compared is in the process of comparing these data to the modeled doses. As discussed previously, this comparisonbased on a preliminary assessment of the comparison, indicates the dosimetry data support that the dose reconstruction approach in Battelle-TBD-6000 presents a bounding approach for the workers at the General Steel Industries site, which includes the proposed worker class dose that is evaluated in this report.

7.4.3 Residual Contamination Dose

SEC-00105: It was asserted that dose from residual contamination might not be included in dose estimates.

Response: Residual contamination was addressed in Battelle-TBD-6000 Appendix BB, and is assigned (as applicable to those individuals who may have worked during the residual radioactivity period at General Steel Industries) during dose reconstruction. The information, reviews, and evaluations in the preceding sections of this report support the ability to bound the residual radioactivity period dose for the SEC-00105 proposed worker class.

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

Other issues have been raised in the review of Battelle-TBD-6000 Appendix BB. These issues have either been addressed in the body of this report or relate to the magnitude of the reconstructed dose. As such, those do not represent SEC issues.

7.6 Summary of Feasibility Findings for Petition SEC-00105

This report evaluates the feasibility for completing dose reconstructions for employees at General Steel Industries from January 1953 through December 1992. NIOSH found that the available monitoring records, process descriptions, and source term data available are sufficient to complete dose reconstructions for the evaluated class of employees.

Table 7-1 summarizes the results of the feasibility findings at General Steel Industries for each exposure source during the time period January 1953 through December 1992.

Table 7-1: Summary of Feasibility Findings for SEC-00105

January 1, 1953 - June 30, 1966 and/or residual period from July 1, 1966 - December 31, 1992

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal	**X**	

Table 7-1: Summary of Feasibility Findings for SEC-00105 January 1, 1953 - June 30, 1966 and/or residual period from July 1, 1966 - December 31, 1992		
- U-238 and associated progeny	X	
- U-235 and associated progeny	X	
- Fission products	X	
- Activation products from steel	X	
External	**X**	
- Gamma	X	
- Beta	X	
- Neutron	X	
- Occupational Medical X-ray	X	

As of July 17, 2008, a total of 238 claims have been submitted to NIOSH for individuals who worked at General Steel Industries and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for 208 individuals (~87%).

8.0 Evaluation of Health Endangerment for Petition SEC-00105

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 has assessed Battelle-TBD-6000, Battelle-TBD-6000 Appendix BB, the most recently discovered personnel external monitoring data, monitoring data that are similar but bounding for operations from other sites, and modeling data associated with the evaluation of the source term at General Steel Industries. NIOSH has determined that it is feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy based on the sum of information available from available resources. Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is not required.

9.0 Class Conclusion for Petition SEC-00105

Based on its full research of the class under evaluation, NIOSH found no part of the subject class for which it cannot estimate radiation doses with sufficient accuracy. This class includes all individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through June 30, 1966, and/or during the residual period from July 1, 1966 through December 31, 1992.

NIOSH has carefully reviewed all material submitted 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 other sources, including the Site Research Database (SRDB), for information relevant to SEC-00105. 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.

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