SEC Petition Evaluation Report
Petition SEC-00210

Report Rev #: 0 Report Submittal Date: January 7, 2014

Subject Expert(s):	Pat McCloskey
Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Receipt Date	Qualification Date	DOE/AWE Facility Name
SEC-00210	83.13	March 12, 2013	July 1, 2013	Kansas City Plant

Petitioner-Requested Class Definition

All employees who worked at the Bannister Federal Complex from 1949 to present.

Class Evaluated by NIOSH

All employees who worked in any area of the Kansas City Plant site in Kansas City, Missouri, from January 1, 1949 through December 31, 1993.

NIOSH-Proposed Class to be Added to the SEC

None

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
SEC-00110	83.13	Kansas City Plant	Closed/Class not added

Related Evaluation Report Information

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

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Peer Review Completed By:	[Signature on File] *Pete Darnell*	1/7/2014 *Date*
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Evaluation Report Summary: SEC-00210, Kansas City Plant

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-00210 was received on March 12, 2013, and qualified on July 1, 2013. The petitioner requested that NIOSH consider the following class: *All employees who worked at the Bannister Federal Complex from 1949 to present.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH reduced the petitioner-requested class. NIOSH evaluated the following class: All employees who worked in any area of the Kansas City Plant site in Kansas City, Missouri, from January 1, 1949 through December 31, 1993.

NIOSH-Proposed Class to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has obtained monitoring records, process descriptions, and source term data for the evaluated class. 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 evaluated 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 evaluated class.

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SEC Petition Evaluation Report for SEC-00210

ATTRIBUTION AND ANNOTATION: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the ORAU Team Lead Technical Evaluator: Pat McCloskey, Oak Ridge Associated Universities (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 Kansas City Plant (KCP) site in Kansas City, Missouri, from January 1, 1949 through December 31, 1993. 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-00210, Kansas City Plant Class Definitions

The following subsections address the evolution of the class definition for SEC-00210, Kansas City Plant. 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-00210 was received on March 12, 2013, and qualified on July 1, 2013. The petitioner requested that NIOSH consider the following class: *All employees who worked at the Bannister Federal Complex from 1949 to present.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the KCP workers in question. NIOSH deemed the following information sufficient to qualify SEC-00210 for evaluation:

> Radiation exposures and doses potentially incurred by members of the proposed class were not monitored either through personal or area monitoring.

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[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.

Operations for which NIOSH has not found complete (i.e., limited internal) monitoring data include:

- Cesium-137 work starting in 1949 (NIOSH is uncertain of the end date)
- Uranium machining from 1951-1958
- Thorium machining from 1961-1979

Based on its KCP research and data capture efforts, NIOSH determined that it has access to monitoring records, process descriptions, and source term data for KCP workers during the time period under evaluation. However, NIOSH also determined that internal monitoring records are not complete for all time periods or for all radionuclides. 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 reduced the petitioner-requested class because the entire Banister Federal Complex is not a "covered facility" as defined by EEOICPA. Therefore for this evaluation effort, NIOSH can only consider the smaller Kansas City Plant located within the Bannister Federal Complex. In an attempt to determine the end date for the period qualifying for evaluation, NIOSH examined approximately 160 claims with employment in 1994 or later, coinciding with the Department of Energy (DOE) implementation of 10 C.F.R. pt. 835 radiological program requirements. The claims review indicated that many 10 C.F.R. pt. 835-era claims have no monitoring reported to NIOSH by DOE; however, this can be expected as not all KCP site employees may have reached the exposure-potential thresholds required for modern-era personnel monitoring. Of the 10 C.F.R. pt. 835-era claims with no exposure monitoring data, the NIOSH review did not find any post-1993 claims with apparent or potentially inadequately-monitored exposures. Therefore, NIOSH defined the following class for further evaluation: All employees who worked in any area of the Kansas City Plant site in Kansas City, Missouri, from January 1, 1949 through December 31, 1993.

3.3 NIOSH-Proposed Class to be Added to the SEC

NIOSH has obtained monitoring records, process descriptions, and source term data. 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

As is standard practice, NIOSH completed an extensive database and Internet search for information regarding the Kansas City Plant site. 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 KCP 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. The Site Profile for a small site may consist of a single document. As part of NIOSH's evaluation detailed herein, it examined the following site profiles for insights into Kansas City Plant or related topics/operations at other sites:

- *Site Profile for the Kansas City Plant*, ORAUT-TKBS-0031; Rev. 00 PC-1; January 6, 2006; SRDB Ref ID: 20217

- *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals*, Battelle-TBD-6000; Rev. 01; June 17, 2011; SRDB Ref ID: 101251

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

- *OTIB: Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, ORAUT-OTIB-0070; effective March 5, 2012; SRDB Ref ID: 108851

- *OTIB: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 04; effective June 20, 2011; SRDB Ref ID: 98147

- *OTIB: Estimation of Ingestion Intakes*, OCAS-TIB-009, Rev. 0; effective April 13, 2004; SRDB Ref ID: 22397

- *OTIB: Use of Coworker Dosimetry Data for External Dose Assignment*, OCAS-TIB-0020, Rev. 3; effective November 14, 2011; SRDB Ref ID: 104029

4.3 Facility Employees and Experts

To obtain additional information relevant to KCP operations, NIOSH interviewed 19 former KCP employees. NIOSH's specific objective was to gain an understanding of specific operations with radioactive materials conducted at KCP and to identify any radiological monitoring performed during KCP operations.

- Personal Communication, 2013a, *Personal Communication with KCP Health Physicist*; Interview by ORAU Team and NIOSH; August 27, 2013; SRDB Ref ID: 127865
- Personal Communication, 2013b, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127871
- Personal Communication, 2013c, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127869
- Personal Communication, 2013d, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127875
- Personal Communication, 2013e, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127868
- Personal Communication, 2013f, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127873
- Personal Communication, 2013g, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127863
- Personal Communication, 2013h, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127878
- Personal Communication, 2013i, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127872
- Personal Communication, 2013j, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127877
- Personal Communication, 2013k, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127876
- Personal Communication, 2013l, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127864
- Personal Communication, 2013m, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 127874

- Personal Communication, 2013n, *Personal Communication with KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 127866

- Personal Communication, 2013o, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 127870

- Personal Communication, 2013p, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 127867

- Personal Communication, 2013q, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 128746

- Personal Communication, 2013r, *Personal Communication with KCP Employee*; Interview by ORAU Team and NIOSH; October 16, 2013; SRDB Ref ID: 128743

- Personal Communication, 2013s, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 128748

- Personal Communication, 2013t, *Personal Communication with KCP Health Physicist*; e-mail correspondence by ORAU Team; September 4, 2013; SRDB Ref ID: 127657

- Personal Communication, 2013u, *Personal Communication with KCP Employees*; e-mail correspondence by ORAU Team; November 27, 2013; SRDB Ref ID: 129196

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. NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. Table 4-1 summarizes the results of this review. (NOCTS data available as of November 22, 2013)

Table 4-1: No. of Kansas City Plant Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	672
Total number of claims submitted for energy employees who worked during the period under evaluation (January 1, 1949 through December 31, 1993)	665
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).	608
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	35
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	103

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. The database contained 1,645 documents that were identified as pertaining to the KCP site. These documents were evaluated for their relevance to this petition. The documents include historical background on monitoring and program descriptions (e.g., air monitoring, urinalysis data, radiation and surface contamination surveys, radiological control program information, medical monitoring, process materials, and process descriptions).

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 for the Kansas City Plant*, also contains four affidavits; received March 12, 2013 and qualified July 1, 2013; DSA Ref ID: 118659

- *Employee Verification-Affidavit from Former KCP Employee*; March 5, 2013; DSA Ref ID: 118733

- *Report of Investigation of Pm-147 Contamination, February 10, 1989*; Allied-Signal Aerospace Company; Published September 1989; DSA Ref ID: 118938

- *Supporting Document: Pm-147 Exhibit*, select pages; DSA Ref ID: 118941-118986

- *Kansas City Plant: Nuclear Reactor Development and Testing and Atomic Bomb Manufacturing Capability*; received June 15, 2013; DSA Ref ID: 119031

- *Petition Response to May 10, 2013 Request*; June 16, 2013; DSA Ref ID: 119033

- *Attachment 10, Comparison of NIOSH, DOL and Site Investigator's Perspective Pm-147 Incident*, first draft; compiled by Cold War Soldiers; DSA Ref ID: 119034

- *Preliminary Support Document and Records Request and Inspection List*; received July 25, 2013; DSA Ref ID: 119153

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at the KCP site from January 1949 to December 1993 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 Kansas City Plant and Process Descriptions

KCP is located at the Bannister Federal Complex (BFC) within the city limits of Kansas City, Missouri. The BFC is located approximately 10 miles south of the city center (see Figure 5-1) at 2000 E. 95th Street, Kansas City, MO 64131. BFC is a compact, highly-developed site (consisting of approximately 300 acres) owned by the National Nuclear Security Administration (NNSA) and the General Services Administration (GSA) (see Figure 5-2). NNSA was established by Congress in 2000 as a separately organized agency within the United States DOE, responsible for the management and security of the nation's nuclear weapons, nuclear nonproliferation, and naval reactor programs.

KCP consists of about 122 acres and 38 buildings. For the period evaluated by NIOSH, the KCP workforce varied; however, it consisted of approximately 2,700 workers on average (DOE, May2013). The workforce peaked at 8,000 during the arms build-up in 1985. In addition, there is a transient population of construction contractor personnel (AlliedSignal, Mar1995, pdf p. 18).

The primary contractor that operated KCP starting in 1949 was Bendix Aviation Co. Bendix then merged with Allied Corporation in 1982, and in 1984, Allied Corporation merged with the Signal Companies to form Allied-Signal Aerospace, Inc. In 1999, Allied-Signal Aerospace merged with Honeywell International and formed Honeywell Federal Manufacturing and Technologies to operate KCP.

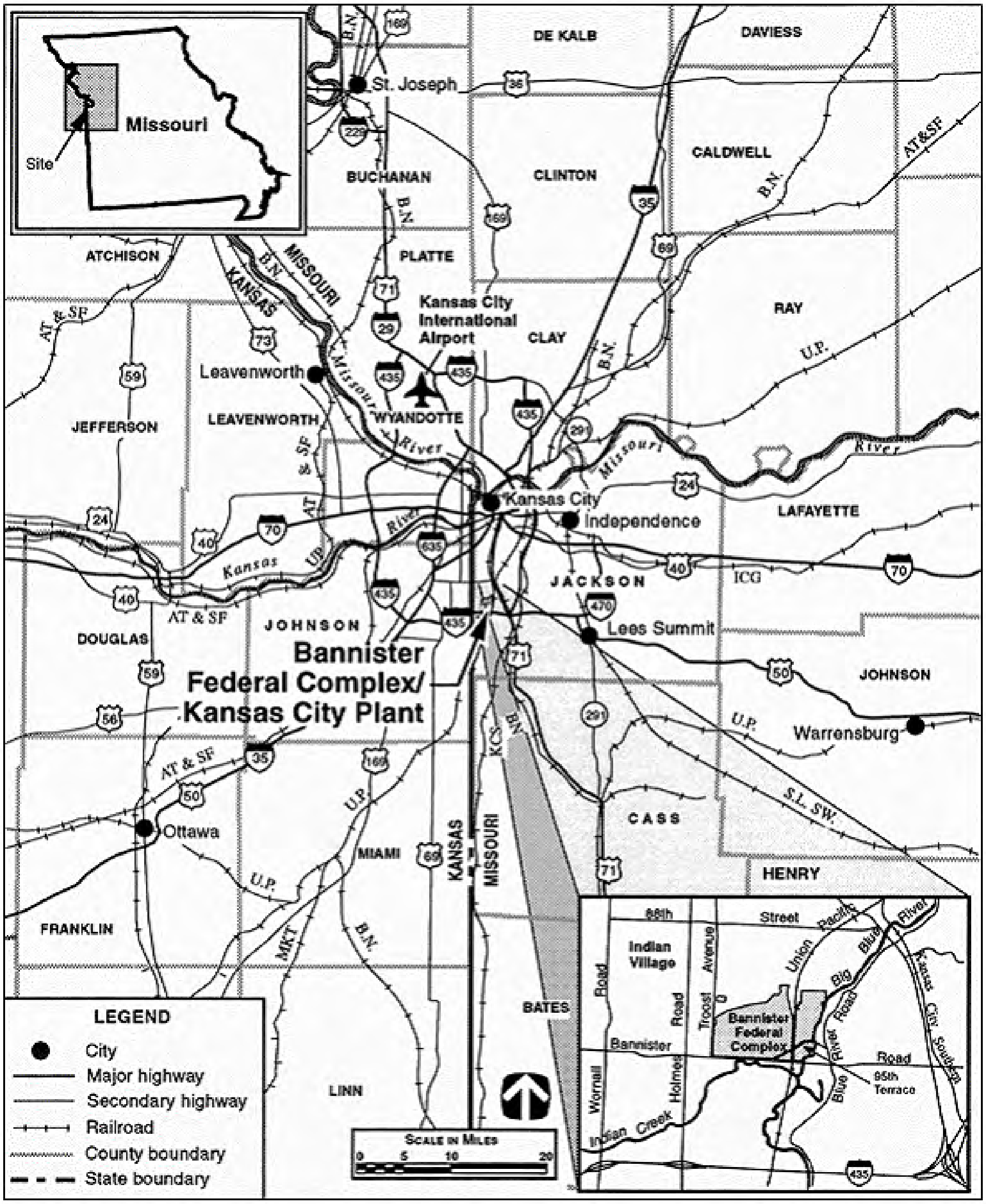


Figure 5-1: Map showing the location of KCP.
Source: DOE, May2013

Figure 5-2: NNSA/DOE and GSA properties at the BFC.
Source: DOE, May2013

5.1.1 Kansas City Plant Site Description

NNSA owns the portion of the BFC known as KCP, consisting of about 122 acres and 38 buildings. The 38 buildings NNSA owns comprise about 2.9 million square feet (see Table 5-1). About 90 percent of this area is industrial space, 2 percent is warehouse space, and 8 percent is office, cafeteria, and administrative space.

The most dominant structure on the BFC is the Main Manufacturing Building, which has about 2.7 million square feet of contiguous space and houses the primary KCP manufacturing operations. NNSA and GSA share this space. NNSA has control of approximately 1.75 million square feet of space in this building. In addition to the Main Manufacturing Building, NNSA owns about 1.2 million square feet of space in the remaining 37 buildings.

The KCP buildings vary in type of construction, ranging from steel and concrete to masonry. They were built at various times and with different design criteria. The Main Manufacturing Building structure uses load-bearing arches, each 40-foot wide, constructed with movable concrete forms. It represents one of the largest integrated projects in the war construction program, virtually under a single roof.

With the exception of the Main Manufacturing Building, the buildings are predominately one- and two-story brick and cast-stone industrial structures with flat roofs. KCP includes smaller structures that relate directly to the history and significance of the complex in support of production operations. Other buildings, while linked to the complex by their utilitarian nature, are prefabricated metal or reinforced concrete, with many being open-air shelters and guard posts (DOE, May2013).

GSA owns the remainder of the BFC, consisting of about 175 acres and 14 buildings. Major highways (Interstate Highway 435 [I-435] and I-49/U.S. Highway 71) and auxiliary and smaller secondary streets provide access. There are no residences or agricultural activities or farmlands on the BFC. There is a daycare facility located on GSA property. The adjoining properties to KCP and the BFC are mostly residential with isolated commercial tracts, except along the eastern and northern sides, which have been designated for public and recreational uses (DOE, May2013).

Table 5-1: Kansas City Plant Building Information

Building Name	Building No.	Year Built	Area (ft^2)	Construction Type
Main Manufacturing Building	1	1942	1,755,593	Reinforced concrete
Main Office Building	2	1942	240,717	Reinforced concrete
West Powerhouse	5	1943	60,760	Reinforced concrete
Manufacturing Support Building	13	1957	142,516	Steel framed with unreinforced masonry block
Four Experimental Test Cells	14	1943	40,077	Reinforced concrete
Polymer Building	15	1943	18,991	Reinforced concrete
Kinematics Building	16	1942	5,331	Steel framed
Unfinished Test Cells	46	1943	5,509	Reinforced concrete
East Powerhouse	48	1961	12,958	Steel framed
High Power Lab	54	1944	31,309	Steel framed
Waste Management	59	1952	24,120	Prefabricated metal
Solid Waste Disposal	73	1972	8,868	Prefabricated metal
Production and Chemical Storage	74	1973	27,294	Pre-engineered metal with unreinforced masonry
Supervisory Control	75	1973	2,294	Reinforced concrete
Oil Storage Building	77	1948	2,319	Steel framed with unreinforced masonry block
North Wing Laboratory	86	1943	28,624	Reinforced concrete frame
Forge and Casting	88	1943	35,960	Reinforced concrete building
Fire Protection Pump House	89	1991	1,904	Steel framed
Mold Heating and Cooling	90	1984	2,400	Reinforced masonry
Plating Building	91	1985	38,113	Steel framed
Technical Transfer Center (Building 92)	92	1985	258,229	Steel framed
Special Process Building	96	1987	13,585	Steel framed
Industrial Waste Pretreatment Facility	98	1988	21,988	Steel framed
Receiving Dock	01-B	1987	3,650	Masonry
Main (West) Switchgear	01-C	1942	2,400	Reinforced masonry
East Employee Entrance	9	1942	1,884	Masonry
Central Guard Post	32	1974	1,043	Steel framed
North Employee Entrance	47	1942	1,747	Masonry

Table 5-1: Kansas City Plant Building Information				
Building Name	**Building No.**	**Year Built**	**Area (ft^2)**	**Construction Type**
Storage Shed	68	1957	576	Steel framed
Explosive Storage Bunker	76	1953	150	Reinforced concrete
East Guard Post	78	1974	413	Steel framed
West Guard Post	79	1974	200	Steel framed
North Guard Post	80	1974	454	Steel framed
Test Cells	87	1943	132,596	Reinforced concrete
Northeast Guard Post	93	1985	191	Steel framed
Northwest Guard Post	94	1987	240	Steel framed
Receiving and Shipping Security Post	99	2004	305	Steel framed
Air Monitoring Building	31	1994	208	Steel framed
Total			**2,925,516**	

Source: This table is a slightly modified version of Table 1-1 in DOE, May2013.

5.1.2 Kansas City Plant Process Description

Note: Some information concerning the history of KCP nuclear weapons assembly activities involves classified information; therefore, a clear description of all activities is not publicly available. The primary KCP work activity involving radiation exposure was fabrication and quality-control testing of components of nuclear weapons (ORAUT-TKBS-0031).

Historically, the area occupied by KCP was primarily agricultural, except for a brief period during the 1920s when it was an automobile racetrack. In 1942, the Federal Government built the Main Manufacturing Building for the U. S. Navy, which Pratt and Whitney used to manufacture airplane engines during World War II in 1945.

After the war ended, from 1945 through 1949, the government used the KCP facility as both a storage facility for tires, raw rubber, sugar, and lumber and as a facility to house government operations. Under contract with the U.S. Navy, Westinghouse built jet engines in part of the facility from 1948 through 1961.

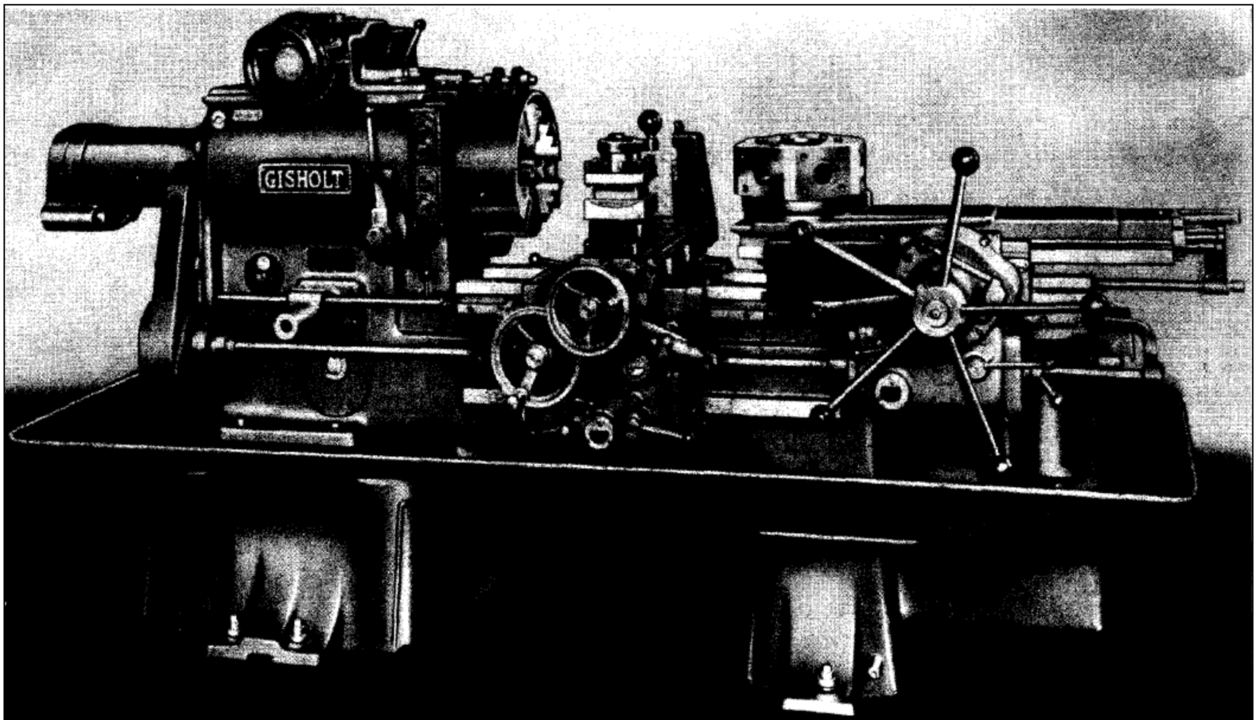
The Bendix Aviation Co. began producing electrical and mechanical weapon components for the U.S. Atomic Energy Commission in part of the Main Manufacturing Building in 1949 and expanded its use of the facilities after Westinghouse left. Since that time, the principal operation at KCP has been the manufacture of nonnuclear components of nuclear weapons, which involves metals and plastics machining, plastic fabrication, plating, microelectronics, and electrical and mechanical assembly (DOE, May2013).

Cesium-137 Work

NIOSH reviewed one trip report covering a visit to Bendix Aviation Co. on May 25, 1949, indicating that "gap tubes" containing Cs-137 were produced by Bendix (Trip Report, 1949). At the time of petition SEC-00210 qualification, NIOSH was unable to determine if KCP was the location of Bendix gap tube production. Since SEC-00210 qualified, through further research as corroborated by interviews of former workers, NIOSH has determined that gap tube manufacturing did not occur at KCP (Personal Communication, 2013c, 2013d, 2013g, 2013h, 2013l, 2013n, 2013p). NIOSH has determined that the Bendix Aviation Co. discussed in the trip report was most likely the Eclipse-Pioneer Division of Bendix Aviation Co. in Teterboro, New Jersey (the Bendix Division where a manager referenced in the report worked as the Safety Director) (Cone, 1950). A document listing the radioactive materials in the KCP plant (KCP, 1950-1963) states that the gap tubes in question (M-26-3) were only handled as an assembled item for a short time and in a controlled manner. A document detailing experience with radioactive sources prior to 1954 (Schiltz, Aug1962) indicates that gap tubes received from the vendor were already assembled. NIOSH has found no evidence that gap tubes were manufactured at KCP; however, there are reports that Bendix Aviation Co. did manufacture gap tubes in New Jersey (Schiltz, Jun1962; Grant, 1962).

Natural Uranium Operations

NIOSH has information that KCP workers inspected and assembled uranium components, machined uranium slugs, and handled uranium billets and ingots at KCP in the early 1950s. Starting in May 1950 and continuing to February 1955, uranium components were inspected and assembled in Department 3A (KCP, 1950-1963). In February 1951, KCP set up a machine shop to produce 1,000 slugs per day to fuel AEC production reactors at the Savannah River Site in South Carolina, and Argonne National Laboratory near Chicago, Illinois. KCP received some of the 10-foot long uranium rod stock for this work from the Lackawanna Test Site in New York. Forty-five thousand (45,000) slugs were produced for the initial order. Ongoing work to produce 5-tons per month was also scheduled. The work was performed in the Main Manufacturing Building in Department 49X, also known as Area X. This area was specifically prepared for this work: a smooth finished concrete floor was laid and painted, steel panel walls were erected, an adjacent storeroom was prepared, and the entire area was cleaned and painted. The equipment used to make slugs in this area included: an 8" Springfield bench lathe; a Fay Automatic lathe; a Schauer air collet machine; a power cut-off saw; and four Gisholt turret lathes (see Figure 5-3). Work was performed during two shifts utilizing machine operators (14), inspectors (3), an accountability officer, and a packaging man (Mahaffey, 1952; Paine, 1951).



No. 4 Gisholt Ram Type Turret Lathe
(Courtesy Gisholt Machine Company, Madison, Wisconsin

Figure 5-3: Image of a Gisholt Turret Lathe
Source: Mahaffey, 1952

The 1.062-inch diameter uranium rods were shipped to KCP already straightened. There, using a power hacksaw, the bar ends were sawed off. The bars were placed in the Gisholt turret lathes and turned to 1-inch diameter and cut in 8.120-inch lengths. These rough slugs were then fed into the Fay Automatic lathe where they were turned to the finished diameter of 0.997-inches and the 30-degree cone chamfer was cut. The final operation was to generate the 0.050-inch to 0.070-inch radius using the Schauer air collet machine and a mill file. If any re-work was necessary, it was performed on the 8-inch Springfield bench lathe (Mahaffey, 1952).

Machining uranium rods into slugs continued in 1952. KCP received unstraightened rods that were rolled at Bethlehem Steel and then KCP sent the slugs they made from those rods to Argonne National Laboratory and the Savannah River Site (Paine, 1951; Laing, 1952). These uranium slug machining operations came to an end at KCP in December 1952.

Also in 1952, KCP machined and handled natural uranium in the form of billets and ingots destined for AEC facilities at the Lake Ontario Ordinance Works in Youngstown, New York; Allegheny Ludlum in Watervliet, New York; and the Fernald site in Harrison, Ohio (Malone, Feb1952; Malone, Mar1952; Hobert, 1953; Harshman, 1952).

Magnesium Thorium Alloy Machining

NIOSH has information indicating that beginning May 1, 1957 (KCP, 1950-1963) and continuing into 1979, as part of the RADEC weapons program, KCP machined and fabricated classified items with a magnesium thorium alloy (Mg-Th) in the Main Manufacturing Building.

The Mg-Th that KCP used was the alloy known as HK-31, supplied by the Dow Chemical Company with a nominal 3% thorium content (Mg-Th, 1957-1970 pdf pp. 7, 22).

The areas where KCP performed operations with Mg-Th were in the Model Shop (also known as Department 851, later renamed Department 823) and in Department 20. The equipment that was used included a Van Norman mill, a CSIP Hydroptic 6A vertical-jig boring-machine, a Kearney & Trecker Milwaukee die mill, a Tape lathe, and a Heli-arc welder (Mg-Th, 1962-1975).

Depleted Uranium (DU) Operations

The first report of DU handling at KCP was in April 1958; however, DU machining began on September 9, 1958 (KCP, 1950-1963, pdf p. 12). KCP used the Machining Area (formerly known as Department 20) for the machining and inspection of DU products. KCP's use of DU oxide is described as follows:

*(Depleted) Uranium powder was mixed with an encapsulant and placed on another part and allowed to dry. Once dry the part was machined. This activity was limited to the Department 20 (D/20) area and was never placed into production (*DOE, Mar2013).

The Machining Area, covering about 12,000 ft^2 in the Main Manufacturing Building, was "cleaned and decommissioned" in the early 1970s after completion of DU production operations (Rockwell, 1987, pdf p. 106). However, there remained measurable levels of fixed radioactivity in sumps, floor drains, piping, floor expansion joints, and other surface areas. DOE remediated this area in phases and completed the final decontamination so that it met industrial standards by September 3, 1986 (ORAUT-TKBS-0031).

NIOSH has reviewed sample results taken during D&D activities in the area where KCP machined both Mg-Th and DU. The sample analysis was gamma spectroscopy for uranium isotopic composition and for specific activity. Gamma-ray intensities at energies of 93 keV attributable to Th-234, and 185 keV attributable to U-235 were evaluated to characterize the uranium enrichment of the material. The sample analysis showed that the Th-234/U-235 gamma ratio was typical of DU (Rockwell, 1987, pdf p. 50).

The primary workplace exposure over the entire history of KCP was associated with machining items containing DU oxide from 1958 to about 1971; the program that used DU oxide ended in 1972 (ORAUT- TKBS-0031). No uranium was processed again until 1997 when a new program was initiated.

KCP also used commercially available products that contained DU as shielding for a radiography unit (DOE, May2013).

Thorium Oxide Powder Operations

NIOSH has located a KCP reference that was included as part of a chronological list of radioactive material at KCP, and the reference reads, "July 23, 1958 to July 1959 – Thorium oxide ThO_2 powder was handled in the plant" (KCP, 1950-1963, pdf p. 12). Inventories of radiological sources were also found and the inventories show that KCP used some ThO_2 sources and that KCP made a thorium nitrate solution at a rate of 20 grams per year (Rad Inventory, 1989). With the information that NIOSH currently has available, including personal communication with KCP site experts (Personal Communication, 2013u), it appears that KCP ThO_2 operations were limited to laboratory analysis and solution preparations used in analytical procedures.

In 1963, the GSA acquired ownership of the Bannister Federal Complex from the U.S. Navy. Excluded from this property acquisition were 8 buildings which were transferred directly to the Atomic Energy Commission (AEC).

In 1976, the GSA transferred ownership of the remaining parcel, known as the Kansas City Plant, to the AEC.

In 1983 a cleanup of the Bannister Federal Complex began with an assessment of previous use of the site and remediation. From 1984 through 1987, the DOE Albuquerque Operations Office initiated the Comprehensive Environmental Assessment and Response Program to identify, evaluate, and conduct remedial actions at sites including the Kansas City Plant.

In the spring of 1984, KCP contracted with Rockwell International Corporation to perform major facility Decontamination and Decommissioning (D&D) of the Main Manufacturing Building (Rockwell, 1985). This D&D work was performed in three phases. Phase I began May 29, 1984, and was a site survey conducted to locate buried waste trenches and to measure radiological activity both in the trenches and in the Machining Area. Phase II began August 7, 1984, and involved the decontamination of the trenches and Machining Area and was completed on November 7, 1984. Radioactive materials (finely divided, DU oxide powder and DU metallic solid forms) were expected to be present in the trenches (Rockwell, 1985, pdf p. 36). However, radiological contamination was not observed at the trenches and radioactive or hazardous waste was not found in the surrounding soil (Rockwell, 1985, pdf p. 13). Some additional work was necessary because of a leaky sump that required removal of a pipe and some soil, which delayed Phase III. Phase III began August 15, 1986, and was completed September 3, 1986, and involved decontamination of the Inspection Area portion of the Machining Area (Rockwell, 1987). During all three phases, Rockwell noted in their final reports that the decontamination requirements imposed by KCP management were below NRC and American National Standards Institute requirements for release of an area for unrestricted use (Rockwell, 1985).

At the request of KCP, an estimate of the total amount of uranium removed from the KCP site was made by the Rockwell Manager of Radiation and Nuclear Safety. The amount was determined to be approximately 16.62 kg. This estimate was based on the mass of the contaminated concrete and its average activity. "As only concrete surfaces were measured, this value should be considered to be a high estimate".(Rockwell, 1985, pdf p. 54).

In 1989, DOE and the Environmental Protection Agency (EPA) entered into a Corrective Action Administrative Order of Consent (VII-89-H-0026) under the authority of Section 3008(h) of the Resource Conservation and Recovery Act (RCRA). The Consent Order requires the evaluation of releases of hazardous wastes and their constituents and remedial measures (corrective actions) to be implemented to protect human health and the environment at the DOE Kansas City Plant. The Consent Order initially listed 35 solid waste management units (SWMUs), which were defined as possible release sites. Eight more were added after the Consent Order for a total of 43. From 1989 through present, sampling and analysis of soil, groundwater, and air quality continue to ensure the effectiveness of remediation activities.

In 1993, DOE officially designated KCP as the consolidated site for all non-nuclear components for nuclear weapons. KCP currently manufactures or procures a wide array of sophisticated non-nuclear mechanical, electronic, and engineered material components for national defense systems. These components comprise about 85 percent of the components of a nuclear weapon (DOE, May2013; Maroncelli, 2002).

5.2 Radiological Exposure Sources from Kansas City Plant Operations

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

5.2.1 Internal Radiological Exposure Sources from Kansas City Plant Operations

The primary potential source of internally deposited radioactivity resulting from KCP operations was inhalation and ingestion of uranium and thorium. This section addresses alpha-emitting radionuclide exposures at KCP.

5.2.1.1 Natural Uranium

In the early 1950s, as described in Section 5.1.2 of this report, KCP personnel worked with natural uranium metal during slug and billet handling and during machining operations. KCP machined a total of 313,070 pounds of uranium metal into slugs and had the capacity to produce 1,000 slugs per day. KCP's slug machining was undertaken as a short-term (22 month) project to demonstrate KCP's ability to improve slug-finish quality with turret lathes (O'Leary, 1951).

Natural uranium refers to uranium consisting of approximately 99.3% U-238, 0.7% U-235, 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. Uranium-235 emits alpha particles with energies of 4.40 MeV and 4.37 MeV.

5.2.1.2 Depleted Uranium

KCP had substantial quantities of DU oxide at the site from April 1958 to about 1971 until the program that used DU oxide ended in 1972. They machined items coated with a film of DU oxide in Department 20 (DOE, Mar2013, pdf p. 6) beginning September 9, 1958 (KCP, 1950-1963, pdf p. 12).

The final decontamination of Department 20 (where this work was performed) was completed on September 3, 1986 (ORAUT-TKBS-0031).

Order number ICO-020757 (Purchase Order, 1962) shows that KCP procured 10,000 pounds of UO_2. Specification Control No. 4542260-00 (Ulitchny, 1998) dictated the minimum density should be no less than 10.8 g/cm^3, the surface area of the powder should be no greater than 1.1 m^2/g, at least 97% by weight of the material should be less than 10 µm in diameter, and 100% by weight should be less than 15 µm in diameter. These specifications are consistent with a powder having an activity median aerodynamic diameter (AMAD) of 1.175 µm and a geometric standard deviation (GSD) of 2.48 (ORAUT-TKBS-0031).

In 1997, a new program was initiated where DU metal was reduced in size and shape by an electrochemical process that involves the placement of DU metal in an acid bath. The parts are rinsed with water and dried before handling. Because the uranium does not become volatile during the electrochemical process, remaining in the acid solution, there is minimal personnel internal dose hazard with this process. There is also no removable contamination with this process (ORAUT-TKBS-0031).

5.2.1.3 Thorium

KCP performed Mg-Th operations in two areas of the Main Manufacturing Building (the Model Shop and Department 20) from May 1, 1957 to April 5, 1979 (Mg-Th, 1962-1975; Monitoring, 1963-1967; Rad Handling, 1987). Information presently available to NIOSH, including personal interviews and project plans, indicates that KCP Mg-Th operations were not a large-scale project and were undertaken on a “temporary basis” (Mg-Th, 1962-1975). As stated in one report, “The KCP has always been involved in special “piece-work,” that is, numerous, small, isolated projects relying on high-quality machining” (DOE, Mar2013, pdf p. 9).

5.2.1.4 Thoron

As indicated above, KCP performed limited thorium work. NIOSH has not identified monitoring data for the thorium daughter-product thoron during the evaluated period. However, NIOSH has identified gross alpha air monitoring data with results for both short and long lived activity that can be used to estimate thoron air concentrations.

5.2.2 External Radiological Exposure Sources from Kansas City Plant Operations

The primary sources of workplace radiation fields at KCP are historically associated with processes involving industrial radiation-generating devices (e.g., X-ray machines and electron accelerators) (see Table 5-2); isotopic beta, gamma-ray, and neutron radiation-emitting sources (see Table 5-3). Table 5-3 includes source inventory lists from 1964 and 1987 to illustrate the change over time. Significant changes from 1964 to 1987 are from extensive earlier use of radium sources and the presence of the 230-Ci Cs-137 instrument calibration source in 1987. The isotopic sources were typically used in the manufacturing or quality control processes to monitor fabrication of non-nuclear weapons components.

Table 5-2: Typical Radiation-Generating Devices				
Devices	**Energy (keV)**	**Types**	**Typical Use**	**Period of Use**
Industrial X-ray units	50 to 2,000 (X-ray)	Rooms & Cabinets	Radiography of parts	1950s to 2004
DXT Device[a]	12 to 200 (X ray)	Cabinets	Density thickness	1960s to 1980s
DXT Device	Cs-137 (1 Ci)	Cabinets	Density thickness	1960s to 1980s
Electron Beam Welders	35 to 150 (X-ray)	Cabinets	Welding small parts	1960s to 2004
Electron Microscopes	30 to 200 (X-ray)	Cabinets	Analysis	1960s to 2004
Electron Beam Vacuum Deposition Systems	10 (X-ray)	Cabinets	Plating metals	1960s to 2004
Neutron generators	14.7 MeV (neutron)	Open & Cabinets	Generate microsec pulsed radiation	1960s to 2004
Neutron source	Pu-239/Be (73 mCi)	Cabinets	Boron-10 analysis	1966 to 2004
Gamma camera	Co-60 (19 Ci)	Exposure Room	Test electronic products	1950s to 1960s
Febetron Accelerator	2,300 (X-ray) pulser	Cabinets	Irradiation of electronic components	1970s to 1980s
Cesium Irradiators	Cs-137 (230 Ci)	Exposure Room	Calibration of radiation detection instruments	1950s to 1980s
Medical X-ray	125 (X-ray)	Exposure Room	Patient diagnostic tests	1960s to 1990s
Electro Curtain	175 (X-ray)	Cabinet	Radiation curing of adhesives	1980s to 1990s

Source: This table is a slightly modified version of Table 4 in ORAUT-TKBS-0031.

Table 5-3: Types of Radiation Sources at Kansas City Plant					
		Source Inventory Lists		**Predominant Radiation**	
Nuclide	**Use**	**1964**	**1987**	**Type**	**Major Energies, keV**
C-14	Calibration source, beta scope, thickness gauges	X	X	Beta	45-156
Fe-55	Testing		X	Gamma	bremsstrahlung to 230
Co-60	Calibration sources	X		Gamma	1,170, 1,330
Ni-63	Gas chromatograph		X	Beta	67
Sr-90	Calibration, thickness gauges		X	Beta	546
Tc-99	Calibrations		X	Beta	292
Tl-204	Beta scope, thickness gauges		X	Beta	766
Cd-109	Plating thickness gauge		X	Gamma	88
Ba-133	Neutron generator		X	Gamma	30-382
Cs-137	Calibration sources	X	X	Beta	514-1,176
				Gamma	662
Pm-147	Calibration sources, thickness gauges		X	Beta	70-256
Tl-204	Beta scope, thickness gauges		X	Beta	766
Radium	Calibration sources, thickness gauges	X	X	Alpha	4,600-4,780
				Gamma	186-610
Uranium	Calibration sources			Alpha/gamma progeny radiations from Th-230, Ra-226, etc.	
Pu-239	Calibration sources, boron analysis	X	X	Alpha	5, 110-5, 160
				Gamma	39-770

Source: This table is a slightly modified version of Table 3 in ORAUT-TKBS-0031.

Based on information available to NIOSH, KCP had the potential for external radiation (photon/beta) exposure from uranium and thorium source material, their decay products, and small amounts of surface contamination present after operations ceased.

The following subsections provide an overview of the external exposure sources at KCP.

5.2.2.1 Photon

The uranium at KCP was derived from naturally-occurring metals, and thus exhibited a natural isotopic abundance except for the DU.

Uranium emits both beta particles (electrons) and photons (gamma and X-rays). The two primordial components of natural uranium are U-238 and U-235, but some of their decay products grow into equilibrium fast enough to contribute to worker exposures during metal processing. 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 follow the parent and will not be considered separately in this document.

Uranium-235 emits alpha particles and gamma photons in about 70% of its transitions, but occurs at 0.720% abundance in natural uranium.

The majority of the photons from natural uranium metals are in the 30-250 keV energy range (Battelle-TBD-6000). However, solid uranium objects provide considerable shielding of the lower-energy photons and "harden" the spectrum, causing the majority of photons emitted from a solid uranium object (e.g., a slug or rod) to have energies greater than 250 keV. While it is recognized that solid uranium sources will have a hardened photon spectrum, exposure to a thin layer of uranium on a surface will result in a larger fraction of exposure to lower-energy photons (Battelle-TBD-6000).

The beta and photon emissions of the radionuclides of major external exposure concern can be found in most standard health physics reference documents. Exposure to these emissions was possible for the period under evaluation during metal-handling and from submersion in contaminated air. Therefore, for the purposes of this evaluation, deep-dose estimates from the uranium sources at KCP are evenly distributed between photons with E=30-250 keV and photons with E= >250 keV.

Thorium has a significant number of higher-energy photons in the Th-232 decay chain. Based on the half-lives of the progeny, only a partial equilibrium is possible; therefore, it is conservative to state that equilibrium would be reached in this decay chain. It has been assumed that Ra-228 and Th-228 progeny were in equilibrium with Th-232. Under this assumption, the progeny are the major source of both penetrating and non-penetrating external exposure.

5.2.2.2 Beta

Beta particle radiation was the dominant source of external radiation exposure associated with uranium-machining activities at KCP, primarily from U-238 decay products. For example, nearly the entire beta radiation field from DU comes from the daughter radionuclide Pa-234m, and to a lesser extent from Th-234. The surface beta dose-rate from a uranium slab is approximately 233 mrad per hour.

Beta doses to the skin, extremities, and (sometimes) the lens of the eye can be limiting in facilities that process uranium. Potentially significant skin exposure from uranium occurs primarily from the Pa-234m beta particles at tissue depths of 4 mg/cm^2 and greater. At 2.29-MeV (E_{max}), beta particles from Pa-234m are the most energetic contributors to the beta exposure.

There are a significant number of high-energy betas representing a shallow dose concern for KCP workers. Workers who handled the uranium metal at KCP would have received these shallow doses. The primary exposure areas would have been the hands and forearms, the neck and face, and other areas of the body that were not covered.

5.2.2.3 Neutron

Sources of neutron radiation at KCP involved Karman Model A-800 pulsed-neutron generators and nuclide (alpha, neutron) interactions, such as ^{239}PuBe sources, as listed in Table 5-3. Based on a review of workplace hazards, the first presence of neutron-emitting nuclides apparently occurred after 1965 (ORAUT-TKBS-0031).

5.2.3 Incidents

Promethium-147 Incident, February 10, 1989

Pm-147 is a relatively low-energy, 100% beta-emitting nuclide (e.g., maximum energy of 224.7 keV, average energy of 62 keV) with a half-life of 2.6 years. The primary concern with this type of nuclide would be direct skin contamination and intake.

Pm-147 sources were used to measure film thickness at KCP. Failure of the integrity of one of these sources resulted in some minor skin contamination and was the subject of an official investigation; however, there were no personal internal exposures. On Friday, February 10, 1989, loose radioactive contamination was discovered on top of an X-ray fluorescent unit in Department 456, Non-Destructive Test (NDT) Laboratory. This discovery was made during a routine radiological survey of an X-ray fluorescent unit by two industrial hygiene personnel.

Subsequent investigation identified loose radioactive contamination on a nearby laboratory stool and on the hand of a member of the survey team. Further checks revealed contamination in the following areas: the NDT Laboratory; the D/456 office area directly above the NDT Laboratory; the stairway connecting the NDT Laboratory area and the D/456 office area; D/33, Precision Pattern Assembly Area (Room E) containing beta backscatter equipment; and one employee's residence.

Decontamination activities conducted by the DOE-Albuquerque Complex and Rockwell International health physics teams revealed that loose radioactive contamination in the previously mentioned areas was extensive and widespread. Rockwell International, by using gamma spectral analysis, positively identified samples of KCP contamination as Pm-147. This contamination was caused by fragile and unsealed Pm-147 sources, fabricated by Oak Ridge National Laboratory, which had been treated as sealed by KCP. Inadequate monitoring and control failed to reveal that these Pm-l47 sources were unsealed prior to this investigation.

According to an extensive investigation report, DOE, EPA, and Missouri Department of Health, Radiological Health Division representatives were notified at the time of this incident. A DOE team of investigators arrived at KCP on February 14, 1989, to assume technical management of the situation. The analytical laboratory that evaluated 97 urine samples from KCP personnel had initially reported 4 of those samples as having activity. A few days later the laboratory determined that they had made an error and there was actually no activity present in any of the samples (AlliedSignal, 1989). The homes of [redacted] KCP workers were inspected and some contamination was found in one home. That home was decontaminated, the cause and extent of the contamination was determined, and corrective actions were put in place to prevent reoccurrences.

Erbium Tritide Incident, September 30, 1987

On August 12, 1987, a W80 Data Analyzer that contained erbium tritide was received from Sandia National Laboratory. On September 30, 1987, a KCP worker removed the analyzer's protective cover. The analyzers were known to be exposed to tritium during operational testing at Sandia; however, they were normally decontaminated prior to returning them to KCP for follow-up testing. The outside cover had a visibly clean appearance, but when the worker removed the cover it was apparent that the interior was not cleaned as was required. The cover was immediately replaced and the Health and Safety group was contacted. The next day, swipe samples were taken inside and outside of the cover of the assembly and taken from nearby work surfaces. Contamination was only detected on the inside of the cover at 986 dpm/100 cm^2. The W80 Data Analyzer was returned to Sandia National Laboratory for decontamination. Urinalysis was performed for the worker who opened and closed the case and the results indicated that there was no detectable activity for tritium as erbium tritide (solubility class M from *International Commission on Radiological Protection (ICRP) Publication 71*). As a result of this incident, procedures were upgraded at Sandia National Laboratory and KCP to ensure that similar incidents would not occur in the future (Tritium Incident, 1987). KCP Health Physics personnel were asked about this incident in August 2013, and they informed NIOSH that this incident was unique and did not reoccur (Personal Communication, 2013t).

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

KCP has developed and maintained a radiological records database that contains records for all monitored worker exposures at KCP for all years of record. The database contains internal and external exposure data for approximately 4,400 workers. KCP has provided NIOSH a summary of internal and external dosimetry results from 1950 to 2003. It provides the number of individuals' monitored, annual mean and maximum external exposure, shallow external dose, as well as bioassay results for uranium. Individual results are obtainable if employee numbers are known (Monitoring, 1950-2003). NIOSH has not discovered any information indicating that radiological work was performed at KCP before the first personal monitoring (external) began in 1950.

The following subsections provide an overview of the state of the available internal and external monitoring data for the KCP class under evaluation. Details regarding the various analyses used and the associated minimum detectable activities are presented in ORAUT-TKBS-0031.

6.1 Available Kansas City Plant Internal Monitoring Data

Discussed below are the surface contamination data, air monitoring data, and bioassay data currently available to NIOSH.

Surface Contamination Data

NIOSH has results from routine quarterly contamination surveys performed in the main processing areas of the Main Manufacturing Building. Table 6-1 summarizes these alpha contamination results from 1962 to 1969 in work areas considered to be most significant for potential worker exposure (KCP, 2004). Table 6-1 is formed from more than 84 routine surveys, each containing multiple data points. Additionally, NIOSH has recently obtained copies of more than 150 alpha contamination surveys for 1959 through 1969 (Monitoring, 1960; Monitoring, 1959-1960; Monitoring, 1965-1969) and 20 quarterly contamination surveys for 1990 through 1994 (Monitoring, 1990-1996).

Table 6-1: Alpha Contamination Levels in DU Work Areas for 1962 to 1969

Facility	Work Area	Measured Levels (dpm/100 cm^2)	
		Average	Maximum
D/34C (D/27C)	Air lock	226	20,000
	Locker room	570	7,000
	General area	2,564	45,000
D/220-22 (D/443-20D D/216-22, D/217-20D)	Air lock	190	800
	Wash-up	180	650
	General area	425	1,000
D/22, D/20D	Air lock	206	350
	Clean area	468	2,000
	General area	892	16,000

Source: This table is a slightly modified version of Table 10 from ORAUT-TKBS-0031.

Air Monitoring Data

NIOSH has found a Safety Survey report showing that the air was sampled by a representative of the AEC's Santa Fe Operations Office during the natural uranium machining operations in August 1952 (Safety Survey, 1952, pdf p. 8). The report from this safety survey states:

> *Atmospheric dust analysis and general observation within the Machining of Uranium Metal Area indicated that personnel are being properly safeguarded. The dust count in the lathe area during cutting operations was well below any limit wherein the toxicity might be considered. Some smoke and oxides were noticed, but the hood ventilation appeared to be adequate. Assembly Area dust samples were negative and the neatness of the area was impressive.*

From 1958 to 1971, KCP workplaces were routinely monitored with air sampling for DU concentrations using gross alpha counting. Air samplers running at rates of 1 or 2 cfm were placed around the machining/processing areas of the Main Manufacturing Building. It is evident that KCP attempted to place these air samplers in locations where the sampled air would be representative of the air breathed by the workers. For example, there are annotations on air sample logs that state air samples were taken in areas such as "in the breathing zone" or "5-feet above floor level, in working area." Air samples were also annotated when higher-risk work was performed, such as containment window replacement (Monitoring, 1958-1961, pdf p. 85). KCP used fixed-filter air samplers that operated continuously during operations; however, there are indications that these samplers were turned off at night and weekends when there was no work being performed (ORAUT-TKBS-0031; Monitoring, 1963-1967; Monitoring, 1958-1970; Monitoring, 1970-1971; Monitoring, 1962-1969; Monitoring, 1958-1961; Monitoring, 1969-1970). Following July 26, 1971, there are no workplace air sampling data available for analysis; however, intakes of DU are not likely after this time because of a process change from machining to the acid-etch procedure described in Section 5.2.1.2 of this report.

Table 6-2 lists the maximum measured workplace airborne concentrations used to calculate the median and 95th percentile statistical parameters. The parameters in Table 6-2 were based on maximum measured air concentrations at several locations in the plant. Some measurement locations were identified only by a number. When locations were indicated, most were near the walls of the work areas. Other locations were labeled as: Mixing Rm, West, Air Lock, Over Shower, Rubber Mill Rm, Mill Stack West, and Dispersion Roll.

Table 6-2: Statistical Parameters of Measured DU in KCP Workplace Air[(a),(b)] for 1958-1970

KCP Measured Results[(a)]				Lognormal Fit		
				Air Concentration		
Year	No. of Measurements	Mean (μCi/cm^3)	Maximum (μCi/cm^3)	Median (μCi/cm^3)	95% (μCi/cm^3)	GSD
1958	22	7.18E-12	4.90E-11	4.01E-13	1.74E-10	4.02E+01
1959	27	8.82E-13	1.22E-11	2.89E-13	2.53E-12	3.74E+00
1960	33	1.32E-12	1.50E-11	3.41E-13	3.94E-12	4.43E+00
1961	31	1.00E-12	2.04E-11	1.97E-13	1.52E-12	3.46E+00
1962	31	7.73E-13	1.13E-11	2.50E-13	2.03E-12	3.58E+00
1963	31	1.25E-12	1.63E-11	2.47E-13	1.90E-12	3.46E+00
1964	31	2.21E-12	3.90E-11	3.91E-13	2.98E-12	3.44E+00
1965	31	1.99E-13	8.70E-13	1.05E-13	8.02E-13	3.45E+00
1966	23	7.01E-13	6.24E-12	2.00E-13	2.00E-12	4.06E+00
1967	22	1.40E-12	1.30E-11	5.70E-13	3.12E-12	2.81E+00
1968	19	1.21E-12	9.88E-12	2.31E-13	3.47E-12	5.19E+00
1969	19	1.88E-11	8.55E-11	3.88E-12	1.42E-10	8.92E+00
1970	19	7.32E-14	5.91E-13	4.02E-14	1.98E-13	2.64E+00
Average	**1958-1970**	**2.85E-12**	**2.15E-11**	**5.49E-13**	**2.62E-11**	

Source: This table is a slightly modified version of Table 11 from ORAUT-TKBS-0031.
(a) All departments.
(b) Based on maximum measured KCP workplace airborne uranium concentrations at several monitoring locations.

In 1970, KCP conducted a study of Mg-Th machining operations in the Model Shop and maintained airborne levels during this test at background (0 cpm recorded) for long-lived activity, and <3.22E-9 µCi/ml for short-lived activity. As part of this test, each machining operation was performed with breathing-zone air samplers running (Mg-Th, 1962-1975, pdf p. 16).

Bioassay Data

Urine assays were found for August 11, 1959 to December 10, 1971 (Monitoring, 1950-2003; Monitoring, 1963-1970; Monitoring, 1964-1967; Monitoring, 1969-1971a; Monitoring, 1959-1971; Monitoring, 1969-1971b). KCP workers were individually monitored for DU intake from 1959 to 1971 using a fluorophotometric method to measure the level of uranium in urine. A KCP document (KCP, 1962) states that the method is sensitive to concentrations of uranium from 5 E-11 to 1 E-10 g per 0.25 g of sodium fluoride with a precision of ±10%. This sensitivity equates to 0.5 to 1 μg U/L of urine. However, this sensitivity may be the theoretical best based on ultra pure water blanks, as opposed to urine blanks. The urine volume used for bioassay analysis was 0.1 ml and the lowest quantity of uranium used to determine a standard curve was 1 E-9 g. The urine concentration that equates to the lowest uranium quantity of the standard curve is 10 μg/L. Bioassay data for four individuals (ORAUT-TKBS-0031) show that concentrations as low as 1 μg U/L were recorded. However, most sites using fluorophotometry at this time were claiming more modest detection levels; for instance, Hanford claimed 4 μg/L, Paducah claimed 10 μg/L, and University of Rochester (used by many AWEs) claimed 5-10 μg/L (ORAUT-TKBS-0031). Because a definitive statement of the detection limit achieved by the Kansas City Plant was not found, an MDA of 10 μg/L is recommended.

By procedure (KCP, unknown date), the workers in radiation areas were to submit urine samples for uranium urinalysis on a semi-annually basis (May and November). Samples were then evaluated in KCP's Industrial Hygiene Laboratory (Monitoring, 1969-1971b, pdf p. 12) using a written procedure (KCP, 1962). Bioassay data were recorded on either the individual's film badge envelope or the annual 3-inch x 5.5-inch radiation exposure record (ORAUT-TKBS-0031). The actual frequency of bioassay analysis for KCP personnel who worked with DU powders varied from person-to-person and from year-to-year (ORAUT-TKBS-0031). The date and results of individual bioassay results are in each individual's dosimetry file.

KCP created a database of bioassay data and shared with NIOSH a spreadsheet summary of the available data (Nasca, 2004a). There are numeric sums of all bioassay measurement results taken during the year for an individual; however, the number of bioassay measurements that comprise the annual sum is not recorded in the spreadsheet.

Bioassay data from four individuals were studied (Monitoring, 1958-2005) to better understand KCP's monitoring frequency and recordkeeping practice. The number of bioassay samples taken per year ranged from 0 to 6. Zero samples per year means that there are gaps in the bioassay record where one or more years of no bioassay data are bracketed by years for which there are bioassay data.

Table 6-3 summarizes an analysis of the electronic bioassay records (ORAUT-TKBS-0031). These data show a peak in 1960 and 1961. The peak is apparently not the result of an incident, but could be due to a large number of bioassay samples being collected in those years for each worker (ORAUT-TKBS-0031). The bioassay data for 1971 are very low; indeed, they are less than the sensitivity level. The low bioassay levels may indicate that no intakes of uranium occurred during that year. As noted above, the excreta data in Table 6-3 represent the sum of an unstated number of bioassay measurements.

Table 6-3: Statistical Parameters of Recorded DU in Urine for 1959-1971[a]								
	Recorded Annual Urine Concentration[b]			Lognormal Fit		Chronic intakes (pCi/d)[c]		
	No. of Workers Reported	Concentration (µg/L)		Concentration (µg/L)				
Year		Mean	Maximum	Median	GSD	5th	Median	95th
1959	214	4.125	52.60	2.642	2.675	1.05E+02	6.42E+02	3.92E+03
1960	281	36.58	140.	19.53	3.813	7.79E+02	4.75E+03	2.89E+04
1961	123	51.40	192.1	37.44	2.402	1.49E+03	9.10E+03	5.55E+04
1962	148	4.327	15.75	3.162	2.508	1.26E+02	7.69E+02	4.69E+03
1963	211	10.96	72.00	7.564	2.532	3.02E+02	1.84E+03	1.12E+04
1964	219	5.627	78.38	3.888	2.431	1.55E+02	9.46E+02	5.76E+03
1965	175	9.572	38.00	5.583	3.422	2.23E+02	1.36E+03	8.27E+03
1966	223	6.432	45.05	4.214	2.640	1.68E+02	1.02E+03	6.24E+03
1967	159	5.438	21.50	3.574	2.713	1.43E+02	8.69E+02	5.30E+03
1968	11	6.055	6.600	6.052	1.029	2.42E+02	1.47E+03	8.97E+03
1969	<10	0.15	0.150	0.150	1.000	5.99E+00	3.65E+01	2.22E+02
1970	59	11.64	45.00	7.576	2.686	3.02E+02	1.84E+03	1.12E+04
1971	47	0.03596	0.1000	0.02993	1.903	1.19E+00	7.28E+00	4.44E+01
ALL	**1,871**	**14.1**	**192.1**	**5.5**	**4.7**			

Source: This table is a slightly modified version of Table 12 in ORAUT-TKBS-0031.
[a] All bioassay measurements.
[b] The recorded annual sum of urine concentration is the sum of all bioassay results for the year. There is one sum for each person-year record. The listed statistics are based on the analysis of the data, which are the sums of all bioassay data for every person for that year.
[c] Chronic intakes that produce the urinary excretion per day on the 365th day of intakes corresponding to the median excretion from the lognormal fit and 5th and 95th percentile intakes using a GSD of 3. Assumes 5-µm AMAD particle size and absorption type S; intakes for 1-µm AMAD particle size, 10.97 g/cm3 density, and absorption type S are smaller.

The workers who received bioassay for uranium had Organization Codes 530001 and 531002. Table 6-4 lists the number of bioassay results for the two organizations and the occupations that had bioassay results. The Organization Code does not provide much information about what groups might have been exposed to airborne uranium because Code 531002 refers to the DOE contractor that operated KCP (e.g., Bendix, Allied-Signal), and Code 530001 refers to DOE workers. The Managers and Administrators occupation category included individuals who performed job estimates and who were commonly in the work areas. The data in Table 6-4 indicate that nearly all types of KCP workers participated in the urinalysis program. Table 6-4 also lists the average of the bioassay measurements for each occupational code.

Table 6-4: Number of Recorded and Average Bioassay Measurements for 1959-1971

Occupation Description	Occ Code	Number of Individual Measurements: Organization Code 530001	Number of Individual Measurements: Organization Code 531002	Bioassay Measurements Ave.[a] (µg/L)
Managers and administrators	110	10	342	9.12
Engineers	160		228	8.85
Scientists	170		15	2.34
Health physicists	184	<10		4.30
Miscellaneous professionals	200		17	8.80
Repair technician	350		44	13.19
Health technician	360		<10	5.39
Technologist, engineering	370		38	13.66
Miscellaneous technicians	390		47	8.90
Administrative support/clerical/work planners	450		60	11.96
Fire fighter	512		58	3.94
Security inspector & guard	513	<10	<10	1.61
Food service employees	521		<10	0.00
Custodian/janitor	524		11	2.85
Mechanics/repairers	610		350	7.68
Electrician	643		153	8.97
Pipe fitter	645		177	8.85
Machinist	681		152	14.08
Sheet metal worker	682		<10	0.00
Operators, plant/system/utility	690		<10	1.23
Machine setup/operators	710	<10	28	7.97
Welders/solderers	771		11	7.01
Miscellaneous precision/production workers	780	14	640	10.54
NA[b]	781		<10	14.05
Drivers	840		28	7.75
Handlers/laborers/helpers	850		145	8.82
All groups				**9.44**

Source: This table is a slightly modified version of Table 13 in ORAUT-TKBS-0031.
[a] Average of recorded bioassay measurements.
[b] NA indicates that information is not available.

6.2 Available Kansas City Plant External Monitoring Data

KCP has an electronic database with portable document format (PDF) files for individual monitored employees. For the years 1950 through 2010, doses are recorded for 4,500 KCP employees on 15,300 records (DOE, 2010). Positive deep, shallow, and extremity doses were first recorded in 1950 (Monitoring, 1950). Recorded extremity dose was higher in 1951 and 1952, than in any other years. Before about 1959, the recorded deep and shallow doses were essentially equal. Relatively high shallow dose (in comparison with deep dose) was recorded from 1959 to 1964 and during 1973.

NIOSH also has copies of KCP dosimeter processing reports with dosimeter reads for employees and area monitors. The records are reported by Landauer and Eberline.

The external dosimeters used at KCP are described in Section 7.3.1 of this report.

KCP positive neutron doses were first recorded in 1966 and recorded a total of 35 times over a period from 1966 through 1996. Most of the work at KCP that included neutron exposures occurred in the 1980s (Monitoring, 1974-1978; Monitoring, 1967-1983). In all cases, except for two, the recorded annual deep dose is equal to the recorded annual neutron implying all recorded deep dose resulted from the neutron dose. The two exceptions occurred in 1976 and 1983 with recorded deep and neutron annual doses of 64 mrem and 26 mrem, and 3 mrem and 1 mrem, respectively. Overall, the recorded neutron dose is a relatively insignificant component of the worker dose.

NIOSH examined KCP dose records and noted that some dose has been recorded for nearly all occupational categories at KCP. Based on information from e-mail correspondence (Nasca, 2004b), some doses in the KCP radiological records system have been assigned to workers even though investigations at the time of measurement have shown unexplainable causes.

Table 6-5 summarizes KCP recorded annual penetrating dose, the arithmetic average and maximum value for all recorded penetrating doses, and the lognormal probability statistical parameters for all positive recorded doses (i.e., dose > 0).

Table 6-5: Statistical Parameters of Recorded Penetrating Annual Doses

	Arithmetic, All Recorded Dose			Lognormal, Dose>0			
		Dose, rem			Dose, rem		
Year	No. of Workers	Mean	Maximum	No. of Workers	Median	95%	GSD
1950	46	7.09E-02	6.47E-01	29	5.01E-02	5.54E-01	4.31E+00
1951	227	2.78E-01	5.32E+00	158	4.97E-02	2.02E+00	9.52E+00
1952	233	1.91E-01	5.90E+00	220	2.45E-02	7.42E-01	7.96E+00
1953	103	1.37E-01	5.32E+00	72	2.13E-02	4.50E-01	6.38E+00
1954	65	1.61E-01	2.99E+00	21	1.19E-01	4.74E+00	9.39E+00
1955	41	9.18E-02	4.18E-01	25	1.10E-01	4.59E-01	2.39E+00
1956	26	2.89E-01	1.75E+00	26	1.35E-01	1.07E+00	3.52E+00
1957	65	5.24E-01	7.89E+00	36	1.77E-01	6.33E+00	8.80E+00
1958	301	3.90E-02	8.43E-01	89	5.44E-02	4.84E-01	3.78E+00
1959	464	8.97E-03	2.30E-01	72	3.57E-02	1.78E-01	2.66E+00
1960	1,043	1.21E-02	1.35E+00	165	4.53E-02	2.31E-01	2.70E+00
1961	948	2.39E-02	5.90E-01	400	3.17E-02	1.64E-01	2.72E+00
1962	700	1.25E-02	1.65E+00	59	4.25E-02	4.53E-01	4.22E+00
1963	597	1.18E-02	1.63E+00	100	3.65E-02	2.02E-01	2.83E+00
1964	530	6.85E-03	6.90E-01	59	3.09E-02	1.97E-01	3.08E+00
1965	436	1.35E-03	8.00E-02	26	1.66E-02	5.59E-02	2.09E+00
1966	415	2.32E-03	2.00E-01	27	2.54E-02	8.95E-02	2.15E+00
1967	370	1.71E-03	2.50E-01	20	2.06E-02	7.14E-02	2.13E+00
1968	469	1.75E-03	3.50E-01	<10	1.10E-01	6.84E-01	3.04E+00
1969	577	20 (a)	0.00E+00	<10			
1970	580	1.60E-03	3.20E-01	29	1.61E-02	7.47E-02	2.54E+00
1971	575	9.39E-04	2.00E-01	16	2.02E-02	9.09E-02	2.50E+00
1972	195	1.19E-02	4.26E-01	68	2.04E-02	8.61E-02	2.40E+00
1973	199	9.86E-02	1.81E+01	69	1.87E-02	1.09E-01	2.91E+00
1974	169	1.30E-02	8.80E-02	67	2.86E-02	6.89E-02	1.71E+00

Table 6-5: Statistical Parameters of Recorded Penetrating Annual Doses							
	Arithmetic, All Recorded Dose			Lognormal, Dose>0			
		Dose, rem			Dose, rem		
Year	No. of Workers	Mean	Maximum	No. of Workers	Median	95%	GSD
1975	150	5.72E-03	8.60E-02	44	1.25E-02	5.96E-02	2.58E+00
1976	126	9.65E-03	2.48E-01	53	1.37E-02	7.34E-02	2.77E+00
1977	123	5.45E-03	3.00E-01	12	2.76E-02	1.72E-01	3.04E+00
1978	152	7.53E-03	1.25E-01	18	4.55E-02	2.25E-01	2.64E+00
1979	162	2.69E-03	8.30E-02	17	2.12E-02	5.64E-02	1.81E+00
1980	185	4.19E-03	1.33E-01	22	2.74E-02	8.49E-02	1.99E+00
1981	210	4.12E-03	1.20E-01	24	2.72E-02	9.27E-02	2.11E+00
1982	209	2.00E-03	5.20E-02	22	1.67E-02	3.72E-02	1.63E+00
1983	226	2.98E-03	3.14E-01	12	2.76E-02	2.06E-01	3.39E+00
1984	216	1.89E-02	3.57E+00	18	2.44E-02	2.80E-01	4.41E+00
1985	201	4.67E-02	8.66E+00	49	1.41E-02	8.34E-02	2.95E+00
1986	194	3.22E-03	5.50E-02	27	2.05E-02	4.71E-02	1.66E+00
1987	196	1.65E-03	4.00E-02	20	1.18E-02	4.82E-02	2.35E+00
1988	188	3.52E-03	1.80E-01	11	4.62E-02	1.81E-01	2.29E+00
1989	233	8.03E-04	1.60E-02	17	1.09E-02	1.37E-02	1.15E+00
1990	217	1.16E-03	4.10E-02	17	1.37E-02	2.50E-02	1.44E+00

Source: This table is a slightly modified version of Table 15 in ORAUT-TKBS-0031.
[a] All 1969 recorded doses = zero. However, NIOSH can bound these doses using Section 2.1.2 of OCAS-IG-001, External Dose Reconstruction Implementation Guideline (Revision 3) and the KCP minimum detection level of 40 mrem.

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

The feasibility determinations 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-00210 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Kansas City Plant 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

NIOSH has not discovered any bioassay data and has limited air monitoring data from which to determine worker doses during natural uranium operations from May 1, 1950 through February 28, 1955. However, NIOSH has source term data in the form of shipping transactions and accountability and contractual records of uranium materials to be processed by KCP. The data sources are copies of original reports and contracts and are therefore considered primary data sources. The data reported by AEC representatives would have been collected in accordance with standard practices using state-of-the-art methods of the day.

NIOSH has not discovered any bioassay data from which to determine worker doses for the Mg-Th work performed during the period from May 1, 1957 through April 30, 1979. However, there are air monitoring data from May 23, 1958 through July 26, 1971, as well as routine, quarterly contamination surveys for 1959 through 1969. These data are copies of original reports and are therefore considered primary data sources. NIOSH also captured uranium bioassay results processed by KCP for radiation workers from August 11, 1959 to December 10, 1971. These results are copies of original reports and are also considered primary data sources.

7.1.2 External Monitoring Data Pedigree Review

Data for the period from January 1, 1949 through December 31, 1993, consist of radiation survey reports. These surveys are copies of original reports and are therefore considered primary data sources. NIOSH also captured results of radiation workers' external dosimetry. These results are copies of original reports and are therefore considered primary data sources.

7.2 Evaluation of Bounding Internal Radiation Doses at Kansas City Plant

The principal source of internal radiation doses for members of the class under evaluation was the potential inhalation and ingestion of airborne uranium and thorium by employees, both those nearby and those directly involved in machining at KCP. Other employees nearby were potentially exposed to the resuspension of surface contamination during the course of their work with non-radioactive materials. 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

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 2,809 urinalysis results for the period from September 1, 1959 through December 31, 1971, and NIOSH plans to use those data to reconstruct doses for workers (Monitoring, 1958-1970; Monitoring, 1950-2003; Monitoring, 1963-1970; Monitoring, 1964-1967).

There was also a urinalysis program for Rockwell employees during D&D activities from June 1, 1984 through September 3, 1986 (Rockwell, 1985). Internal doses to Rockwell employees can be reconstructed using that data.

7.2.1.2 Airborne Levels

NIOSH has identified air monitoring data obtained during routine air sampling for uranium from May 23, 1958 to July 26, 1971 (Monitoring, 1963-1967; Monitoring, 1958-1970), and also from a safety survey in August of 1952 (Safety Survey, 1952). In 1970, KCP performed a test run of Mg-Th machining operations in the Model Shop and performed an air monitoring assessment of each operation. NIOSH has the air concentration results from this assessment (Mg-Th, 1962-1975).

7.2.1.3 Alternative Data Sources for Bounding Internal Dose

NIOSH has information that KCP machined and handled natural uranium beginning on May 1, 1950 and continuing through February 1955 (Paine, 1951; Harshman, 1952; KCP, 1950-1963). NIOSH has not found reports that indicate this natural uranium work extended beyond this time period. NIOSH has detailed information regarding this work and can use Battelle-TBD-6000 to bound internal doses during this period and until the KCP urinalysis monitoring program started in 1959.

NIOSH has information that KCP machined and handled Mg-Th beginning May 1, 1957 through April 30, 1979 (KCP, 1950-1963; KCP, 1979, pdf p. 18). NIOSH has not found reports indicating that Mg-Th work extended beyond this time period. NIOSH has detailed information regarding the Mg-Th work and can use engineered air concentration limits in conjunction with ORAUT-OTIB-0070 to bound internal doses during this period and until the start of D&D activities on June 1, 1984.

KCP workers would have also been exposed to thoron (the thorium daughter product) during Mg-Th operations. NIOSH will calculate the thoron exposure using the thorium air concentration determined for the exposure period and apply a claimant-favorable factor to arrive at a bounding thoron air concentration.

7.2.2 Evaluation of Bounding Ambient Environmental Internal Doses

The primary and apparently only substance handled in large quantities with a potential for significant environmental release involved DU from 1958 through 1970. Beginning in 1990, there is assurance that no significant environmental releases occurred based on the multi-agency response findings to the Pm-147 incident.

NIOSH can bound ambient environmental doses to KCP personnel using methodology as described in Battelle TBD-6000 for the "Other" category of worker. The "Other" category of worker includes employees such as those performing primarily administrative and clerical duties with no reason to enter the restricted, radiological areas.

7.2.3 Methods for Bounding Internal Dose at Kansas City Plant

7.2.3.1 Methods for Bounding Operational Period Internal Dose

Internal dose estimates for KCP work evaluated in this report can be bound as detailed in the subsections below.

Natural Uranium Operations from May 1, 1950 through February 28, 1955

Details regarding KCP's work from May 1, 1950 through February 28, 1955, that potentially generated uranium contamination are provided in Section 5.1.2 of this report.

A chronological list of radioactive materials at KCP (KCP, 1950-1963) states that natural uranium components were inspected and assembled in Department 3A of the Main Manufacturing Building from May 1950 through February 1955. This document also states that natural uranium machining was performed in Department 49X (also known as Area "X") of the Main Manufacturing Building from February 1951 to December 1952. These "machining" operations would likely generate more airborne activity than "inspection and assembly" operations. However, NIOSH will assume machining operations occurred in both areas from May 1, 1950 through February 28, 1955.

Departments 3A and 49X were totally enclosed areas and access was controlled with the use of a "Permanent Access List" maintained by the Security, Medical and Safety Departments. No women were permitted in these areas. Employees that met the medical and security requirements for entry had their entries documented on the "Exclusion Area Register" (Medical, 1950-1953; Thiel, 1955; ORAUT-TKBS-0031; Schiltz, Aug1962; Stowers, Jun1951; Frazer, 1952).

The uranium that was processed in Departments 3A and 49X was not directly handled in any other areas of KCP. Receiving, Internal Transportation, and Shipping areas were the only other areas at KCP that handled this material; however, in these areas only uranium that was in containers was handled (KCP, 1950-1963).

NIOSH has information that KCP machined a total of 313,070 pounds of natural uranium into slugs, and had the capacity to produce 1,000 slugs per day. The KCP machining process is well documented. The quantity and types of machines are known, as are the sequence and description of machining steps. Cutting speeds are also specified (Stowers, Apr1951). It is also known that KCP used a very high coolant flow rate (coolant type was Texaco Soluble Oil "C"). Provisions for reclamation of scrap material, chips, dust, and oxides were implemented. KCP had designated storage areas for raw material, finished metal, and reclaimed waste. KCP also assigned an accountability officer to track uranium metal, and uranium metal transportation was always under the supervision of a security guard (Paine, 1951).

NIOSH compared the operations and conditions known and postulated for KCP to those used to establish "air sampling data for facilities machining uranium" in Battelle-TBD-6000, Table 7.5. To accomplish this, NIOSH reviewed a study used as the foundation for radionuclide intake derivations related to uranium machining in Battelle-TBD-6000. NIOSH finds *The Industrial Hygiene of Uranium Fabrication* (HASL-39) (Harris, 1958) to be a bounding approximation of KCP work activities under consideration. Therefore, NIOSH is satisfied that Battelle-TBD-6000 can be used to estimate KCP exposures in this case and concludes that internal exposures to KCP employees during natural uranium operations can be bound based on the intake rates for machining (1951 to December 31, 1955) in Battelle-TBD-6000, Table 7.8 for inhalation and Table 7.9 for ingestion. After reviewing existing information regarding work controls and limited air sample data, NIOSH finds this approach to be adequately conservative and claimant favorable.

Natural Uranium Post-Operations Period from March 1, 1955 to August 31, 1959

After reviewing existing information regarding work controls and limited air sample data, NIOSH selected the job category "operator" from Table 7.5 of Battelle-TBD-6000, from which to determine likely air concentration during machining operations. This category is the closest approximation of KCP operations during their work with the most potential for generating airborne radioactivity. That corresponding air concentration for the "operator" category is 5,480 dpm/m^3.

Using the settling and resuspension method presented in Battelle-TBD-6000, NIOSH estimated the airborne concentration after natural uranium operations ceased. The average residual surface contamination present at the start of the period was estimated based on the air concentration during operations, determined above as 5480 dpm/m^3. The estimate of surface contamination was made by assuming continuous settling of this airborne radioactive material at a rate of 0.00075 m/s for 30 days. This resulted in an average floor contamination level of 10,650,000 dpm/m^2.

This settled activity is assumed to have been resuspended during ongoing KCP operations with the application of a resuspension factor of 1 x 10^{-5}/m to provide an air concentration of 106.5 dpm/m^3 (48. pCi/m^3) on March 1, 1955 for the start of the post-operations period.

KCP operations did not generate "new" airborne radioactivity until the start of DU machining operations on September 9, 1958. Therefore, NIOSH modeled the depletion of the March 1, 1955 airborne concentration down to the concentration that existed prior to the start of DU machining.

The first air sample that NIOSH has been able to find after March 1, 1955, was a sample taken on May 23, 1958, and the maximum measured air concentration found during this period prior to the start of large-scale DU machining was reported as 4.90 E-11 μCi/ml (49 pCi/m^3). This meant that both concentrations that NIOSH desired to use in the "depletion" equation from ORAUT-OTIB-0070 were essentially the same.

Therefore, NIOSH determined that the best method for estimating internal exposure at KCP after natural uranium operations ceased in 1955 until the start of KCP's urinalysis program in 1959, is to use the maximum gross-alpha measured air sample from prior to the start of large-scale DU machining (49 pCi/m^3) and assume that concentration remained constant during this post-operations period. NIOSH will assume that machine operators in the Main Manufacturing Building breathed air at this concentration for 2000 hours per year.

NIOSH will use methodology described in Battelle-TBD-6000 to determine air concentrations for classes of workers that had less exposure potential or spent less time in the Main Manufacturing Building than the machine operators. NIOSH will assume that air concentration for the general laborers was half the concentration of that for the operators. Supervisors had half the air concentration of the general laborers. Other worker types, such as clerical workers, had 10% of the supervisors' air concentration.

The ingestion rate will be derived with methodologies presented in OCAS-TIB-009.

Mg-Th Operations from May 1, 1957 through April 30, 1979

From the onset of Mg-Th operations, KCP sought out methods to perform Mg-Th work safely and instituted strict operational controls to prevent airborne generation (Mg-Th, 1957-1970, pdf p. 21). These operational controls were stricter than those used at AWEs in earlier years, including maintaining surface contamination levels in the work area to <2000 dpm/100 cm^2 (alpha), the use of wet methods, and the use of local ventilation (Foster, unknown date; Thorium, unknown date; Mg-Th, unknown date; Mg-Th, 1957-1970, pdf p. 15; Lalli, 1971). KCP also used access lists to promulgate which employees had medical approval to perform Mg-Th work, and to control or restrict entries into the work area (Lalli, 1971; Burchett, 1972; Renick, 1972).

In 1957 at the beginning of Mg-Th operations, KCP established engineered airborne limits and controlled these operations so as to not exceed 9E-11 μCi/ml (Th-232). KCP also instituted an industrial hygiene and fire protection limit of 0.1 mg/m^3 (thorium) (Thorium, unknown date). NIOSH examined the implication of this 9E-11 μCi/ml control limit. The Mg-Th used at KCP had a nominal 3% Th-232 content as a strengthener, alloyed with 97% magnesium. Assuming a Th-232 specific activity of 1.1E-7 Ci/g, the 9E-11 μCi/ml limit would equate to 0.82 mg/m^3 (approximately eight times higher than the industrial hygiene limit). When the remaining 97% of magnesium mass is added the result is 27.3 mg/m^3 of total airborne dust. NIOSH believes this analysis supports the selection of these limits as bounding airborne concentrations in a typical industrial environment because of a similar evaluation performed for the Bethlehem Steel site. An evaluation performed by Wesley R. Van Pelt Associates for the S. Cohen & Associates review of the Bethlehem Steel Site Profile concluded that about 30 mg/m^3 provides a plausible upper bound dust concentration for continuous exposure in the work place (SC&A, 2005). NIOSH observed similarities in the type of work performed at both KCP and Bethlehem Steel and believes the comparison to be relevant and applicable to the KCP model.

In 1959, KCP lowered their control limit to 3E-11 µCi/ml (Th-232) (Mg-Th, 1957-1970, pdf pp. 14-16).

KCP performed gross alpha fixed-filter air monitoring from 1958 through 1971 in the Main Manufacturing Building and maintained operations at: 2.85E-12 µCi /ml (average measured level for the period) and <8.55E-11 µCi /ml (maximum measured level for the period) ORAUT-TKBS-0031, pdf p. 20).

In 1970, KCP performed an evaluation of Mg-Th machining operations in the Model Shop and validated that their process did not generate airborne radioactivity. As part of this test, each machining station was evaluated with breathing-zone air samplers running while performing the machining operation. KCP machinists maintained airborne levels during this test at background (0 cpm recorded) for long-lived activity, and <3.22E-9 µCi/ml for short-lived activity. Direct-probe surveys of the Mg-Th are shown as: 0.3-1.2 mr/hr for beta-gamma radiation, and 250-700 cpm alpha (Mg-Th, 1962-1975).

From May 1, 1957 through October 31, 1959, internal exposures can be bound by using KCP's initial engineered limit of 9E-11 µCi/ml and applying it as a constant.

NIOSH will assume that machine operators in the Main Manufacturing Building breathed air at this concentration for 2,000 hours per year.

NIOSH will use the methodology described in Battelle-TBD-6000 to determine air concentrations for classes of workers that had less exposure potential or spent less time in the Main Manufacturing Building than the machine operators. NIOSH will assume that the air concentration for general laborers was half the concentration of that of the operators. The supervisors of the operators and general laborers had half the concentration of the general laborers' concentration. All other worker types, such as those performing primarily administrative and clerical duties with no reason to enter the restricted, radiological areas, had 10% of the supervisors' concentration.

From November 1, 1959 through April 30, 1979, when Mg-Th operations ceased, the lowered engineered limit of 3E-11 µCi/ml can be applied as a constant.

NIOSH will assume that machine operators in the Main Manufacturing Building breathed air at this concentration for 2,000 hours per year.

NIOSH will use the methodology described in Battelle-TBD-6000 to determine air concentrations for classes of workers that had less exposure potential or spent less time in the Main Manufacturing Building than the machine operators. NIOSH will assume that the air concentration for general laborers was half the concentration of that of the operators. The supervisors of the operators and general laborers had half the concentration of the general laborers' concentration. All other worker types, such as those performing primarily administrative and clerical duties with no reason to enter the restricted, radiological areas, had 10% of the supervisors' concentration.

The ingestion rate will be derived with methodologies presented in OCAS-TIB-009.

The thoron exposure bounding basis uses the highest 1970 short-lived sample (3.2E-9 μCi/ml), which yields an exposure rate of 5.1 WLM/yr. This amount will be assigned for each year of Mg-Th work.

Thorium and Thoron Exposures during Mg-Th Post-Operations Period from May 1, 1979 through May 31, 1984

NIOSH assumes that air concentration at the end of operations was the lower limit of 3E-11 μCi/ml (66.6 dpm/m^3) and that radioactive material was deposited on the floor with a deposition velocity of 0.00075 m/s for a period of 30 days. This settled activity was then resuspended during KCP operations and was depleted until the initial D&D characterization survey on May 31, 1984.

The settling of the final air concentration yields a surface contamination level of 1.3 E5 dpm/m^2 (alpha) on June 1, 1979. Applying a resuspension factor of 1E-5/m, yields an air concentration of 1.3 dpm/m^3 (0.59 pCi/ m^3) for the start of the post-operations period on June 1, 1979.

A characterization survey was performed prior to D&D activities. The maximum "accessible" contamination level was 6E4 dpm/m^2. Applying a resuspension factor of 1E-5/m, yields an air concentration of 0.6 dpm/m^3 (0.27 pCi/ m^3) for the end of the post-operations period on May 31, 1984.

These two concentrations were inserted into the exponential interpolation (depletion) equation from ORAUT-OTIB-0070.

- λ = -ln(A1984/A1979) /t = 4.23 E-4/yr

This depletion rate (4.23 E-4/yr) will be applied to the initial air concentration to determine the remaining activity available for inhalation and ingestion for each year of this post-operations period.

NIOSH will assume that machine operators in the Main Manufacturing Building breathed air at this concentration for 2,000 hours per year.

NIOSH will use the methodology described in Battelle-TBD-6000 to determine air concentrations for classes of workers that had less exposure potential or spent less time in the Main Manufacturing Building than the machine operators. NIOSH will assume that the air concentration for general laborers was half the concentration of that of the operators. Supervisors had half the concentration of the general laborers' concentration. All other worker types, such as those performing primarily administrative and clerical duties with no reason to enter the restricted, radiological areas, had 10% of the supervisors' concentration.

The ingestion rate will be derived with methodologies presented in OCAS-TIB-009.

The thoron exposure bounding basis for this post-operations period will start the period at 5.1 WLM/yr as derived above and will use the same depletion rate (4.23 E-4/yr) to determine the exposure to assign for each year of this May 1, 1979 through May 31, 1984, post-operations period.

Uranium Exposures during the Mg-Th Post-Operations Period from May 1, 1979 through May 31, 1984

NIOSH will use uranium residual data to bound exposures to KCP personnel that performed work in areas adjacent to the Mg-Th work area.

The maximum measured surface contamination survey taken during DU operations will be used to model a starting point air concentration for this post-operational period. The value of 45,000 dpm/100 cm^2 (4.5 E6 dpm/m^2 alpha) was re-suspended during KCP operations and was depleted until the initial D&D characterization survey on May 31, 1984.

Applying a resuspension factor of 1E-5/m, yields an air concentration of 45 dpm/m^3 (20.3 pCi/ m^3) for the start of the post-operations period on May 1, 1979.

A characterization survey was performed prior to D&D activities. The maximum "accessible" contamination level was 6E4 dpm/m^2. Applying a resuspension factor of 1E-5/m, yields an air concentration of 0.6 dpm/m^3 (0.27 pCi/ m^3) for the end of the post-operations period on May 31, 1984.

These two concentrations were inserted into the exponential interpolation (depletion) equation from ORAUT-OTIB-0070.

- λ = -ln(A1984/A1979) /t = 2.36 E-3/yr

This depletion rate (2.36 E-3/yr) will be applied to the initial air concentration to determine the remaining activity available for inhalation and ingestion for each year of this post-operations period. NIOSH will assume that machine operators in the Main Manufacturing Building breathed air at this concentration for 2,000 hours per year.

NIOSH will use the methodology described in Battelle-TBD-6000 to determine air concentrations for classes of workers that had less exposure potential or spent less time in the Main Manufacturing Building than the machine operators. NIOSH will assume that the air concentration for general laborers was half the concentration of that of the operators. Supervisors had half the concentration of the general laborers' concentration. All other worker types, such as those performing primarily administrative and clerical duties with no reason to enter the restricted, radiological areas, had 10% of the supervisors' concentration.

The ingestion rate will be derived with methodologies presented in OCAS-TIB-009.

D&D Activities from June 1, 1984 through September 3, 1986

Rockwell employees that performed the D&D work would have most likely received the highest exposures during this D&D period. The Rockwell Final Report states that continuous in-progress radiologic surveys were performed as concrete and drain system removal progressed. Although moderate levels of fixed DU contamination were located throughout this area, no significant radiation hazards were identified in the course of this effort and personnel encountered no radiation exposure problem in the area (Rockwell, 1985, pdf p. 25).

Bioassay by means of urinalysis for uranium and blood testing for lead was utilized as a means of assessing internal deposition of hazardous materials in Rockwell personnel. Baseline samples prior to assignment of work and quarterly samples thereafter were obtained from each worker that entered the contaminated areas during D&D operations (Rockwell, 1985, pdf p. 25).

Rockwell workers had barriers around their work and used continuous air monitors outside their perimeter, monitoring for U-238 at a control level of 1E-12 μCi/ml (Rockwell, 1985, pdf p. 25).

NIOSH will use urinalysis for Rockwell D&D workers and assume that KCP employees were exposed at the perimeter air-concentration level during this period.

7.2.3.2 Methods for Bounding Ambient Environmental Internal Dose

As stated above for the various time periods, NIOSH will use the methodology described in Battelle-TBD-6000 to determine air concentrations for classes of workers that had less exposure potential or were unmonitored for internal exposures. NIOSH will assume that the air concentration for general laborers was half the concentration of that of the operators. Supervisors had half the concentration of the general laborers' concentration. All other worker types, such as those performing primarily administrative and clerical duties with no reason to enter the restricted, radiological areas, had 10% of the supervisors' concentration.

Using available KCP workplace-control and monitoring information, with methods available in Battelle-TBD-6000, NIOSH concludes it is feasible to bound internal ambient radiation doses for unmonitored workers for the period from January 1, 1949 through December 31, 1993 at KCP.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

NIOSH concludes that there are methods available in Battelle-TBD-6000 and ORAUT-OTIB-0070, as well as breathing zone air data, bioassay data, and operational descriptions, so that uranium, thorium, and thoron internal radiation doses can be completely reconstructed with sufficient accuracy for KCP workers from January 1, 1949 through December 31, 1993.

7.3 Evaluation of Bounding External Radiation Doses at Kansas City Plant

The primary sources of workplace radiation fields at KCP are historically associated with processes involving industrial radiation-generating devices (e.g., X-ray machines and electron accelerators) (see Table 5-2) and isotopic beta, gamma-ray, and neutron radiation-emitting sources (see Table 5-3). KCP workers were also potentially exposed to gamma and beta radiation associated with handling and working in proximity to uranium and thorium. Some employees were also potentially externally exposed to radiation from resuspended contamination from uranium and thorium metal surfaces and the floor during the course of their work with these 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 located external monitoring records for neutron, beta, and gamma radiation for KCP workers associated with uranium and thorium processing during the class period under evaluation. Individual dosimetry data are the preferred data source for evaluating the external radiation doses for members of the KCP class.

NIOSH has access to 13,846 external dosimetry records that include monitoring data for deep dose, shallow dose, extremity dose (rings), and neutron dose for the years 1950 through 1993. KCP participated in Department of Energy Laboratory Accreditation Program (DOELAP) performance testing using Landauer-provided services beginning in October 1992.

KCP performed extremity monitoring with ring dosimeters 1,853 times from 1950 to 1993. Positive results were recorded 635 times with the highest dose being 4.448 rem, recorded in 1952.

NIOSH has knowledge of the neutron, beta, and photon (X-ray and gamma) dosimeters used at KCP. They include:

- Landauer Neutrack I Dosimeter: This dosimeter was used at KCP from 1991 through 1993 to measure neutron doses. It is a polycarbonate (Lexan) neutron recoil track registration device used to monitor fast neutron interactions. It has a uniform energy response from 3 to over 14 MeV with a threshold of 1 MeV.
- Other neutron dosimeters used at KCP included: Controls for Radiation from 1961 to 1967, Landauer film from 1967 to 1973, Landauer NTA film from 1974 to 1982, and Landauer Lexan track-etch from 1983 to 1990.
- Pocket Ionization Chamber (PIC): This is a self-reading instrument that provides the user with "real-time" data, with which the user can better manage their exposure. The PIC also provided KCP with the ability to exercise administrative control until dosimeter results were available. The PICs were not used to generate a dose of record.
- KCP Film Dosimeter: This dosimeter is a two-piece, stainless-steel, film holder with front and rear matching rectangular windows. The front and rear faces have a 1-mm thick cadmium filter in the area of the open window. Two different types of personal dosimetry film packets are used in this dosimeter: Kodak Type-2 for mixed beta and gamma radiation and DuPont Type-558 for X-ray and gamma radiation. The DuPont Type-558 film packet contains two films, Type-508 and Type-1290. The Type-508 film has a range of 0.003 to 30 R, and Type-1290 has a range of 0.68 to 3,000 R. KCP calibration data using uranium and Co-60 sources are available (Bendix, 1964). This dosimeter was used at KCP from 1950 through 1972.
- KCP thermoluminescent dosimeter (TLD) (two-chip,): This dosimeter was used from 1973 to 1982 at KCP.
- Eberline Standard (three-chip, TLD-100) TLD: This TLD was used from 1983 through 1990 at KCP. This dosimeter employs one chip under a 10-mg/cm^2 filter to measure the shallow or skin dose, and one or two chips under a 285-mg/cm^2 filter to measure the deep or whole-body dose (ORAUT-TKBS-0031). The use of this dosimeter was terminated due to its inability to pass

DOELAP lower energy photon performance testing categories (although it had passed National Voluntary Laboratory Accreditation Program testing) (AlliedSignal, 1991).

- Landauer K1 (three-chip, TLD-700) TLD: This TLD was used beginning April 1, 1991, to measure beta, X-ray, and gamma radiation exposure to KCP workers.

During the D&D operations from 1984 to 1986, Rockwell's final report stated that the total exposure from the job was expected to be less than 0.4 man rem for each of the three phases (Rockwell, 1985, pdf pp. 103, 114, 123, 137). Rockwell personnel exposure was measured with film badges and no measurable doses of radiation were incurred by any member of the decontamination crew (Rockwell, 1985, pdf p. 54).

The available personnel external monitoring data discussed in Section 6.2 of this report, obtained from Neutrack film badges, TLDs, and pocket ionization chambers, provide external photon, beta, and neutron dose information for the personnel working during the evaluated period at KCP. These data can be used to reconstruct dose for members of the class under evaluation. While external dosimetry data are not available for all members of the class under evaluation, monitoring data do exist for some KCP employees within the class being evaluated. As discussed in this evaluation, the available personnel monitoring data include data that represent the maximally-exposed work group and work scenario during the KCP evaluated period. NIOSH believes that external monitoring data obtained from workers associated with the production activities can be used to bound external exposures to all members of the class under evaluation. Therefore, NIOSH has concluded that the available personnel monitoring data and information for KCP support its ability to bound the external dose for the class under evaluation.

7.3.2 Evaluation of Bounding Ambient Environmental External Doses

KCP prepared a Site Safety Assessment report in 1995 in compliance with DOE requirements (AlliedSignal, Sep1995). The report concluded that KCP operations had produced no undue hazard to the general public and had no significant effect on the environment. Air and water effluents have been monitored routinely to assess compliance with relevant criteria. KCP has routinely handled hazardous chemicals, with limited handling of radioactive materials and thus essentially little likelihood of a significant occupational environmental exposure associated with releases. KCP has generated low-level radioactive waste that includes equipment radiation sources, tritium exit signs, irradiated components, gap tubes, smoke detectors, small amounts of cleanup materials, and personal protective equipment. Mixed wastes consisted of encapsulated electronic assemblies.

NIOSH had found no indication that ambient external radiation fields were a significant contribution to worker doses at KCP. NIOSH concludes it is feasible, using available external monitoring data for KCP radiation workers and methods available in the KCP Site Profile (ORAUT-TKBS-0031) and ORAUT-OTIB-0020, to bound external ambient radiation doses for unmonitored workers for the period from January 1, 1949 through December 31, 1993 at KCP.

7.3.3 Kansas City Plant Occupational X-Ray Examinations

Starting in 1949 as part of the requirements for employment at KCP, employees received pre-employment, periodic, and/or termination physical examinations (Todd, Apr2004). These physical examinations might have included radiographic examinations of the chest to screen for disease. The medical X-ray units used for these exams belonged to and were operated by the KCP Medical Department (ORAUT-TKBS-0031, pdf p. 14).

All workers, including fire, patrol, radiation, and cafeteria workers, received a chest X-ray during the pre-employment examination and annually thereafter until the mid-1980s when it was discontinued (Todd, Jun2004; Todd, Aug2004; Brendlinger, 1974; Stowers, Aug1951). Several sources mention that the chest X-ray consisted of a single Posterior-Anterior (PA) projection (Monitoring, 1976; Brendlinger, 1974; Jacobson, 1988; Todd, Jun2004). This is evident from the claim-file records, as LAT chest X-rays are rare. Beginning in 1993, chest X-rays were taken every five years or more frequently if worker history or physical circumstances indicated the need. Based on a review of X-ray films from the 1950s and 1960s conducted by KCP staff, there is no evidence that photofluorography was used at KCP (Todd, Aug2004).

Therefore, NIOSH concludes that it is feasible to reconstruct occupational medical dose for KCP workers with sufficient accuracy.

7.3.4 Methods for Bounding External Dose at Kansas City Plant

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 (as applicable per Section 7.3.3)

7.3.4.1 Methods for Bounding Operational Period External Dose

Beta and Photon Dose

Beta and photon doses to KCP personnel can be reconstructed using available external dosimetry reports for all years associated with the evaluated period.

The DOE-reported photon deep dose for KCP workers is expected to provide a reasonable estimate of the actual photon dose. Dosimetry technology is capable of detecting and measuring the photon dose based on studies of historical performance (NBS, 1955; Unruh, 1967). The energy of prevalent photons based on the radiation sources is readily measured, so no adjustment of recorded dose would be likely based on the response characteristics of the different dosimeters.

Neutron Dose

Neutron doses to KCP personnel can be reconstructed using available external dosimetry reports for all years associated with the evaluated period.

Positive neutron doses were recorded at KCP a total of 34 times over a period from 1966 through 1993, with most instances occurring in the 1980s. In all but two cases the recorded annual deep dose is equal to the recorded annual neutron, implying all recorded deep dose resulted from the neutron dose. The two exceptions occurred in 1976 and 1983 with recorded deep and neutron annual doses of 64 mrem and 26 mrem, and 3 mrem and 1 mrem, respectively.

NIOSH can bound neutron doses to workers where it finds dosimetric photon monitoring results for a worker. If NIOSH determines that there was a potential unmonitored neutron exposure, then a neutron-to-photon dose ratio of 1:1 as a conservative estimate of neutron dose will be used. Overall, the recorded neutron dose is a relatively insignificant component of the worker dose. The recorded neutron dose must be adjusted to include conversion to the *International Commission on Radiological Protection (ICRP) Publication 60* (1991) neutron weighting.

Because there are no workplace measurements of neutron spectra, NIOSH's analysis assumed that 100% of the workplace neutron radiation is within the range of 0.1 to 2 MeV. This option provides the highest organ dose estimate. The approach can be simplified using the following expression:

> Neutron dose = adjusted photon dose × upper 95th-percentile neutron/photon dose ratio × ICRP 60 DCF

Medical X-ray Dose

NIOSH has data sufficient to support establishing a bounding dose estimate for the medical X-ray doses to members of the evaluated class.

A revision to the Site Profile for the Kansas City Plant, ORAUT-TKBS-0031, has updated X-ray information that NIOSH will use to bound these KCP X-ray exposures. It includes dose equivalents from PA chest X-ray examinations for each period and skin dose equivalents. From 1949 through 1985, NIOSH will assume that KCP personnel received preemployment, annual, and termination PA chest X-rays. From 1986 through 1993, NIOSH will assume KCP personnel received annual and termination PA chest X-rays.

7.3.4.2 Methods for Bounding Ambient Environmental External Doses

NIOSH has data sufficient to support establishing a bounding dose estimate for the ambient environmental external doses to members of the evaluated class.

NIOSH had found no indication that ambient external radiation fields were a significant contribution to worker doses at KCP. NIOSH can bound ambient environmental doses to KCP for the "Other" category of worker. The "Other" category of worker includes employees such as those performing primarily administrative and clerical duties with no reason to enter the restricted, radiological areas.

NIOSH concludes it is feasible, using available external monitoring data for KCP radiation workers and methods available in the KCP Site Profile (ORAUT-TKBS-0031) and ORAUT-OTIB-0020, to bound external ambient radiation doses for unmonitored workers for the period from January 1, 1949 through December 31, 1993 at KCP.

7.3.5 External Dose Reconstruction Feasibility Conclusion

Due to the availability of external personal monitoring data throughout the period under evaluation, NIOSH considers reconstruction of external radiation dose to be feasible for KCP workers for the period from January 1, 1949 through December 31, 1993. NIOSH also considers reconstruction of medical X-ray dose to be feasible.

7.4 Evaluation of Petition Basis for SEC-00210

The following subsections evaluate the assertions made on behalf of petition SEC-00210 for the KCP site.

7.4.1 Class Definition

Issue: The petitioner requested that the evaluated class include all members of the BFC.

NIOSH Response: The BFC is not a covered facility as defined by EEOICPA. KCP, located within the BFC, is a covered facility. This issue is further addressed in Section 3.2 of this report.

7.4.2 Promethium Contamination Incident

Issue: The petitioner identified the “Promethium Contamination Incident” in 1989 as an unmonitored, unrecorded, or inadequately monitored exposure incident.

NIOSH Response: After viewing detailed information regarding this incident, NIOSH has determined it can bound exposures during the event with available personal monitoring records. This issue is addressed in Section 5.2.3 of this report.

7.4.3 DU Machining

Issue: The petitioner stated that workers machined DU product and were not monitored.

NIOSH Response: After viewing detailed information regarding DU machining, NIOSH has determined it can bound exposures during the operations with available personal monitoring records. This issue is addressed in Section 7 of this report.

7.4.4 Unmonitored Exposure

Issue: The petitioner stated that there were unmonitored exposures, including the following: many surface and airborne uranium isotopes, plutonium, tritium, weapons grade uranium-235, uranium-233, neutrons and other ionizing radiation from industrial X-ray gauging devices, electron beam welders, neutron generators, neutron plutonium-beryllium sources, accelerators, cesium irradiator, medical X-ray, and Electro Curtain.

NIOSH Response: After viewing detailed process and source-term information regarding these issues, and considering the external and internal monitoring data available, NIOSH has determined it has sufficient information to document potential exposures and bound associated doses.

7.5 Summary of Feasibility Findings for Petition SEC-00210

This report evaluates the feasibility for completing dose reconstructions for employees at KCP from January 1, 1949 through December 31, 1993. 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 KCP for each exposure source during the time period from January 1, 1949 through December 31, 1993.

Table 7-1: Summary of Feasibility Findings for SEC-00210
January 1, 1949 through December 31, 1993

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal[1]	**X**	
- Natural Uranium	X	
- Depleted Uranium	X	
- Thorium	X	
- Thoron	X	
External	**X**	
- Gamma	X	
- Beta	X	
- Neutron	X	
- Occupational Medical X-ray	X	

Note:
[1] Internal includes an evaluation of urinalysis (in vitro), airborne dust data, documented operational controls process descriptions, and source term data.

As of November 22, 2013, a total of 665 claims have been submitted to NIOSH for individuals who worked at KCP during the period under evaluation in this report. Dose reconstructions have been completed for 608 individuals (~91.4%).

8.0 Evaluation of Health Endangerment for Petition SEC-00210

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

NIOSH's evaluation determined that it is feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy based on the sum of information available from available resources. Therefore, a health endangerment determination is not required.

9.0 Class Conclusion for Petition SEC-00210

Based on its full research of the class under evaluation, NIOSH found no part of said class for which it cannot estimate radiation doses with sufficient accuracy. This class includes all employees who worked in any area of the Kansas City Plant site in Kansas City, Missouri, from January 1, 1949 through December 31, 1993.

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-00210. 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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10.0 References

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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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Monitoring, 1967-1983, *Film Badge Exposure Date for January 1967 through December 1983*; various dates ranging from January 1967 through December 1983; SRDB Ref ID: 128404

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Personal Communication, 2013c, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127869

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Personal Communication, 2013e, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127868

Personal Communication, 2013f, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127873

Personal Communication, 2013g, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127863

Personal Communication, 2013h, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127878

Personal Communication, 2013i, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 28, 2013; SRDB Ref ID: 127872

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Personal Communication, 2013o, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 127870

Personal Communication, 2013p, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 127867

Personal Communication, 2013q, *Personal Communication with Former KCP Employee*; Interview by ORAU Team and NIOSH; August 29, 2013; SRDB Ref ID: 128746

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Attachment One: Data Capture Synopsis

Table A1-1: Summary of Holdings in the SRDB for KCP			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Primary Site / Company Name: Kansas City Plant; DOE 1949 - Present Contractors: Honeywell FM&T (1999 - Present); Allied-Signal Aerospace / formerly Bendix (1949 - 1999) Physical Size of the Site: 1999 - ~3.2 million square feet. New location currently relocating to is 1.5 million square feet. Site Population: 1997 is ~3,455; 1998 is ~2,981; 2013 is ~2,700	Annual report test laboratory department 213, Landauer exposure results, annual report for emissions of radionuclides, annual environmental report, air sample results, ALARA information, radiation and contamination surveys, area TLD information, building floor plans and property layout, film badges calibration, chronological list of radioactive materials in the plant, personnel entry into areas, decontamination reports, termination reports, evaluation of the X-ray fluorescence method, gap tubes documents, hydrogen-tritium getters, medical X-ray information, machining of U-238, magnesium-thorium alloy information, bioassay results, incident reports, radionuclide emissions reports, trip reports, safety survey, shipping documents for radioactive waste, source program data, thorium exposure levels and handing instructions, Troxell vs. Bendix files, waste trenches and machining area decontamination final report.	11/21/2013	1,202
State Contacted: NA	NOTE: Contacting the state was not considered necessary KCP is an active DOE site and cooperated with relevant data collection.	12/12/2013	0
Brookhaven National Laboratory	Compilation of ambient air monitoring parameters.	03/01/2006	1
Claimant Provided	Exposure information and air sample results.	12/14/2012	2
Department of Labor / Paragon	Production, operational, and progress reports.	01/23/2012	7
DOE Germantown	Search procedures and a plant mission policy.	08/08/2012	4
DOE Legacy Management - Grand Junction Office	Weekly progress reports, environmental assessment, machining of U-238, trip report, triple dip canning program, shipment of rods, and a low-level waste disposal capacity report.	08/29/2011	15
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Incineration of radioactive solid wastes, annual radionuclide air emission report, history of production machining of uranium, and a tritium feasibility study.	05/18/2010	6
DOE OSTI	History of the production complex and environmental restoration and waste management site maps and facilities listings.	05/17/2007	2
Federal Records Center - Atlanta	Personnel external dosimetry quality assurance.	03/19/2004	1
Federal Records Center - Kansas City	Health Physics audit by DOE Headquarters, radiological protection	10/10/2013	57

Table A1-1: Summary of Holdings in the SRDB for KCP			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
	procedures, bioassay results, dosimeter issue report, radiological surveys, Health and Safety guide for handling magnesium-thorium, TLD lab certificate of accreditation, radioactive waste inventories, radiation monitoring service results, source leak tests, ionizing and non-ionizing radiation-generating equipment inventory, personnel radiation dosimetry report, radiation protection program manual, segregation and disposing of radioactive waste, ALARA report, and radiological incidents.		
Federal Records Center - Lenexa	Personnel exposure data.	10/24/2013	10
Hanford	DOE site profiles.	01/12/2013	1
Idaho National Laboratory	DOELAP application information.	06/11/2009	2
Internet - Defense Technical Information Center (DTIC)	Uranium alloy metallurgy, LANL institutional plan, and an annual report to Congress.	01/09/2012	4
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	No relevant documents identified.	12/04/2013	0
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	Monthly reports.	10/24/2008	2
Internet - DOE Legacy Management Considered Sites	Mixed waste inventory report and a progress report.	04/23/2013	2
Internet - DOE National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant documents identified.	04/22/2013	0
Internet - DOE Environmental Management	Linking Legacies - Wastes.	10/28/2007	1
Internet - DOE OpenNet	Radiation safety and major activities in the atomic energy programs, history of nuclear weapons program, weapons production schedule, and a purchase order summary.	03/30/2012	8
Internet - DOE OSTI Energy Citations	Fifty year history of the chemical technology division at Argonne National Laboratory, annual report of waste generation, progress report, program summary, bioaccumulation monitoring and toxicity testing in streams and groundwater wells, and occupational radiation exposure.	02/01/2013	10
Internet - DOE OSTI Information Bridge	Environmental management progress and plans, report of radioactive waste inventory, report to Congress, descriptions of representative contaminated sites and facilities within the DOE Complex, summary of radionuclide air emissions, transportation and disposal configuration for DOE - managed low-level and mixed low-level waste quarterly report, annual programmatic reports, low-level waste inventory, naturally occurring arsenic in the groundwater at the Kansas City Plant, routine environmental audit, and a	01/26/2013	35

Table A1-1: Summary of Holdings in the SRDB for KCP			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
	short history of plutonium in the US and Russia.		
Internet - DOE OSTI SciTech Connect	No relevant documents identified.	04/22/2013	0
Internet - EECAP	No relevant documents identified.	12/04/2013	0
Internet - Google	Accelerating cleanup - paths to closure, ALARA analysis, onsite review report, relocating Rocky Flats plutonium operations, scope of prime contractor at Kansas City Plant, application of plasma shield technology, area air and surface dust monitoring report, legacy contamination clarification, DOE activities and plans, development of radiological profiles for low-level mixed wastes, occupational radiation exposure records, environmental assessment, toxicological profile for uranium, program assessment, events at the Rocky Flats site from the 1930s to present, final environmental assessment for the transfer of Kansas City Plant, improving the scientific basis for managing excess nuclear materials and spent nuclear fuel, Kansas City Plant mission and history, KCP Pm 147 contamination, area air and surface dust monitoring report, nuclear matters a practical guide, nuclear weapons complex weaknesses, and DOE stockpile stewardship program.	10/24/2013	123
Internet - Health Physics Journal	No relevant documents identified.	12/04/2013	0
Internet - Journal of Occupational and Environmental Hygiene	No relevant documents identified.	12/04/2013	0
Internet - National Academies Press (NAP)	Nuclear weapons complex management for health, safety, and the environment.	05/28/2010	1
Internet - NIOSH	Report on residual radioactive and beryllium contamination.	06/07/2007	1
Internet - NRC Agencywide Document Access and Management (ADAMS)	Integrated data base on spent fuel and radioactive waste inventories and a final programmatic environmental impact statement for stockpile stewardship.	09/16/2012	7
Internet - USACE/FUSRAP	No relevant documents identified.	04/23/2013	0
Internet - US Transuranium and Uranium Registries	No relevant documents identified.	04/22/2013	0
Kansas City Plant / SC&A	Department D/435 NFE shielding evaluation of leakage/exposure issues, bioassay results, promethium-147 investigation committee report, Health Physics appraisal, unusual occurrence reports, radiological surveys, low-level beta radiation detected in D/456 and D/33, radioactive waste inventories, precious materials inventories, magnesium-thorium in department 851, technical safety appraisal, nuclear safety program	08/19/2013	41

Table A1-1: Summary of Holdings in the SRDB for KCP			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
	appraisal, and employee dosimeter assignments.		
Landauer Client (site) List	No relevant documents identified.	12/12/2013	0
Los Alamos National Laboratory	Radioactive waste disposal and an environmental assessment.	12/06/2007	2
Missouri Department of Natural Resources	Draft environmental impact statement, environmental, plutonium working group safety and health vulnerabilities report, and an emergency plan.	10/01/2008	9
Mound Museum	Manufacturing statement for weapons production schedule of transfers.	05/18/2010	3
National Archives and Records Administration (NARA) - Atlanta	Inspections at Kansas City Plant and United Nuclear Corporation Hematite Plant, indoor radon study, radioactive material shipments, and an industrial accident summary.	10/20/2005	5
National Archives and Records Administration (NARA) - Atlanta / SC&A	Pinellas, Mound, Kansas City Inhalation Toxicology Research Institute Ram Inventories.	08/12/2004	1
National Archives and Records Administration (NARA) - Lee's Summit	Exposure information.	10/14/2008	2
National Institute for Occupational Safety and Health (NIOSH)	Magnesium-thorium alloys industrial health experience in fabrication and production and AEC history.	08/27/2012	11
New York State Archives	Shipment and storage of radioactive waste.	03/19/2012	1
Nevada Test Site	Final environmental impact statement.	10/01/2003	1
Nuclear Regulatory Commission (NRC) Public Document Room	Industrial health experience with magnesium-thorium alloys.	11/01/2006	1
Ohio Department of Health	Report on residual radioactive and beryllium contamination.	11/20/2007	1
ORAU Team	Documented communication on thorium oxide powder/gap tubes/ uranium and thorium machining/ tritides, recommendations on neutron weighting factors, ambient environmental dose, and occupational X-ray dose.	12/03/2013	29
SAIC	Radiation exposure summary.	09/02/2004	4
Sandia National Laboratory (SNL) - NM	Tritium bioassay data, Ross Aviation shipment surveys and shipping documents, and Ross Aviation laboratory surveys.	10/20/2010	5
Savannah River Site	Dosimetry visitor cards.	08/26/2008	1
SC&A / Idaho National Laboratory	Environmental survey and preliminary report.	06/24/2010	1
SC&A / Kansas City Plant	Internal dosimetry radiation monitoring for personnel working with depleted uranium.	07/23/2013	1
SC&A / Nevada Test Site	Report of Santa Fe Operations Office.	06/24/2010	1
SC&A / Pinellas Plant	Annual report on waste generation and minimization progress.	06/24/2010	1
SC&A / Sandia National Laboratory - CA	Albuquerque Operations annual report.	02/16/2009	1
SC&A / Sandia National Laboratory - NM	Radiological surveys.	09/15/2010	3
Southern Illinois University	AEC construction cost differentials.	10/15/2008	1

Table A1-1: Summary of Holdings in the SRDB for KCP			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Unknown	Radiological incidents, operations, and safety, Rocky Flats site history, decommissioning information, investigations and summary reports of thorium, occupational radiation exposure reports, annual reports, and DOE waste management operations.	10/04/2004	13
Y-12	Radioactive material shipment inspection reports.	05/16/2012	2
Total			**1,645**

Table A1-2: Database Searches for KCP			
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 "Copy of Kansas City Plant Rev 00 12-18-13."			
Defense Technical Information Center (DTIC) https://www.dtic.mil/ COMPLETED 12/04/2013	See Note above	231	0
DOE CEDR http://cedr.lbl.gov/ COMPLETED 12/04/2013	See Note above	0	0
DOE Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 04/22/2013	See Note above	0	0
DOE Legacy Management Considered Sites http://csd.lm.doe.gov/ COMPLETED 04/23/2013	See Note above	0	0
DOE NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 04/22/2013	See Note above	0	0
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 04/22/2013	See Note above	1,818	1
DOE OSTI Energy Citations http://www.osti.gov/energycitations/	See Note above	73,290	12

Table A1-2: Database Searches for KCP			
Database/Source	**Keywords**	**Hits**	**Uploaded into SRDB**
COMPLETED 04/22/2013			
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 04/22/2013	See Note above	71,367	6
DOE OSTI SciTech Connect http://www.osti.gov/home/osti_launch_scitech COMPLETED 04/22/2013	See Note above	378	0
Energy Employees Claimant Assistance Project (EECAP) http://www.eecap.org/index.htm COMPLETED 12/04/2013	See Note above	1	0
Google http://www.google.com COMPLETED 08/28/2013	See Note above	968,692,676	120
HP Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 12/04/2013	See Note above	45	0
Journal of Occupational and Environmental Health http://www.ijoeh.com/index.php/ijoeh COMPLETED 12/04/2013	See Note above	11	0
National Academies Press http://www.nap.edu/ COMPLETED 04/23/2013	See Note above	8,206	1
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U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 04/22/2013	See Note above	0	0