SEC Petition Evaluation Report
Petition SEC-00068

Report Rev #: 0 Report Submittal Date: August 5, 2008

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Petition Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition Qualification Date	DOE/AWE Facility Name
SEC-00068	83.13	November 20, 2007	Pantex Plant

Petitioner Class Definition
All employees who worked in all facilities at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991.

Class Evaluated by NIOSH
All employees who worked in any facility/location at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991.

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

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

Related Evaluation Report Information	
Report Title	DOE/AWE Facility Name
None	NA

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Evaluation Report Summary: SEC-00068, Pantex 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-00068, qualified on November 20, 2007, requested that NIOSH consider the following class: *All employees who worked in all facilities at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. NIOSH evaluated the following class: *All employees who worked in any facility/location at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991.*

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

Based on its full research of the class under evaluation, NIOSH has obtained numerous documents containing monitoring results, as well as Pantex process and source information. Pantex has provided monitoring data summaries from its employee exposure records databases, and current and retired site personnel have been interviewed. Employee-specific information provided through the EEOICPA claims process and Technical Basis Documents written by NIOSH have also been available for this evaluation. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

Feasibility of Dose Reconstruction

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

Health Endangerment Determination

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

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SEC Petition Evaluation Report for SEC-00068

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked in any facility/location at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

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

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

2.0 Introduction

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

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

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

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

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

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

3.0 SEC-00068, Pantex Plant Class Definitions

When a petition is submitted by a claimant, the requested class definition is evaluated as submitted. If the available site information and data justify a change in the petitioner's class definition, NIOSH will specify a modified class to be fully evaluated. After a complete analysis, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition. The following subsections address the development of the class definition for SEC-00068, Pantex Plant.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00068, which qualified on November 20, 2007, requested that NIOSH consider the following class for addition to the SEC: *All employees who worked in all facilities at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991*.

The petitioners provided information and affidavit statements in support of their belief that accurate dose reconstruction over time is impossible for the Pantex Plant workers in question. During the qualification process for SEC-00068, the petitioners made several claims using multiple petition bases. At the conclusion of the process, the petitioners proposed a Pantex SEC designation on the basis that radiation exposures and radiation doses were not monitored, either through personal or area monitoring (F1 basis). NIOSH believes that the following statement provided by the petitioners best summarizes their final claims:

> *The argument we have made is that there are inadequate individual radiation exposure monitoring data from which to perform accurate, valid, and timely dose reconstructions for members of the group. There are no data from Pantex for the majority of the workforce before 1979 and real questions* [remain] *regarding the efficacy of the Health Physics (HP) Program and Industrial Hygiene (IH) Program at this site, as reflected by workers' histories and the Tiger Team report.*

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

Because radiation exposure and area monitoring data applicable to members of the proposed class are available, NIOSH determined that the petitioner provided inadequate support to qualify the petition for additional evaluation. Furthermore, NIOSH determined that the documentation provided by the petitioners did not provide adequate support for their F1 basis, and in some cases the documentation was not provided in the required affidavit format.

Following NIOSH's determination, the petitioners requested an administrative review of NIOSH's proposed finding to deny qualification of the petition. The Administrative Review panel decided that the petitioners had provided sufficient information to raise some doubts regarding the adequacy of the monitoring data at Pantex; therefore, the review panel recommended that the petition qualify for a full evaluation.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-proposed class with a slight modification of the petitioner-requested definition (i.e., "worked in all facilities" was changed to "worked in any facility/location"). Therefore, NIOSH defined the following class for further evaluation: All employees who worked in any facility/location at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991.

3.3 NIOSH-Proposed Class to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has obtained numerous documents containing monitoring results, as well as Pantex process and source information. Pantex has provided monitoring data summaries from its employee exposure records databases, and current and retired site personnel have been interviewed. Employee-specific information provided through the EEOICPA claims process and Technical Basis Documents written by NIOSH have also been available for this evaluation. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

NIOSH identified and reviewed numerous data sources to locate 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. As part of NIOSH's evaluation detailed herein, it examined the following TBDs for insights into Pantex Plant operations or related topics/operations at other sites:

- *TBD for the Pantex Plant – Introduction*, ORAUT-TKBS-0013-1; Rev. 02; May 11, 2007; SRDB Ref ID: 20152
- *TBD for the Pantex Plant – Site Description*, ORAUT-TKBS-0013-2; Rev. 02; May 8, 2007; SRDB Ref ID: 20153
- *TBD for the Pantex Plant – Occupational Medical Dose*, ORAUT-TKBS-0013-3; Rev. 02; February 1, 2007; SRDB Ref ID: 20154
- *TBD for the Pantex Plant – Occupational Environmental Dose*, ORAUT-TKBS-0013-4; Rev. 01; June 22, 2007; SRDB Ref ID: 20155
- *TBD for the Pantex Plant – Occupational Internal Dose*, ORAUT-TKBS-0013-5; Rev. 01; June 22, 2007; SRDB Ref ID: 26727
- *TBD for the Pantex Plant – Occupational External Dose*, ORAUT-TKBS-0013-6; Rev. 01; June 22, 2007 SRDB Ref ID: 11068

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. An ORAU Procedure provides specific requirements and guidance regarding EEOICPA project-level activities, including preparation of dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs and procedures as part of its evaluation:

- *OTIB: Maximum Internal Dose Estimates for Certain DOE Complex Claims*, ORAUT-OTIB-0002, Rev. 02; February 7, 2007; SRDB Ref ID: 29947
- *OTIB: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 03 PC-1; December 21, 2005; SRDB Ref ID: 20220
- *OTIB: Interpretation of Dosimetry Data for Assignment of Shallow Dose*, ORAUT-OTIB-0017, Rev. 01; October 11, 2005; SRDB Ref ID: 19434
- *OTIB: Internal Dose Overestimates for Facilities with Air Sampling Programs*, ORAUT-OTIB-0018, Rev. 01; August 9, 2005; SRDB Ref ID: 19436
- *OTIB: Analysis of Coworker Bioassay Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Rev. 00; December 29, 2004; SRDB Ref ID: 19439
- *OTIB: Estimating Doses for Plutonium Strongly Retained in the Lung*, ORAUT-OTIB-0049, Rev. 00; February 6, 2007; SRDB Ref ID: 29975

- *OTIB: Internal Dose Reconstruction*, ORAUT-OTIB-0060, Rev. 00; February 6, 2007; SRDB Ref ID: 29984

- *PROC: Occupational Onsite Ambient Dose Reconstruction for DOE Sites*, ORAUT-PROC-0060, Rev. 01; June 28, 2006; SRDB Ref ID: 29986

- *PROC: Occupational X-Ray Dose Reconstruction for DOE Sites*, ORAUT-PROC-0061, Rev. 02; January 2, 2008; SRDB Ref ID: 39338

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed former Pantex employees and reviewed the documentation associated with interviews performed as part of the ORAU Site Profile development. Interviewee selection was based on individual availability and the potential knowledge of Pantex working conditions during the period of the proposed class. For the current SEC interviews, NIOSH developed and refined interview questions based on interviewees' job titles and work experiences. Information obtained during these interviews contributed to NIOSH's general knowledge of Pantex Plant conditions and monitoring practices.

- Personal Communication, April 7, 2008, *Personal Communication with [Name Seven Redacted]*, communication with a former Pantex Weapons Engineer; April 7, 2008; SRDB Ref ID: 45919

- Personal Communication, October 1, 2003, *Personal Communication with [Name Eight Redacted]*, communication with a member of the Pantex Radiation Safety Department; October 1, 2003; SRDB Ref ID: 11077

- Personal Communication, September 24, 2003a, *Personal Communication with [Name Nine Redacted]*, communication with Pantex Training Manager; September 24, 2003; SRDB Ref ID: 11078

- Personal Communication, June 29, 2003, *Personal Communication with [Name Four Redacted]*, communication with Pantex Safety Engineer; June 29, 2003; SRDB Ref ID: 11079

- Personal Communication, October 8, 2003, *Personal Communication with [Name Five Redacted]*, communication with former Pantex Radiation Safety Manager; October 8, 2003; SRDB Ref ID: 11081

- Personal Communication, September 24, 2003b, *Personal Communication with [Name Six Redacted]*, communication with retired Pantex Training Manager; September 24, 2003; SRDB Ref ID: 11083

- Personal Communication, September 23, 2003, *Personal Communication with [Name Ten Redacted]*, communication with former Pantex employee; September 23, 2003; SRDB Ref ID: 11084

- Personal Communication, June 20, 2003 & May 27, 2004, *Personal Communication with [Name Four Redacted]*; communication with Pantex Safety Engineer; June 20, 2003 and May 27, 2004; SRDB Ref ID: 14542

- Personal Communication, June 16, 2004, *Personal Communication with [Name Four Redacted]*; communication with Pantex Safety Engineer; June 16, 2004; SRDB Ref ID: 13467

- Personal Communication, October 11, 2006, *Personal Communication with [Name Eleven Redacted]*; communication with Pantex Safety Engineer; October 11, 2006; SRDB Ref ID: 27015

- Personal Communication, April 8, 2008, *Personal Communication with [Name Five Redacted]*; communication with site expert; April 8, 2008; SRDB Ref ID: 46110

In addition to the personal communications listed above, two additional interviews were conducted. However, notes from these interviews have not been returned from the Pantex site. Additionally, Computer-Assisted Telephone Interviews (CATI) conducted with Pantex claimants provided more detailed information as noted in Section 4.4 below.

4.4 Previous Dose Reconstructions

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

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

Description	Totals
Total number of claims submitted for dose reconstruction	380
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (January 1, 1951 through December 31, 1991)	357
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation[1]	244
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	157
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	240

Notes:
[1] Number reflects the number of claims completed by NIOSH and submitted to the Department of Labor (DOL) for final approval.

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. As indicated in Table 4-1, NIOSH has been able to obtain monitoring data for many of the claims that meet the proposed class definition. Of the total number of claims submitted for energy employees that meet the worker class definition being evaluated in this report, 157 (44%) contain internal monitoring data and 240 (67%) contain external monitoring data.

The CATI conducted with Pantex claimants provided additional detailed information regarding work locations, hours worked, incidents, and hazards encountered. The CATI also identified conditions for which there would have been potential for either internal or external exposures.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the evaluation of the proposed class. Five hundred ninety-six documents in this database were identified as pertaining to Pantex. These documents were evaluated for their relevance to this petition. The documents include historical background on external and internal dosimetry programs and evaluations, monitoring summary reports, annual environmental reports, reviews and assessments of the Pantex Plant, evaluations of specific buildings, site surveys, and facility and process descriptions.

4.6 Other Technical Sources

In addition to its own SRDB, NIOSH also examined data contained within the following repositories:

- Historical Exposure Records System (HERS), located at the Pantex Plant (now incorporated into the Dosimetry Records Management System)

- Dosimetry Records Management System (DoRMS), located at the Pantex Plant

- Optix® Imaging System (a document imaging storage system), located at the Pantex Plant

4.7 Documentation and/or Affidavits Provided by Petitioners

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

- *Petition Form B*; [Name One, Name Two, and Name Three Redacted]; September 6, 2006; OSA Ref ID: 100557

- *Letter of Transmission for SEC Petition*; [Name One Redacted]; September 6, 2006; OSA Ref ID: 101753

- *Table 6.1-1 History of External Radiation Exposures at the Pantex Plant*, extracted from an October 1998 Safety Information Document; OSA Ref ID: 100559, pp. 1-4

- *Table 6.1-2 History of Internal Radiation Exposures at the Pantex Plant*, extracted from an October 1998 Safety Information Document; OSA Ref ID: 100559, pp. 4-5

- *Table 6.1-3 Percent of Total Doses Attributed to Neutron Radiation*, extracted from an October 1998 Safety Information Document; OSA Ref ID: 100559, p. 6

- *Three Pantex Incident Descriptions*, extracted from an October 1998 Pantex Safety Information Document; OSA Ref ID: 100559, pp. 8-10

- *Abstract from Mortality Update for the Pantex Weapons Facility: Final Report Health-Related Energy Research Branch*, a 1990 NIOSH epidemiologic study; OSA Ref ID: 100559, pp. 11-12

- *Various excerpts from the 1990 Tiger Team Assessment of the Pantex Plant Amarillo, Texas, DE000634*; OSA Ref ID: 100559, pp. 12-19

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at the Pantex Plant from January 1951 through December 1991 and the radiological exposure source information available to NIOSH that characterizes 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 Pantex Plant Process Descriptions and Facilities

Located approximately 17 miles northeast of Amarillo, Texas (in the Texas panhandle), the Pantex Plant played an important role in the U.S. Nuclear Weapons program. Operations included fabricating high explosives and assembling and disassembling nuclear weapons.

5.1.1 Pantex Plant Process Descriptions

<u>ATTRIBUTION</u>: Section 5.1.1 was completed by Jerome Martin, Dade Moeller and Associates. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The Pantex Plant, one of the last plants built by the United States to support the war effort during the World War II era, was built to load, assemble, and pack ordnance. The original WWII-era work at Pantex was all non-nuclear. By the end of the war, Pantex had three loading lines running full-time. World War II operations at Pantex stopped the week after the war ended (Mitchell, 2003). Because the original scope of the work is not related to nuclear weapons operations/activities, this timeframe is not covered under the EEOICPA radiological dose reconstruction program (i.e., not included in the NIOSH-evaluated worker class for this petition or included in the evaluation performed within this report).

In 1951, the U.S. Atomic Energy Commission (AEC) was looking for a new High Explosives (HE) Fabrication plant, and decided on the unused 6-year-old HE loading line at Pantex. AEC contracted with Silas Mason Company to construct 10 new buildings and modify three other buildings; construction began on April 13, 1951 (Mitchell, 2003).

Pantex completed its first HE operations in December 1951. By mid-1952, Pantex was at full production and was responsible for HE fabrication, assembly of nonnuclear components, retrofits, modifications, and disassembly for retirements. Between 1952 and 1954, Pantex's primary mission was to precision-machine HE castings before sending them to Sandia National Laboratory for assembly. The retrofits and modifications, performed during the 1952 through 1957 timeframe, involved in-flight insertable nuclear weapons (i.e., the insertable pits required to make a complete nuclear weapon were not handled at Pantex). Since these weapons did not yet contain pits, the only nuclear component involved prior to 1957 was depleted uranium (DU). Beginning in 1957, tritium reservoirs were received from the Savannah River Plant, and in 1958, the Rocky Flats Plant started shipping sealed plutonium pits to Pantex (Personal Communication, June 29, 2003 & May 27, 2004; Personal Communication, June 29, 2003). With the advent of the sealed-pit design in 1958, all assembly and disassembly work was performed on complete, sealed-pit weapons (Mitchell, 2003).

The nuclear weapons assembly process was highly standardized and consistent. Rigorous procedures were followed to ensure product quality and uniformity. Classified records documented every step of the assembly and disassembly of every weapon, including the badge number or inspection stamp of the person completing the step (Personal Communication, September 24, 2003a; Personal Communication, April 2008).

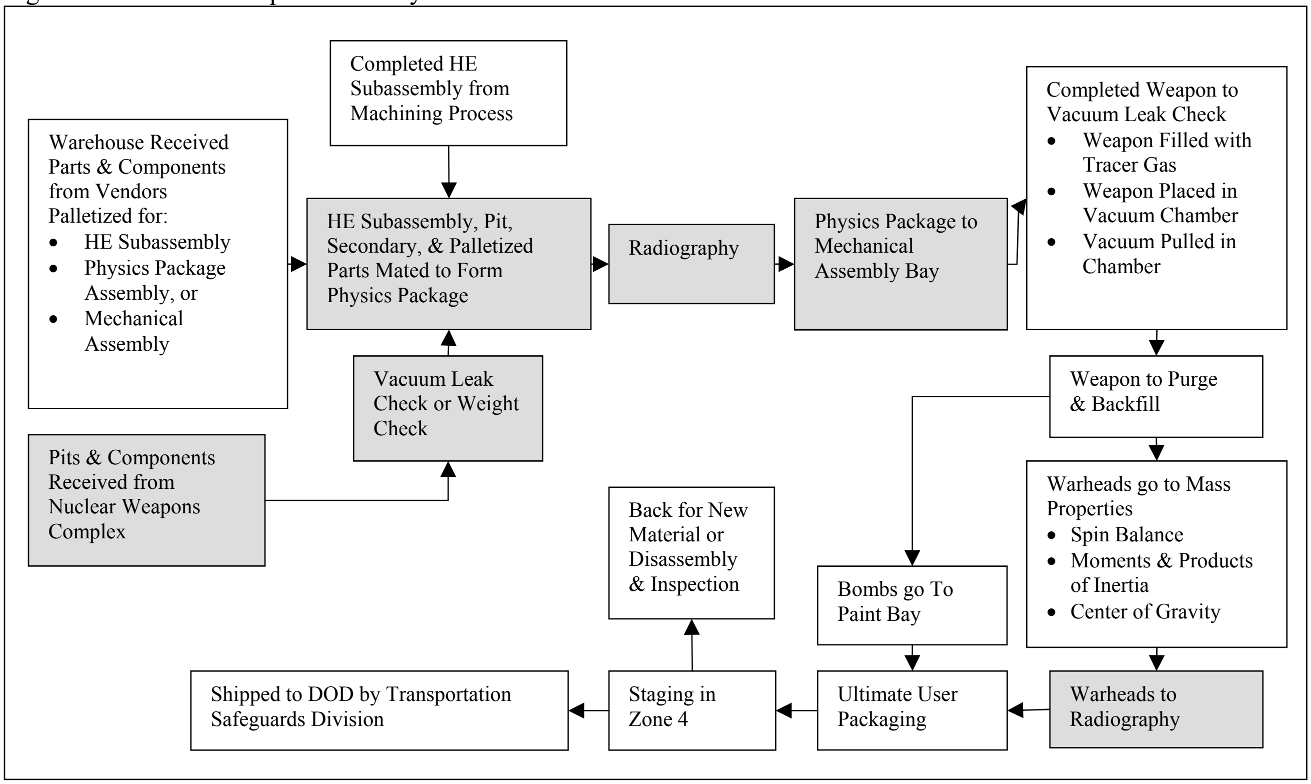
Most nuclear weapon assembly parts were manufactured within the Nuclear Weapons complex of government-owned/contractor-operated facilities. Pantex received nuclear parts as completed major components (Mitchell, 2003). These components supported one of three major processes: HE subassembly, mechanical assembly, or "physics package" (1958 and later). Unlike the physics package, the HE subassembly and mechanical assembly did not involve any radioactive components.

The physics package operation (1958 and later) involved combining the HE subassembly with the nuclear components. Once assembled into a single unit, the physics package was sent to the Non-Destructive Examination section for radiography. Next, it was sent to Mechanical Assembly where the weapon was built around the physics package. The completed weapon was checked for leaks by filling the weapon with a tracer gas such as helium or argon, placing the weapon in a vacuum chamber, and applying a vacuum in the chamber to detect any tracer gas leaking from the weapon. After the vacuum leak check was successfully completed, the interior of the weapon was purged and backfilled with an inert gas, usually nitrogen (BWXT, 2001).

Warheads were sent to the Mass Properties area for spin balancing, to test moments and products of inertia, and to test the center of gravity. Once the mass properties procedures were complete, warheads were sent back to the Non-Destructive Examination section for radiography. Bombs from the paint bay and warheads from radiography were both processed for ultimate user packaging, which included final checks on stenciling, serial numbers, and other program-specific documentation. Completed and packaged weapons were staged for shipment to the U.S. Department of Defense (DOD) (BWXT, 2001).

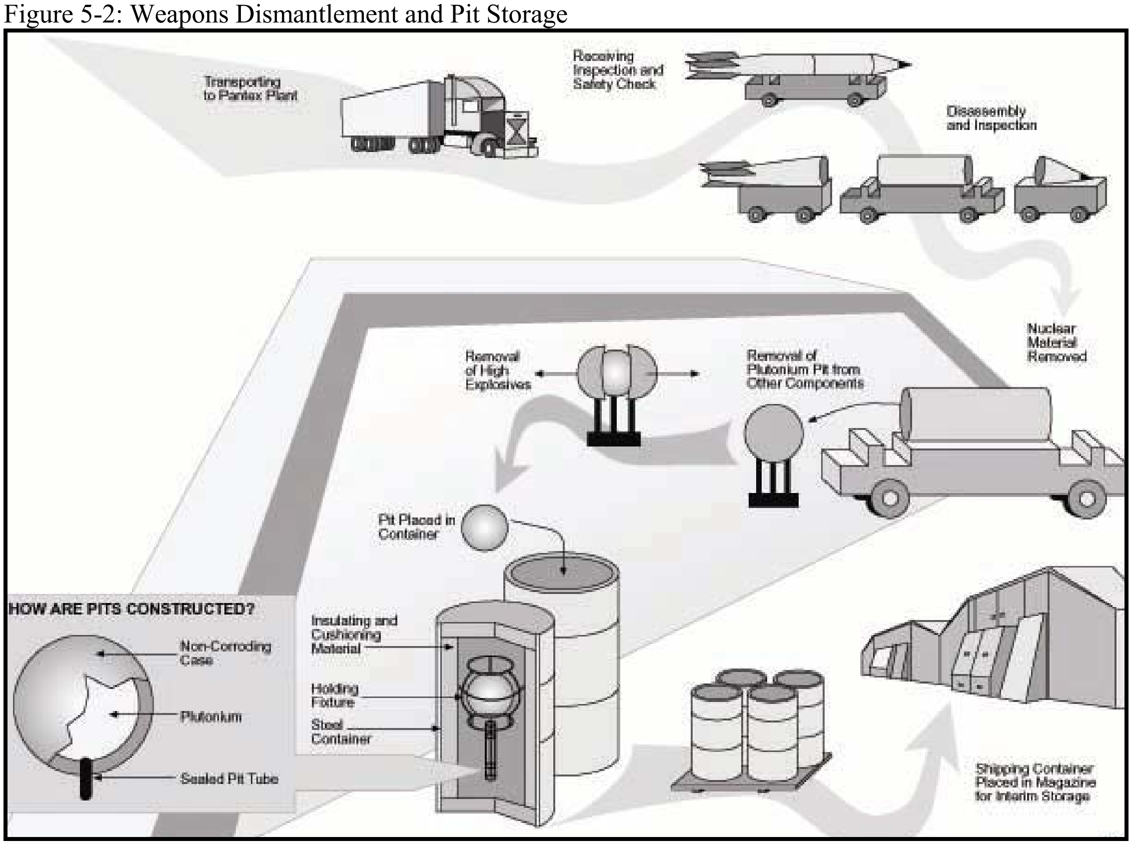
Figure 5-1 is a schematic illustration of the weapon assembly process at Pantex Plant. The shaded steps are those with the highest potential for radiation exposure. Figure 5-2 shows how the dismantlement of nuclear weapons at Pantex Plant was basically the reverse of the assembly process (Mitchell, 2003).

Figure 5-1: Nuclear Weapon Assembly Process



Source: Mitchell, 2003

Figure 5-2: Weapons Dismantlement and Pit Storage



Source: Mitchell, 2003

5.1.2 Pantex Plant Facilities

ATTRIBUTION: Section 5.1.2 was completed by Jerome Martin, Dade Moeller and Associates. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

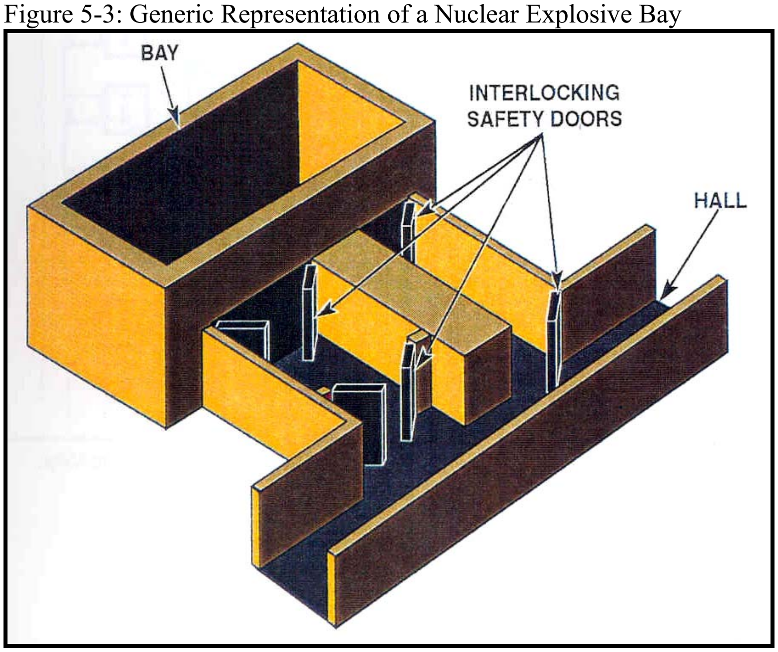
Major operations included staging special nuclear materials in Zone 4 and assembling and disassembling nuclear weapons in Zone 12 South (BWXT, 2001). The Moderate-hazard facilities at Pantex were primarily used for assembly and disassembly. The Special-Purpose and Nuclear Staging facilities handled the completed nuclear weapons (nuclear explosives) and components (BWXT, 2001). The bays, cells, Special-Purpose facilities, and Nuclear Staging facilities at Pantex are described below.

Bays

Figure 5-3 shows a generic bay situated off a ramp or hall for transport of a weapon or weapon component into the bay. Bays were accessed through a pair of interlocked blast-proof doors, which prevented the outer door from opening unless the inner door was closed (and vice-versa). A pair of double doors (also with an interlocking system) was used to bring equipment into the bay. A special work stand for weapons work occupied the middle of the floor space (ORAUT-TKBS-0013-2).

The principal functions of the bays were the assembly and disassembly of nuclear explosives, particularly the mechanical portion, which included the electrical components and tritium reservoirs (BWXT, 2001). The major operations in these bays included the partial assembly or disassembly of nuclear weapons containing HE and the complete assembly and disassembly of nuclear weapons containing insensitive high explosives (IHE).

Figure 5-3: Generic Representation of a Nuclear Explosive Bay



Source: Mitchell, 2003

Alpha and tritium continuous air monitors, connected to the Pantex Radiation Alarm Monitoring System (RAMS), were used to detect airborne radiological contamination in the bays and cells

(BWXT, 2001). The Radiation Safety system in the radiography bays provided interlocking safety devices to protect workers from accidental exposures (BWXT, 2001). Additional safety measures included interlocks between the operating controls; gamma radiation detectors; panic switches; warning lights, chimes, and horns; passageway door switches; and fire alarms.

Nuclear explosive assemblies and subassemblies were inspected and certified in the radiography bays, which currently house an 8-million-electron-volt (MeV) linear accelerator (Linac) and a 9-MeV Linac (BWXT, 2001). The current radiography bays were built in 1970. Prior to that time, the original radiography machines and sources were used primarily in Building 12-21 (BWXT 2001). Per a NIOSH interview with an early radiation safety officer (Personal Communication, April 7, 2008), the original radiography equipment at Pantex included a 1 MeV X-ray, Ir-192, Cs-137, and Co-60 sources.

Additional details regarding bay operations are provided in ORAUT-TKBS-0013-2.

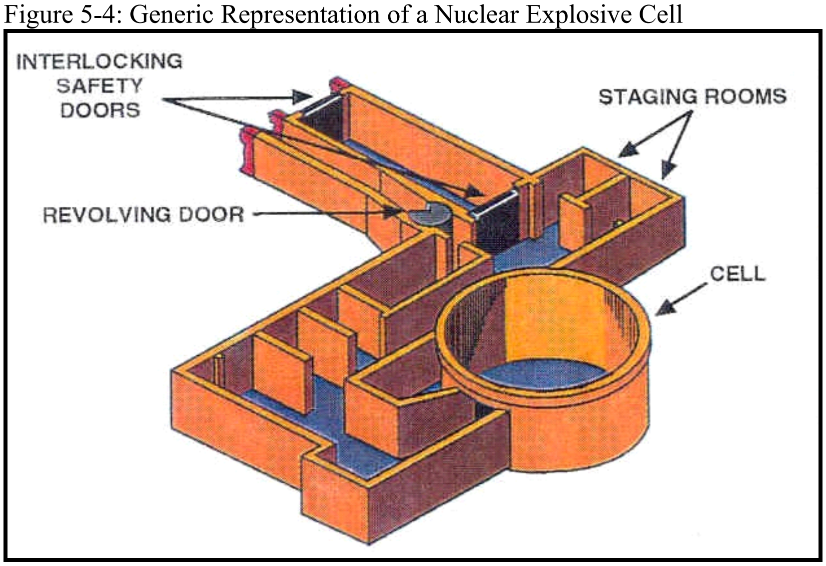
Cells

The principal functions of the cells included the assembly and disassembly of nuclear explosives, particularly operations on the physics package of nuclear explosives that contained HE; work on nuclear explosives that contained IHE could be performed in the bays (BWXT, 2001).

The cell facilities consisted of a round room, staging rooms, a corridor area, and a unit equipment/mechanical room. All of these areas were inside the blast-resistant cell structure and provided protection from external events, including external explosions, winds, and tornados.

The mounded earth and gravel cover over a cell was supported by a cable catenary system. The cables were suspended from the top of a cell's round room wall. The cell roof consisted of the support cables, layers of wire mesh, gravel and earth coverings, and a gunite or concrete cap. Figure 5-4 shows a generic cell design (Mitchell, 2003).

Figure 5-4: Generic Representation of a Nuclear Explosive Cell



Source: Mitchell, 2003

Cell design was based on “Gravel Gertie” experiments showing that the cell structure largely dissipated blast pressures (BWXT, 2001). The mounded gravel roof over the round room was designed to lift and vent gas pressure produced in an explosion. Plutonium was filtered from the vented gases by the gravel structure so that releases into the environment would be minimized. The equipment passageway doors were designed to remain intact in the event of an accidental detonation, and the doors were interlocked so that only one door at a time could be opened. The two blast doors were also interlocked.

Additional details regarding cell operations are provided in ORAUT-TKBS-0013-2.

Special-Purpose Facilities

The Special-Purpose facilities at Pantex included the Paint facility, the Separation Testing facility, the Mass Properties facility, the Weapons Aging facility, and the Weapons Transfer Station (BWXT, 2001). Details regarding these facilities are provided in ORAUT-TKBS-0013-6.

Nuclear Staging Facilities

Nuclear Staging facilities were located in Zone 4 and Zone 12-South. Zone 4 facilities were used as a staging or interim storage area for weapons, weapon components, and other process-related materials (BWXT, 2001). Nuclear explosive components without HE were staged in Zone 12 facilities, including pit vaults, warehouses, and Special Nuclear Material (SNM) component staging facilities (BWXT, 2001). Details regarding these facilities are provided in ORAUT-TKBS-0013-6.

Burning Grounds and Firing Site

The burning grounds were used to burn waste HE, some of which was contaminated with uranium-238 (Drummond, 1971). Burning HE was a part-time task for Transportation Department workers involving a few hours approximately once a week. Only a few workers would have been involved during any single burn. The ignition operators were about 100 yards from the burn pad during each burning. Access for all other workers was restricted to about 300 yards or more. Ash from the burn was collected and placed in 10- to 20-gallon cans for burial. Operators wore half-face respirators with high-efficiency particulate air filters during the ash collection task (Personal Communication, June 16, 2004).

Pantex has used firing sites for HE quality control and research since 1952. Some of the test firings at Firing Sites 4, 5, and 10 involved DU through 1985 (DOE, 1997, Chapter 7). According to a former employee who worked at the firing sites from 1959 to 2000 and was supervisor of the firing site since 1960, the first hydroshot that involved DU occurred in late 1959 or 1960 (Personal Communication, October 11, 2006). According to this supervisor, operators were in a bunker a few tens of feet from the detonation site. The bunker was fully enclosed with a ventilation system that was shut down during the detonation. After the detonation, the operators walked to ground zero to retrieve their instruments. A driver, who was outside the fenced area (approximately 2,000 feet from ground zero), drove to the detonation site to retrieve the operators. The total exposure time for the operators was less than 30 minutes. The cloud from the detonations was clearly visible and the operators and driver avoided direct exposure to the cloud (Personal Communication, June 16, 2004).

5.2 Radiological Exposure Sources from Pantex Plant Operations

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

5.2.1 Internal Radiological Exposure Sources from Pantex Plant Operations

ATTRIBUTION: Section 5.2.1 and its related subsections were completed by Melton Chew, M. H. Chew and Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The major workplace radiation environments that contributed to internal exposure involved nuclear weapons components assembly and disassembly, high explosives research and development, weapons evaluation, and component storage. This historically included tritium, uranium (U-234, U-235, U-238, and uranium metal), thorium (Th-232), and plutonium (Pu-238 and Pu-239). Modification operations, assembly, and disassembly activities started at the Pantex Plant in the summer of 1952. The weapons dismantlement function has existed since the latter part of 1952 (DOE, 1995).

As noted in Section 5.1, the retrofits and modifications, performed during the 1952 through 1957 timeframe, involved in-flight insertable nuclear weapons. Since these weapons did not yet contain pits, the only nuclear component involved prior to 1957 was DU. Because DU components were new at the time of assembly, there was minimal potential for depleted uranium oxide contamination on the components (Personal Communication, October 8, 2003; Davis, 1967). Likewise, the potential for significant removable plutonium or tritium contamination (1957 and later) was minimal because the sealed plutonium pits and tritium reservoirs had to meet rigorous shipping requirements. Records indicated that very little, if any, contamination was detected on weapon components (Davis, 1967). The only other sources of radiation exposure at Pantex during this early period were industrial radiography and medical X-rays (Personal Communication, September 24, 2003b).

Workers may have been exposed to indoor radon and its short-lived radioactive daughter products at select facilities within the Pantex complex (the source of this exposure being the natural source of radiation and radioactive decay associated with the materials that were used in the construction of some facilities at Pantex).

5.2.1.1 Uranium

Uranium at Pantex was enriched, natural, and depleted. All of the unsealed uranium used at the Pantex facility was either depleted uranium or natural uranium. Natural uranium was in a form referred to as tuballoy. Kilogram quantities of enriched uranium were processed through the Pantex Plant. Weapons processed at Pantex contained enriched uranium as a part of the primary and/or secondary component (with composition was up to 93.5% in some units). Some weapons had composite pits that contained both uranium and plutonium. Enriched uranium was always associated with a sealed component with little likelihood of release and therefore not considered a significant potential exposure source for the proposed worker class evaluated in this report. Many of the weapons containing enriched uranium have been modified or dismantled since the closure of the Medina, Clarksville, and Iowa weapons plants (ORAUT-TKBS-0013-5).

Beginning in 1952, some DU was released at the burning grounds through burning DU contaminated high explosives. Some DU was also released at the hydro test firing sites when hydro tests involved DU components (Firing Sites 4, 5, and 10 only). Machining was performed on DU for a period in the early 1960s for one particular weapon design (Personal Communication, June 29, 2003 & May 27, 2004).

5.2.1.2 Tritium

Tritium was introduced into weapons systems in the late 1950s. Reservoirs began arriving at Pantex in late 1956 or early 1957 (ORAUT-TKBS-0013-5). The primary form of tritium used in the Pantex weapons programs was gas contained in pressured gas cylinders (reservoirs) (BWXT, 2004). During disassembly of tritium-containing parts there were routine and expected small releases of tritium into the work space. Portable tritium monitors were used to detect tritium off-gassing, and local ventilation was available.

A Cockcroft Walton neutron generator in use before 1956 also produced some tritium in the off-gas, and titanium tritide particulate contamination probably existed in the target and the area where the drift tube connected to the target, but the amount would have produced negligible intakes (ORAUT-TKBS-0013-5). Tritium sealed under high pressure in the reservoir units has the potential to leak during disassembly. The *Internal Dosimetry Technical Basis and Quality Assurance Document* states that tritium could leak through reservoir materials, which presumably refers to concern for migration of molecular tritium through welds. The tritium in the reservoirs is 99% gaseous molecular hydrogen (DT, HT, or T_2) and 1% tritiated water vapor (HTO or T_2O) (Pantex Plant, August 2001).

Tritium gas interacts over time with moisture in the air, hydrogenated materials (e.g., hydrocarbons, organic compounds, and concrete), and some forms of metals to form tritiated compounds and metal tritides (Peterson, 2002).

The potential for tritium compound exposure existed at Pantex. Tritides were formed as a result of the tritium gas reacting with metal components of weapons and producing tritiated compounds. In addition, tritium compounds were used in some weapons programs.

5.2.1.3 Plutonium

Weapons components that contained plutonium were hermetically sealed units. Since the late 1950s, these units were inventoried and tracked. Particular radionuclides of plutonium were also used in other capacities in the weapons system. The components were surveyed upon arrival at the plant and through various stages of assembly and disassembly. Pantex serves as the interim storage for plutonium components and continues to monitor them (Pantex Plant, August 2001).

Plutonium at Pantex was located in the encapsulated pits of nuclear weapons. Strict workplace monitoring practices, including contamination smear checks during assembly and disassembly, ensured the integrity of the encapsulation (Pantex Plant, August 2001).

5.2.1.4 Thorium

Thorium was handled during assembly, modification, and disassembly of particular weapons programs. Thorium at Pantex existed as thorium metal, thorium alloys, or materials impregnated with a thorium compound. Workers handled these forms during assembly and disassembly of certain weapons. Because of the relative hazard of thorium, Pantex used strict workplace monitoring practices, including smear checks of components, to verify the integrity of the thorium encapsulation. Although information regarding source terms of weapons containing thorium is still classified, it is assumed that workers could have encountered oxidized thorium components during disassembly of weapons in the mid-1960s. Pantex has never conducted machining of components containing thorium (ORAUT-TKBS-0013-5, Section 5.2.3).

5.2.1.5 Radon

While the general characteristics of areas with the potential for elevated levels of indoor radon, as well as construction designs that tend to enhance radon levels, are known, it is rarely possible to predict indoor radon levels for a given structure. In general, structures that exhaust air to the environment without adequately engineered replacement air have higher indoor radon levels than do better-engineered structures. In addition, structures that have exposed soil (dirt floors, sumps) or exposed minerals (e.g., gravel) tend to have higher radon levels. Underground structures have a higher ratio of soil surface to building volume. All other factors being equal, an underground building would be likely to have a higher radon concentration than an aboveground building.

At Pantex, the Gravel Gertie cells were in Buildings 12-44, 12-85, 12-96, and 12-98, which were considered to be underground even though they are not below-grade. Bays, which were also considered underground, were in Buildings 12-17, 12-19, 12-21, 12-56, 12-64, 12-84 East, 12-84 West, 12-99, 12-104, and 12-117. Workers in these buildings were likely to have greater exposures to radon and its decay products than workers in other buildings (ORAUT-TKBS-0013-5).
The radon progeny associated with thorium (Rn-220) is a radioactive noble gas, commonly called thoron. Thoron has a much shorter half-life (55.6 seconds) than its parent. In general, Rn-220 decays before it can build up to significant levels unless there are large quantities of Th-232 and its decay products present. Based on this information, and because work on thorium weapons was infrequent (ORAUT-TKBS-0013-5), there is no reason to expect that Pantex had significant Rn-220.

5.2.2 External Radiological Exposure Sources from Pantex Plant Operations

ATTRIBUTION: Section 5.2.2 and its related subsections were completed by Melton Chew, M. H. Chew and Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

Details regarding Pantex workers handling sources of radiation, such as depleted uranium, plutonium, and other nuclear weapon materials, involve classified information. Work activities varied over time. Analysis of historical information showed that assembly activities at Pantex began in 1952, which corresponds with the first record of personnel monitoring (Carr, unknown date). The nature of the radiation fields a Pantex worker could have encountered depends on the type of facility in which the work occurred. Nuclear weapons components emit alpha, beta, X-rays, gamma rays, and neutrons; however, doses to workers depend strongly on the configuration (i.e., material and shielding) of the source of radiation and the work performed (BWXT, 2001). In addition, industrial radiography operations had the potential to expose some workers to X-ray, gamma, and neutron radiation.

At first, Pantex issued dosimeters only to workers likely to receive a significant radiation dose per existing radiation protection guidelines. From 1952 through 1957, this included only radiographers;

other sources for significant external exposures were minimal (Personal Communication, April 7, 2008). From 1958 through 1988, only radiation workers were monitored. From 1989 to 2005 (up to the time that ORAUT-TKBS-0013-6 was completed), all Pantex workers were monitored for external radiation exposure.

5.2.2.1 Photon

Photon radiations encountered at Pantex have widely-varying energies, ranging from about 30 keV to a few MeV (ORAUT-TKBS-0013-6). Of the various photon radiation sources at Pantex, the lowest energy (about 30 keV) was produced by X-ray diffraction machines. The highest energy (2.6 MeV) is produced by the thorium decay product thallium-208. Table 5-1 summarizes the photon-emitting radionuclides and corresponding emission energies found at Pantex. The cladding on plutonium pits attenuates the low-energy photons and X-rays associated with the respective plutonium decay chains.

Table 5-1: Pantex Plant Photon-Emitting Radionuclides

Radionuclide	Energy (MeV)
Thorium-232 decay series	Up to 2.614
Uranium-235 decay series	Up to 0.898
Uranium-238 decay series	Up to 2.204
Americium-241	0.014 (43%), 0.060 (36%)
Plutonium-238	0.014 (12%)
Plutonium-239	0.014 (4%)
Plutonium-240	0.014 (11%)

Source: Schleien, 1998

Sources of photon radiation have included weapon components, analytical devices employing X-rays produced by radiation-generating devices, and low-activity radioactive sources such as those used to check or calibrate radiation detectors (ORAUT-TKBS-0013-6).

Weapons assembly at Pantex has been performed with nuclear components of purified metals. The purification process separates progeny radionuclides from their parent metals, which provides some insight into potential sources of radiation. However, weapons-grade plutonium contains several isotopes of plutonium, including various amounts of Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242. With a half-life of 14.4 years, Pu-241 immediately begins to decay to Am-241.

Am-241 starts accumulating within the plutonium matrix as a daughter product resulting from the decay of Pu-241 immediately as its parent radionuclide Pu-241 decays with a half-life of 14.4 years. The Am-241, which emits 60-keV photons, reaches maximum activity after about 80 years, but it reaches about 85% of this maximum in 40 years (ORAUT-TKBS-0013-6). Thus, for nuclear weapons activities, Am-241 was an increasingly significant source of exposure to workers performing weapons disassembly, which often occurred many years after assembly (ORAUT-TKBS-0013-6).

5.2.2.2 Beta

The sources for beta exposures at Pantex were associated primarily with depleted and enriched uranium (ORAUT-TKBS-0013-6). However, beta particle-emitting radioactive materials used at Pantex also included tritium and thorium. Table 5-2 lists the beta-emitting radionuclides and their maximum beta energies; the average beta energy is approximately 1/3 of the maximum energy. Beta emissions from tritium are not considered an external radiation hazard, due to their very low energy.

Table 5-2: Pantex Plant Beta-Emitting Radionuclides

Radionuclide	Maximum Energy (MeV)
Tritium (Hydrogen-3)	0.018
Thorium-232 decay series	0.039, 0.334, 2.246, 1.800
Uranium-235 decay series	0.205, 0.287, 0.304
Uranium-238 decay series	0.189, 2.280

Source: Schleien, 1998

5.2.2.3 Neutron

There have been three main types of facilities or activities at Pantex with the potential for neutron exposure to workers: (1) bays and cells, (2) vaults and igloos (storage facilities), and (3) transportation (BWXT, 2001). The specific workplace neutron fields for selected types of nuclear weapon components are classified. Unclassified information on neutron spectra from fission and sealed plutonium sources is available.

Plutonium pits that are not associated with high explosives are referred to as “bare pits,” although all pits are sealed or encapsulated (Shipler, 2004). Assembly and disassembly operations that occur in cells comprise the only times workers have been exposed to neutrons emanating from bare pits. In the workplace, these spectra are significantly changed through scattering in nuclear weapon components, equipment, and building materials. The average energy is higher for unshielded neutrons resulting from plutonium and beryllium interactions than for fission neutrons (ORAUT-TKBS-0013-6).

With a change in algorithm from 1992 to 1993, some questions were raised about the overestimation of neutron dose during this period (ORAUT-TKBS-0013-6). For this reason, the TBD proposes to employ neutron-to-photon ratios for the period prior to 1994.

The TBD neutron-to-photon ratios are based on worker dosimeter measurements that were recorded using the Panasonic UD-809/UD-812 system and correspond to doses in which both the photon and neutron doses of the individual exceeded 50 mrem per year. From these data, a median neutron-to-photon ratio of 0.8 and a 95th percentile value of 1.7 were calculated. For dose reconstruction of monitored workers, NIOSH recommends the 95th percentile neutron-to-photon ratio of 1.7.

5.2.3 Incidents

ATTRIBUTION: Section 5.2.3 was completed by Melton Chew, M. H. Chew and Associates, Inc. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

Incidents that occurred at the Pantex Plant were documented and worker exposures were assessed when incidents involved radioactive sources. Incident reports are still maintained at Pantex; copies of many of these reports have been obtained through data capture efforts and are now also included in the SRDB. A list of Pantex incident/accident report titles applicable to the NIOSH-evaluated timeframe has been reviewed by NIOSH (Author unknown, 1970-1989; Author unknown, 1961-2007).

Documented monitoring data obtained from response work is available for bounding the doses associated with incidents that occurred at Pantex. There is no indication that any incidents occurred that resulted in exceptionally high exposures/doses (like a criticality) to Pantex workers. Summaries of three of the most significant incidents that occurred during the evaluation time frame are provided below.

An incident of plutonium exposure occurred in 1961. The details of the event are classified, but NIOSH has access to associated data that can be used to estimate intakes. These data include external dosimetry results and bioassay data from the employees involved in the incident and subsequent decontamination. Cell air monitoring data are also available.

Sometime just before November 14, 1978 (exact date not known), a nuclear materials inventory of a Nuclear Weapons Accident Residue (NWAR) storage cylinder was attempted. The mounded earth overcap was removed and the cylinder was opened. Heavy rainfall occurred during the time that the cylinder was open, and the cylinder was flooded, soaking various radioactive waste storage cans. Consequently, the cans were removed, surveyed, and moved to Magazine 4-75 (also referred to as Igloo 75). Although no contamination was found during the initial survey, the cans were wet so the alpha survey was ineffective. A subsequent survey on November 14 found alpha contamination associated with a small hole in one 11-M can that contained mostly plutonium waste (uranium and tritium contamination was also possible). The igloo was secured. Potentially exposed workers were given bioassays on or about November 17, 1978. This event was well documented via an incident report, a decontamination plan, and a list of personnel involved and their bioassay results (Unknown author, unknown date-b; Pantex Plant, 1979; Pantex Plant, 1978).

A release of tritium gas occurred within Cell 12-44-1 at the Pantex Plant on May 17, 1989. This release was the result of a nuclear component failure. Bioassays were performed on all affected individuals and NIOSH has access to the results (Mason & Hanger, 1989). This event was also well documented. Available information includes a list of personnel involved and the internal doses they received from tritium exposure.

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

<u>ATTRIBUTION</u>: *Section 6.0 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.*

A radiation dosimetry program was first established at Pantex in 1952 by the manager of the Radiography group. The radiation program gradually evolved as the scope of work at Pantex included more sources of potential radiation exposure (sealed pits containing fissile materials and increased plant throughput). Additionally, a major expansion of the radiation protection program occurred after a tritium release incident in May 1989. Overall, personal monitoring was focused on those workers most likely to be exposed to radiation: radiography technicians, production technicians, material handlers, transportation workers, quality control technicians/inspectors, and warehouse production workers. Other workers at Pantex had little occasion to enter radiological areas, and their potential for radiation exposure or intakes of radioactive materials were considerably less.

Sources of monitoring data for this evaluation include the SRDB, NOCTS, DoRMS, and the Optix® imaging system. An older database system constructed at Pantex, known as HERS, has been incorporated into DoRMS. The HERS database was used to maintain available personnel dose data applicable to the proposed 1951 through 1991 timeframe. HERS was initiated in 1989 when original personnel dose records were reviewed and discrepancies were identified and corrected. Individual workers were interviewed, and their records checked for accuracy. Missing records or anomalies were analyzed, with worker assistance, and appropriate notes entered into the record (Rawlston, 1991).

Documentation of worker monitoring results stemming from non-routine sampling efforts (event-driven or as a result of high air sampling results or surveys) was generally not loaded into the HERS database. As a result, these data are not reflected in the DoRMS database query outputs. However, these monitoring results are actively being captured in the Optix® imaging system, which is being used to electronically store individual worker records in a PDF format.

The following subsections provide an overview of the available internal and external monitoring data for the Pantex Plant class under evaluation. The primary sources of internal radioactive contamination have been DU oxide and tritium. The primary sources of external radiation exposure included plutonium pits and DU or thorium components (Personal Communication, October 1, 2003).

6.1 Available Pantex Plant Internal Monitoring Data

ATTRIBUTION: Section 6.1 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

During essentially all years under evaluation, there was no Pantex bioassay program for uranium, thorium, or plutonium that would be considered "routine." Instead, bioassay was performed for specific events and for known or suspected exposure incidents. As for the aforementioned radionuclides, tritium bioassay was also performed for specific events and for known or suspected exposure incidents. However, during the 1960s, tritium monitoring was also performed on a rotating sample basis and included about 10 workers per month as a means of spot-checking for potential uptakes associated with various jobs (ORAUT-TKBS-0013-5; Davis, 1967; Personal Communication, April 8, 2008). For example, in 1961 bioassay samples were collected from workers involved in a specific plutonium contamination event and from those involved in decontaminating the facility after the event (ORAUT-TKBS-0013-5). A 1967 *Health Protection Survey Report* describes an inspection of the Pantex Radiation Protection program and states that Pantex used air samples and contamination surveys to indicate the need for bioassay samples. The report further confirms that Pantex performed about 10 tritium urinalyses a month with no indication of personnel exposures (Davis, 1967).

To support the incident/suspected exposure-driven program, all aspects of work at Pantex have always involved procedures and routine contamination checks (e.g., swipes, air sampling) to assist in identifying work locations with the potential for personnel internal exposures (Personal Communication, April 7, 2008; Personal Communication, April 8, 2008). According to both procedures and interviewed employees, evidence of potential exposures was always followed by additional area monitoring/media sampling (as appropriate), and also included personnel bioassay monitoring (if deemed necessary). Data indicating the presence of contamination, personnel exposure sources, or monitoring for potential internal exposures to workers (bioassays) were maintained in site records. Data that did not indicate contamination and/or exposures ("negative" data) were often not saved for future reference, particularly in the earliest years of operations (Personal Communication, April 8, 2008). This Pantex recordkeeping practice, coupled with the relative cleanliness of the materials and work performed at Pantex, and the site's practice of only collecting bioassay samples when other monitoring/events dictated a need, has resulted in apparent monitoring data gaps for many types of internal monitoring data over the years.

The approach used for collection of bioassays from Pantex workers changed towards the end of the evaluated class timeframe. A 1991 procedure titled *Analysis of Biological Samples for Uranium, Thorium, and/or Plutonium* stated that urinalysis was to be conducted for personnel exposed to 40 derived air concentration (DAC)-hour integrated air concentrations, as measured by breathing-zone monitors, or was to be estimated if not specifically monitored (Mason & Hanger, 1991a). The procedure also stated that "personnel working in potentially contaminated areas shall be entered into the routine bioassay program and shall have a routine bioassay for the suspect heavy metal radionuclide performed every 4 to 6 months." The routine bioassay program for radionuclides other than tritium was short-lived, occurring mostly in 1991 and 1992 (ORAUT-TKBS-0013-5). Research did not reveal the level of air concentrations or other workplace indicators that triggered special bioassays before 1991 (ORAUT-TKBS-0013-5).

Except for a single measurement made for Pu-239 and Am-241 at the Los Alamos Scientific Laboratory in 1978, no records of *in vivo* measurements made within the 1951 through 1991 evaluation period are available. More than 200 personnel working on the B28 Disassembly Program were monitored by the Helgeson *in vivo* counter in 1989; however, the results of the *in vivo* counts were later determined to contain a positive bias and were deemed not credible (Helgeson, 1989).

Table 6-1 shows the number of Pantex employees with bioassay monitoring doses recorded in the DoRMS databases from 1972 to 2004. DoRMS does not contain any internal monitoring data prior to 1972. Data from years extending beyond the 1951 through 1991 evaluation period are being presented due to their potential for use in reconstructing dose for the pre-1991 period.

Table 6-1: Pantex Employee Monitoring Doses Recorded in the HERS and DoRMS Databases

Table 6-1 spans two pages.

Year	No. of Workers Monitored for Tritium*	No. of Workers Monitored for Uranium*	No. of Workers Monitored for Thorium*	No. of Workers Monitored for Plutonium*
1972	4	0	0	0
1973	1	0	0	0
1974	0	0	0	0
1975	0	0	0	0
1976	463	0	0	0
1977	466	0	0	0
1978	519	0	0	0
1979	712	0	0	0
1980	14	0	0	0
1981	41	0	0	0
1982	5	0	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	17	0	0	0

Table 6-1: Pantex Employee Monitoring Doses Recorded in the HERS and DoRMS Databases

Table 6-1 spans two pages.

Year	No. of Workers Monitored for Tritium*	No. of Workers Monitored for Uranium*	No. of Workers Monitored for Thorium*	No. of Workers Monitored for Plutonium*
1986	626	0	0	0
1987	481	0	0	0
1988	499	0	0	0
1989	212	0	0	0
1990	2,341	46	0	0
1991	1,115	431	0	0
1992	879	239	17	12
1993	1,078	90	0	0
1994	1,104	138	4	3
1995	971	37	90	33
1996	940	69	56	17
1997	933	89	13	18
1998	610	12	1	2
1999	554	13	16	1
2000	535	33	9	8
2001	512	65	16	1
2002	511	57	11	10
2003	441	87	25	9
2004	421	109	15	0

Notes:
*The numbers presented in the table reflect the number of workers for which calculated doses were compiled and recorded in the HERS (originally) and DoRMS databases.

As mentioned previously, additional limited internal monitoring data collected to assess a specific activity, contamination event, and/or elevated air concentration result are also available. In many instances these results are only available as images linked to individual personnel files in Optix® or in documents that Pantex has kept on file or put into long-term storage. Optix® was designed with employee identification as the primary sort key; as such, it is not possible to efficiently query this system specifically for monitoring results. Similarly, data contained solely in documents are not included in Table 6-1 above.

Through data capture efforts, NIOSH has collected and reviewed many internal data-containing documents. Within these documents there are considerable variations in the quantity of data available as well as support information such as sampling and analytical methods details. Attachment One of this report provides a listing of the data-containing documents in the SRDB. This table is sorted by year, data type, and SRDB document ID number.

Hardcopy air monitoring results applicable to specific activities have been documented and are available to NIOSH (see Attachment One of this evaluation report). Some pre-1991 air monitoring results are stored as scans of hard copies that have been included in some workers' files (Optix®). Examples of available air sample results can be found in various Air Sample Monitoring Logs (Pantex Plant, 1959 -1967) that document air quality during the burning of high explosives at the burning grounds and firing sites (hydroshots). Additional data obtained from radio-controlled drones flown through clouds produced from hydroshots are available in Gidley, 1971; Alexander, March 1972; Alexander, May 1972; Alexander, August 1972; and Alexander, October 1974.

Additional details regarding various analyses, reporting protocols (when known), and associated minimum detectable activities are presented in ORAUT-TKBS-0013-5.

6.2 Available Pantex Plant External Monitoring Data

ATTRIBUTION: Section 6.2 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following discussion provides a summary of the Pantex Plant external dosimetry program as well as the types, quantity, and quality of data that can be used for external dose reconstruction. Details regarding the various analyses used and the associated minimum detectable activities are presented in ORAUT-TKBS-0013-6, unless noted otherwise.

Pantex started monitoring workers for external radiation exposure in 1952 (Personal Communication, October 1, 2003; Personal Communication, October 8, 2003). At first, Pantex issued dosimeters only to workers likely to be exposed to radiation. From 1952 through 1957, the only workers considered likely to be exposed were radiographers (see Section 5.1.1 of this evaluation). From 1958 through 1988, only workers specifically classified as radiation workers were monitored (Personal Communication, October 1, 2003). The variations in numbers of radiation workers reflect changes in weapon production rates (Carr, unknown date). From 1989 to the present, all Pantex workers who entered a radiologically-controlled area were monitored for external radiation exposure (Griffis, 1988). Table 6–2 presents the numbers of Pantex employees monitored throughout the years.

Table 6-2: Annual No. of Monitored Pantex Employees

Year	No. Monitored	Year	No. Monitored	Year	No. Monitored
1950	0	1964	253	1978	518
1951	0	1965	416	1979	714
1952	1	1966	581	1980	819
1953	1	1967	563	1981	915
1954	2	1968	423	1982	1,002
1955	1	1969	432	1983	1,027
1956	1	1970	468	1984	1,113
1957	3	1971	495	1985	1,172
1958	19	1972	467	1986	1,129
1959	22	1973	441	1987	1,160
1960	69	1974	500	1988	1,121
1961	71	1975	493	1989	1,438
1962	64	1976	463	1990	2,090
1963	218	1977	465	1991	2,126

Pantex Plant dosimetry methods evolved with the development of improved technology and a better understanding of the complex radiation fields encountered in the workplace. The accuracy of dosimetry methods depends on radiation type, energy, and exposure geometry (BWXT, 2001). Dosimeter exchange frequency gradually lengthened and corresponded to changes in Radiation Protection Guidelines (RPGs) (Morgan, 1961). Table 6-3 summarizes major changes in Pantex external dosimetry systems and routine dosimeter assignment periods for workers; it shows the dosimeter type, period of use, and exchange frequency.

Table 6-3: Pantex Dosimeter Information from 1959-1991			
Dosimeter Type	**Provider**	**Period**	**Exchange Frequency**
βγ film	Tracerlab	January 1952 - December 1959	Weekly
βγ film and NTA film	Tracerlab	January 1960 - March 1961	Weekly
		April 1961 - May 1963	Monthly
βγ film and NTA film	Eberline	June 1963 - September 1964	Monthly
βγ film and NTA film	Landauer	October 1964 - December 1968	2/Month
		January 1969 - December 1972	Monthly
TLD 2-element	in-house and NTA film/Landauer[1]	January 1973 - December 1976	Monthly
TLD 6-element	in-house	January 1977 - September 1980	Monthly
Panasonic 802 TLD	in-house	October 1980 - December1991	Monthly

Notes:
[1] The Pantex in-house two-element thermoluminescent dosimeter (TLD) was implemented in 1973 for monitoring beta-gamma radiation exposures only. Use of NTA film continued for monitoring neutron exposures until implementation of the six-element TLD system in 1977 (Personal Communication, October 8, 2003).

The first dosimeter used at Pantex was a two-element film badge supplied by Tracerlab for measuring beta, X-ray, and gamma exposures (Tracerlab, 1962-1963). Beginning in 1960, Pantex used a multi-element film badge that incorporated NTA film to measure beta, X-ray, gamma, and fast neutrons (Tracerlab, 1962-1963). From 1972 to 1976, a two-element, in-house thermoluminescent dosimeter (TLD) system was used to measure beta, X-ray, and gamma exposures; NTA film was retained to measure fast neutrons (Personal Communication, October 8, 2003; Alexander, 1973). From 1977 to 1980, Pantex used a six-element, in-house TLD system that included personal nuclear accident dosimeter elements (Ihne, 1980; Personal Communication, October 8, 2003). Beginning in 1980, Panasonic TLD systems with automatic readers were used; the UD-802 TLD was used from 1980 to 1993.

Details regarding the various analyses used and the associated minimum detectable activities are presented in ORAUT-TKBS-0013-6.

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

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

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

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00068 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Pantex Plant Data

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

This subsection 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.

Dosimetry records have been maintained at Pantex since 1952. There have been essentially only two primary contractors to DOE and its predecessor agencies responsible for managing the plant and its records during the timeframe of the NIOSH-evaluated class. Prior to October 1956 the plant was operated by Procter and Gamble. From October 1956 through October 1991, the plant was managed and operated by Mason and Hanger-Silas Mason Co., Inc. (MHSM). In October 1991, Battelle joined with MHSM to operate the plant.

Pantex staff originally used forms to manually record dosimeter processing and dose information. As the technology became available at the Pantex Plant, paper records were augmented with mainframe computers and microfilm to maintain worker exposure histories (exact times unknown). Throughout this period, paper records were often moved into a storage status. In November 1989, a project was initiated to consolidate all known employee paper, electronic, and microfilm records into individual worker files to be maintained in both hardcopy and contemporary electronic format. This project was conducted by the Delphi Groupe and led to the creation of the Historical Exposure Records System (HERS).

The HERS effort was completed in 1991; in 1992 the HERS files were then integrated into another recordkeeping system called the Dosimetry Records Management System (DoRMS). Designed to meet or exceed requirements set in 10 CFR pt. 835, DOE and Pantex Radiological Control Manuals, and DOE M 231.1-1A, this system is still used and serves as a comprehensive and centralized repository for Pantex Plant radiation dosimetry-related data and activities. To comply with DOE Records Management Order 243.1, another electronic records management application, called Optix®, was adopted at Pantex in 2001 to augment the DoRMS system. Among other functions, Optix® is still being used to electronically store images of historical documents pertinent to individual Pantex workers (e.g., medical records, accident/incident memos). The documents are scanned into the database and stored as part of workers' individual files (Unknown author, unknown date-c).

A majority of the exposure data applicable to the evaluation of dose reconstruction feasibility for the evaluated class timeframe was collected and analyzed during construction of the HERS. The work performed (and documented) during this effort best describes the pedigree of the available Pantex exposure data and as such, a summary of this effort is included below. The HERS work was well-documented and details regarding project execution aspects such as design, data acquisition processes, security, administrative controls, data transcription and reconstruction, and quality control are available in SRDB references (Roser, 1980; Delphi Groupe, 1990). Pantex maintains a complete set of HERS documentation onsite. A HERS project report (Delphi Groupe, 1990) indicates that the HERS project conformed to the following DOE Orders:

- DOE Order 1324.2A, *Records Disposition* (dated September 13, 1988),
- DOE Order 5484.1, *Protection, Safety, and Health Protection Information Reporting System* (dated November 6, 1987, Change 3),
- DOE Order 5480.11, *Radiation Protection for Occupational Workers* (dated December 21, 1988), and
- DOE Order 5480.15, *Accreditation Program for Personnel Dosimetry*.

In addition to the DOE Orders, the HERS project also conformed to the following American National Standards Institute (ANSI)/American Society of Mechanical Engineers (ASME) requirement:

- NQA-1-1986, *Quality Assurance Program Requirements for Nuclear Facilities*.

A HERS project report (Delphi Groupe, 1990) indicates that the following American National Standards Institute (ANSI), American Nuclear Insurers (ANI), Mutual Atomic Energy Liability Underwriters (MAELU), and Nuclear Management and Resources Council (NUMARC) standards were followed:

- ANSI N13.601966, *American Standard Practice for Occupational Radiation Exposure Records Systems* (R1972),
- ANI/MAELU Information Bulletin 80-1A, *Nuclear Liability Records Retention* (Revision 2, dated February 28, 1986), and
- NUMARC/NESP-003, *Radiological Recordkeeping for Workers in the Nuclear Industry* (dated December 1988).

Upon completion, the HERS project provided Pantex with an electronic database containing the best-available personnel dose information and a complete individual occupational dosimetry file for each employee. All original external exposure readings were preserved. Internal results were recorded as individual doses. In addition to the requirements contained within the DOE Orders and the standards listed above, the following specific HERS project objectives are relevant to the SEC-00068 data pedigree evaluation:

- The review of Pantex personnel occupational radiation exposure records generated prior to calendar year 1983;

- Computerization of all available exposure records for the period 1957 through 1983. including the reconstruction and verification of incomplete, missing, or unmonitored exposures for input (eventually, external data back to 1952 was located and incorporated);
- Verification of all Pantex employee internal and external radiation exposure data for the period of 1983 through 1989; and
- Computerization and/or reformatting of prior or concurrent exposures received at other corporate or military facilities for the period of 1983 through 1989.

Original personnel exposure records were provided by MHSM Radiation Safety Department to Delphi Groupe for this work. In addition to Pantex-maintained paper records, all Pantex-related records that had been stored at the Idaho National Engineering Laboratory's System Safety Development Center were obtained to fill in "holes." Exposure records from previous employment at other sites were also collected and incorporated into workers' exposure files, as were workers' offsite exposures while employed at Pantex. Site microform documentation was also obtained; however, many of the microform data proved duplicative of data on paper documents (and other microforms).

The project records were physically transferred to a single room in Building 136, and in keeping with the Orders and Standards listed above, an inventory system was maintained. All records were administratively controlled as "Sensitive Material." The room was kept locked when not physically occupied by Delphi personnel. Computer equipment used to input and process data was password-protected, and processes were in place to minimize the likelihood of clerical errors (e.g., duplicate entries). Ultimately, a complete quality-control check of all data input into HERS was performed. During the final phase of the project, interviews were conducted with all employees to help ensure the accuracy of the individual exposure files assembled for HERS.

During the HERS data review, Delphi noted that there were pervasive typographical errors in hardcopy records (primarily incorrect data transcription from vendor reports). Delphi's project procedure was to not modify any of the hardcopy records in any way. When possible, however, corrections were made to these types of errors for input into the electronic database if the corrections were well-substantiated and did not compromise the project's policy of recording employee doses that were conservatively high (Delphi Groupe, 1990). All such changes were explained in "comments" and "remarks" fields of the HERS database for accountability. All original data have been kept for comparison. Project-specific procedures used for data transcription, error correction, and reconstruction rules are detailed in Attachment 1 of Delphi Group, 1990.

7.1.1 Internal Monitoring Data Pedigree Review

ATTRIBUTION: Section 7.1.1 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

While the quantity of Pantex internal data collected during the proposed class time is relatively low, it is consistent with the internal exposure potential associated with work conducted at the Pantex Plant (Vespe, 1965; Davis, 1967; DOE, 1989).

As noted in Section 7.1, the HERS project collected and reviewed available data records per applicable DOE Orders and several industry standards. Analytical methods used for tritium bioassays collected during the proposed class timeframe were consistent with prevailing industry standards.

Data available for estimating internal doses due to potential uranium, plutonium, and thorium exposures are predominantly from sampling/analyses performed in 1989 and later. These data also were obtained per industry standards and are suitable for conservatively estimating doses for the class under evaluation.

Upon request, Pantex provided original hardcopy records in addition to database printouts, ensuring NIOSH's ability to confirm data. Per Dose Reconstruction Training (ORAUT-TRNG-0051), dose reconstructors compare these data sets when performing dose assessments. The analytical work performed for the HERS project, the availability of original records, and the training negate the need for an additional internal consistency check of manually-entered data.

7.1.2 External Monitoring Data Pedigree Review

ATTRIBUTION: Section 7.1.2 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

NIOSH has found that Pantex policies for the collection and maintenance of employee external monitoring data provide alpha, beta, and gamma external exposure records that are sufficient to estimate external dose in terms of the pedigree parameters described in Section 7.1. Measurement methods used for external exposures made during the evaluated timeframe were consistent with prevailing industry standards. With the exception of neutron exposure data obtained from NTA film (see Section 7.3), the data obtained from the evaluated class timeframe are sufficient in quality and quantity to be used to evaluate external doses. Subsection 7.3.4 describes a method to bound potential neutron exposures.

As previously described and noted for internal dosimetry records, the HERS project collected and reviewed available external data records per applicable DOE Orders and several industry standards. Upon request, Pantex provided original hardcopy records in addition to database printouts which allows for data confirmation. Per ORAUT-TRNG-0051, dose reconstructors compare these data sets when performing dose assessments. The work performed for the HERS project and having the original records in place negate the need for an additional internal consistency check of manually entered data.

7.2 Evaluation of Bounding Internal Radiation Doses at the Pantex Plant

ATTRIBUTION: Section 7.2 and all of its related subsections were completed by Eva Hickey, Pacific Northwest National Laboratory (PNNL). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

Internal radiation dose for members of the class under evaluation would have occurred primarily through inhalation and ingestion of radiological contamination from the following sources:

- Molecular tritium leakage through welds in weapons components known as reservoirs;
- Disassembly of aged uranium components from certain weapons programs (The uranium was most likely depleted, but there was both some natural uranium and possibly very small amounts of enriched uranium depending on the weapon design. It is unlikely that significant amounts of

removable depleted uranium oxide would have been on the components during assembly because components were new and clean during assembly operations.);

- Burning of DU-contaminated HE components at the burn pads;
- Explosion of DU during hydro tests, which would have produced some thermally-oxidized DU;
- Machining of DU-contaminated metal (associated with one weapon design);
- Handling thorium metal, thorium alloys, or materials impregnated with a thorium compound during assembly and disassembly of certain weapons;
- Plutonium in the encapsulated pits; and
- Elevated radon levels from the cells and gravel gerties.

Table 7-1, taken from ORAUT-TKBS-0013-5, shows the job titles and associated work descriptions for the Pantex Plant. The table is included here for reference as a means to demonstrate that the data and methods used to reconstruct doses was bounding and covered all Pantex employees.

Table 7-1: Pantex Job Titles and Job Descriptions with the Possibility for Occupational Intake

Table 7-1 spans two pages.

Job Title	Work Description	Possibility for Intake (1 highest)[a]
Production Technician, Assembler, Assembly Operator, Assembly Fabrication	Assemble, disassemble, reassemble, inspect components	1
Quality Assurance Technician I	Conduct NDE evaluations with linear accelerators, X-ray machines, etc.; conduct telemetry testing; perform confirmatory measurements on components, assemblies, containers, etc.	1
Quality Assurance Technician II	Perform NDE, electronic, destructive, telemetry, and radiation measurement testing	1
Radiation Safety Technician (RST) (entry)	Perform monitoring and sampling; collect samples; assist RST in monitoring personnel	1[a]
RST	Perform monitoring and sampling; collect samples; perform radiation and contamination surveys; conduct surveillance work	1
RST (Senior)	Respond to contamination or radiation alarms; perform surveillance, monitor radiation conditions in workplace	1
Firing Site Technician	Includes hydroshot operators, driver, anyone involved with cleanup of hydroshot contamination	1
Not known, possibly drivers or teamsters	Includes burning of HE and cleanup of ash at burning ground	1
Material Handler (pits and cans)	Operate material handling/moving equipment; transport material; load and unload materials and containers	2
Operations Manager, Production Supervisor	Supervise personnel engaged in manufacturing, assembly, packaging, material control, etc.	2
Quality Control Inspectors/ Auditors	Conduct special audits; different from quality assurance technicians	2
Security, protective force, guard	Perform per job title	2[b]
Engineer, engineering	Perform variety of tasks associated with design, testing, procedure development	2[c]
Machinist	Machining on DU for one weapon design only	See Section 5.2.2.4 of ORAUT-TKBS-0013-5
Metrology laboratory staff	Perform nonradiological metrology calibrations	Environmental only
Fireman	Perform per job title	Environmental only

Table 7-1: Pantex Job Titles and Job Descriptions with the Possibility for Occupational Intake *Table 7-1 spans two pages.*		
Job Title	**Work Description**	**Possibility for Intake (1 highest)[a]**
Computer Programmer, Electronic Data Processing Analyst	Perform computer programming, maintenance	Environmental only
Secretary, Administrator, Technical Writer, Non-operations Management, Planner	Perform per job title	Environmental only
Tool and Dye Maker	Perform per job title	Environmental only
Food Service	Perform tasks associated with operation of cafeteria	Environmental only
Stores Stockman, Clerk, Supervisor	Perform tasks associated with general stores	Environmental only

Notes:

a. Based on actual contact with components, contamination, or RSTs assisting potentially contaminated personnel.

b. In general, security personnel had little chance of intakes; however, some small intakes from contamination in cells or igloos were possible. The default assumption is to place security personnel in Category 2, but *Environmental only* intakes may be assumed in cases where the security personnel tasks did not involve entry into cells, Gravel Gerties, igloos, or locations with resuspended contamination.

c. Engineering tasks covered a wide range, and most had no potential for intakes. However, some tasks might have involved observations during assembly or disassembly work or observations during hydroshots. *Environmental only* intakes may be assumed in cases where the engineering personnel were not considered radiological workers (i.e., were not assigned to wear dosimeters or had no recordable dose).

The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction for all employees working at the Pantex Plant from January 1, 1951 through December 31, 1991.

7.2.1 Evaluation of Bounding Operational Internal Monitoring Data

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. Although the evaluation period for this report is through December 1991, when looking at intakes and resulting doses during various time increments, data and other references after 1991 were used to estimate doses up through 1991. For this reason (even though times are stated to 1991), data on other references to support the basis of the analysis may be after 1991.

7.2.1.1 Urinalysis Information and Available Data

Uranium: During most of the history of Pantex, uranium bioassay was event-driven. All records related to bioassay were reviewed and evaluated in ORAUT-TKBS-0013-5. Most uranium exposure data are for DU; however, the Pantex-produced *Internal Dosimetry Technical Basis and Quality Assurance Document* mentions natural uranium (Pantex Plant, August 2001). Uranium contamination at Pantex is either uranium metal or air-oxidized uranium from assembly and disassembly or from DU-contaminated HE components at the burn pads and explosion of DU during hydro tests. The data used for bounding doses is provided here and the methods used are summarized in Section 7.2.3.

A review of new data obtained since the issuance of ORAUT-TKBS-0013-5 determined that uranium doses at Pantex are still bounded by the methods in ORAUT-TKBS-0013-5. No new additional bioassay data were obtained.

The most comprehensive set of depleted uranium intake data found in the Pantex records is related to a contamination incident in February 1989 (Radiation Protection Department, 1990). The bioassay data were analyzed at the Y-12 plant under state-of-the-art quality control requirements. Because this data set is large, of known high quality, and documents intakes from exposures that are expected to be above normal operational exposures, this data can be used for bounding potential uranium doses for assembly/disassembly workers belonging to the evaluated class. The bioassay samples were taken in late 1989 and early 1990, approximately one year after the contamination incident was identified. The document titled *Historical Exposure Records System (HERS)-developed by the Delphi Groupe, Inc.* (Radiation Protection Department, 1990) contains bioassay data from these urinalyses. This is the oldest set of data that provides isotopic determination of uranium alpha activity in urine samples, and it contains sufficient data to perform statistical analysis.

Martin Marietta Energy Systems processed the bioassay samples at the Y-12 Plant Laboratory. The minimum detectable activity (MDA), 0.03 pCi per isotope per sample, was calculated from the formula in *Health Physics Society American National Standard-Performance Criteria for Radiobioassay* (HPS, 1996). The calculation included a 1,000-minute count, a detector efficiency of 0.0985, and an average recovery of 75%. The average chemical recovery for the data for this incident was 70%. Recoveries less than 25% were considered not accurate due to counting statistics associated with low recoveries. A dose assessment was not provided with the data set. Data with a negative value indicated that the background was higher than the activity in the sample (Martin Marietta, 1990).

No bioassay data were found for Pantex workers involved in the burning of DU-contaminated high explosives or hydroshots; however, the doses can be adequately bounded by doses calculated from air sampling data (discussed below under *Airborne Levels*).

Tritium: Interviews with former Pantex employees confirmed that when tritium containers arrived, detectable tritium contamination was possible (Personal Communication, April 8, 2008). From 1972 to the present, Pantex has had a routine tritium bioassay program for workers (i.e., at-risk workers). Pantex monitored on a monthly basis and analyzed tritium bioassays onsite. In addition, one-twelfth of the worker population received a urinalysis each month. A review of 1972 through 1980 bioassay results helped identify a MDA, although actual documentation of the MDAs was not found (Mason & Hanger, 1972-1984). For 1972, records show a consistent use of 0.25 µCi/L as a less-than value (Mason & Hanger, 1972-1984).

The available tritium monitoring data was statistically analyzed and adjusted to apply current dose methods. From available procedures, program reviews, and interviews conducted, it is evident that Pantex tritium monitoring has been appropriately focused on workers with the highest likelihood of exposure. As such, the data obtained from this monitoring can be used to bound tritium doses for all Pantex workers. Methods detailing the application of this data to monitored and unmonitored workers are provided in ORAUT-TKBS-0013-5.

In addition to information previously considered in ORAUT-TKBS-0013-5, additional bioassay data (found since the TBD was issued), were reviewed (Pantex Plant, 1962-1971). Tritium urinalyses were conducted in 1960 through 1971 using a T series airborne monitor fitted with a kit for aerosolizing tritium from a urine sample. Sampling was conducted on about 10 workers per month who were judged to be at highest risk for tritium exposure. The intent was to provide a relatively insensitive check on the workplace exposure conditions; doses apparently were not calculated. Because of the insensitivity of the method for urinalysis, these data show that general monitoring was conducted during this period and corroborates that the approach using the post-1971 data is bounding; however, the results were not used by NIOSH in the development of the dose reconstruction method for Pantex workers.

Plutonium: Bounding doses from plutonium can be calculated for Pantex employees. However, these calculations are not based on bioassay data obtained from the evaluated timeframe. Section 7.3 of this evaluation addresses the methods used for bounding doses.

There is a very limited amount of bioassay data for plutonium found in the documents captured by NIOSH (see Attachment One). As discussed in Section 5.2 of this evaluation, this is because plutonium was in the encapsulated pits of the nuclear weapons and strict workplace monitoring practices were in place to ensure the integrity of the encapsulation, including contamination smear checks during assembly and disassembly (Pantex Plant, August 2001). Interviews with former and current Pantex staff validate the assumption that exposure to plutonium was carefully controlled (Personal Communication, April 8, 2008).

Although no documented trigger levels for bioassay were found for the time between 1958 (the time when plutonium was introduced at Pantex) and the early 1990s, it appears that bioassay was performed whenever there was an indication of contamination on the weapons or if the continuous air monitors had positive results (Personal Communication, April 8, 2008; Personal Communication, April 7, 2008).

The potential for plutonium internal exposures has been minimal at Pantex, and therefore routine bioassay was not performed; exposure to plutonium would have been acute rather than chronic. Bioassay was performed and analyzed offsite when an incident occurred that might have resulted in an intake of plutonium. Bioassay results were found for the years 1961 (an incident of known plutonium release), 1963, 1966, 1968, the early 1980s, and 1994 to the present. Doses were not found for all years during the 1960s; this is probably because the prevailing recording level was not reached.

Thorium: Bounding doses from thorium can be calculated for Pantex employees. However, these calculations are not based on thorium bioassay data from the NIOSH-evaluated timeframe. When ORAUT-TKBS-0013-5 was prepared, information indicated that thorium was not onsite until 1980. New information indicates that thorium was onsite as early as the 1960s. Section 7.2.3 of this evaluation addresses a methodology for assessing a bounding dose for thorium using uranium data for time periods before and after 1980.

As with plutonium, Pantex used strict workplace thorium monitoring practices, such as smear checks of components, to verify the integrity of the thorium. Bioassays would only be taken if there was evidence that a contamination event had occurred. There is no evidence that workers potentially exposed to thorium were routinely monitored.

7.2.1.2 Airborne Levels

As described in ORAUT-TKBS-0013-5, air monitoring or sampling data have not been directly utilized for reconstructing doses for tritium, plutonium, or thorium for Pantex Plant dose reconstruction, but has been used for reconstructing some uranium exposures. In many cases, there are numerous sources of air sampling and monitoring data that demonstrate that there was no (or very little) surface or airborne contamination in the work place. If an upset condition existed, the need for bioassay was evaluated in accordance with the Pantex Radiological Program requirements.

Air samples taken from the burning grounds are available for bounding doses to workers present in that work area. The burning grounds have operated since 1952 (DOE, 1997). Air sample results from the burning grounds cover 1960 to 1967, with no results for 1963 (Pantex Plant, 1959-1967). Two categories of results are listed: during burning and during clean-up. Some results are recorded as disintegrations per minute per cubic meter and others as counts per minute. For air samples taken during burning, 24 were listed as zero or background, nine had results that ranged from 4 to 112 dpm/m^3, and 17 had non-zero results in counts per minute (in the logs, the results are written as d/m/m^3) (Pantex Plant, 1959-1967). Section 7.2.3 summarizes the methods used to determine the bounding doses at the burning grounds.

As with the burning grounds, air monitoring data at the firing sites can be used to bound the doses to those workers. Pantex has used firing sites for HE quality control and research since 1952. Some of the test firings at Firing Sites 4, 5, and 10 involved DU through 1985 (DOE, 1997; Mason & Hanger, 1990, Chapter 7). According to a former employee who worked at the firing sites from 1959 to 2000 and was supervisor of the firing site since 1960, the first hydroshot that involved DU occurred in late 1959 or 1960 (Personal Communication, October 11, 2006).

The analysis in ORAUT-TKBS-0013-5 found data providing air concentrations inside and outside the bunker at Firing Site 4 for October 1959 to January 1962 (Pantex Plant, 1959-1967). The data list 94 results for inside the bunker and 79 results for outside. Eighty-five percent of the results are recorded as 0 dpm/m^3 with the lowest non-zero value recorded as 1 dpm/m^3 (only one significant figure was recorded). Additional air sample data for Firing Site 5 in 1973 were found. Those air sample concentrations were compared to the 1960s concentrations and were less at both the median and 95th percentiles. The method used to bound doses is addressed in Section 7.2.3.

7.2.2 Evaluation of Bounding Ambient Environmental Internal Doses

The ambient environmental dose would be accounted for by the available operational personnel and area monitoring data. Additionally, a thorough evaluation of environmental dose assignment to Pantex workers has been demonstrated and provided in ORAUT-TKBS-0013-4. Therefore, further evaluation of this dose was not performed as part of this evaluation.

7.2.3 Methods for Bounding Internal Dose at the Pantex Plant

Uranium: As mentioned previously, assembly and disassembly line workers represent a group of Pantex workers whose uranium exposure potentials are expected to be as high as or higher than other employees at the Pantex Plant. Although in some cases these workers do not have bioassay data in their records (presumably because they were not involved in contamination incidents determined to involve intake potential), data are available for use to bound internal uranium doses for the evaluated class. NIOSH has described (in Section 5.2.2.3.1 of ORAUT-TKBS-0013-5) the details of the analysis of the available 1990 uranium urinalyses collected as a result of a contamination incident. ORAUT-TKBS-0013-5 addresses how this data can be used to conservatively bound doses to appropriate employees, including assembly/disassembly workers, RSTs, and Quality Assurance technicians. In addition, a summary of default intakes is also provided in Table 7.2 of ORAUT-TKBS-0013-5.

When bioassay data are available to assess intakes for workers whose jobs had a lower potential for intake, but who might have had incidental exposure to contamination from disassembly activities, an adjusted dose based on a percentage of the intake to maximally exposed monitored production technicians can be assigned.

Depleted Uranium Intakes from Burning of Contaminated High Explosives: There were no bioassay data found that could be attributed to burning HE. However, intakes can be determined and bounded using available air sample results and additional assumptions related to intake. Section 5.2.2.5 of ORAUT-TKBS-0013-5 details how to assess intakes from burning of contaminated HE. Because the employees that worked at the burning sites were likely different than the assembly/disassembly workers, it is necessary to consider a separate dose bounding approach for this set of workers. The summary of doses can also be found in Table 7.2 of ORAUT-TKBS-0013-5.

Intakes from Hydroshots: No bioassay data were found that could be attributed to intakes from hydroshots; however, bounding intakes can be determined using available air sample results and additional assumptions related to intake. Section 5.2.2.6 of ORAUT-TKBS-0013-5 explains how to conservatively assess intakes from hydroshots. Because the employees that worked at the firing sites were likely different than the assembly/disassembly workers, it is necessary to consider a separate dose bounding approach for this set of workers. A summary of doses can also be found in Table 7.2 of ORAUT-TKBS-0013-5

Tritium: ORAUT-TKBS-0013-5 addresses tritium in four periods: 1956 to 1971; 1972 to 1982; 1983 to 1988; and 1989 to present. In addition, recent reviews addressed exposure to metal tritides. The assessment of metal tritides revealed that the doses would be very small (less than 1 mrem per year), and therefore does not impact the bounding doses in the previous analysis.

The discussion that follows summarizes how the bounding doses for tritium were calculated in ORAUT-TKBS-0013-5. Review of new data obtained since the effective date of ORAUT-TKBS-0013-5, June 22, 2007, confirms that the dose reconstruction methods addressed in ORAUT-TKBS-0013-5 are suitable for bounding potential exposures to tritium for this proposed class.

The most complete set of tritium information consists of maximum and average doses for 1972 to 2001 (Table 5-3 in ORAUT-TKBS-0013-5). Because tritium doses rather than actual bioassay results were found in the worker files, methods to convert from recorded dose to uptake (for input into IMBA or the tritium tool) were used to determine bounding doses. ORAUT-TKBS-0013-5 provides the details for assigning dose to workers for the following:

- Tritium intake from dose records, 1972 to 1982
- Tritium intake for missed dose and unmonitored workers, 1956 to 1971
- Tritium intakes, 1983 to 1988
- Tritium intakes, 1989 to Present
- Tritium missed dose, 1972 to 1988
- Tritium missed dose, 1989 to Present
- Unmonitored workers, 1956 to 1971
- Unmonitored workers, 1972 to Present

Because the data from the T series of air monitors adapted for analysis of urine was too insensitive, all workers prior to 1972 were considered unmonitored. However, because few disassemblies occurred during the early period compared to the 1972 through 1982 time period, and because the reservoirs were newer, assigning a dose to all category 1 (from Table 7-1) workers of twice the maximum dose observed from the 1970s results is assumed to be conservative and bounding.

ORAUT-TKBS-0013-5 also addresses assigning doses to the four employees involved in the tritium release event that occurred in 1989. Because there was only one individual that had an acute tritium exposure, other workers are given the dose from the event assessed as environmental dose.

Unmonitored Workers: When bioassay data are available to assess intakes for workers whose jobs had a lower potential for intake, but who might have had potential incidental exposures associated with tritium, an adjusted dose based on a percentage of the intake to maximally exposed monitored individuals can be assigned.

Plutonium: In assessing doses from plutonium, because the pits were sealed, and incoming shipments were monitored for contamination upon arrival and at several stages during the assembly or disassembly, it was assumed that exposure to plutonium would be acute rather than chronic and that the potential for intake was rare. As mentioned in 7.2.1.1, because plutonium bioassay monitoring was driven by workplace monitoring that indicated possible contamination spread, routine plutonium bioassay monitoring was not performed until very late in the history of the plant, and only limited data are available for plutonium bioassay from the evaluated timeframe. There were no recorded doses associated with 106 bioassays collected from 1991 to 2003.

Because intakes were rare, for the period 1992 to 2000 (1991 for the evaluated class), the criterion for investigation of possible acute intake (including obtaining special bioassay) can be used to support establishing bounding intake estimates for the proposed worker class evaluated in this report. During this period, when the number of disassemblies was highest and the plutonium was oldest, the criterion for investigation was any workplace indicator, indicating that an intake of 40 DAC-hour (290 pCi) might have occurred. These intakes can be assigned to the workers with the highest exposure potential as the mode of a triangular distribution with a minimum of zero and a maximum of 10 times the mode. The factor of 10 for the upper limit of the distribution is set to account for the possibility of more than one intake per year and the possibility that the air-sampling system is not representative. The bounding intake for the period from 1991 through 2000, therefore, is 400 DAC-hr (2900 pCi, acute intake) per year of employment for the high-risk tasks.

The Pantex *Internal Dosimetry Technical Basis and Quality Assurance Document* states that plutonium at Pantex should be considered an aged weapons-grade mixture. The intake activities are for the total alpha activity of the mixture. For the purpose of bounding the plutonium dose, a 20-year aged mixture, inhalation Type S, can be assumed (ICRP, 1994) because the source is aged plutonium, oxidized from the metal state.

For the period from 1958 (the year that plutonium was introduced to Pantex) to 1991 (except 1961, as discussed below), air sample levels that would have triggered bioassay are not known; however, fewer disassemblies occurred and the plutonium was newer, meaning that there was less potential for oxidation and therefore, personnel exposures to plutonium. Assemblies would have involved newly sealed plutonium metal. Consequently, the possibility of intakes and the severity of intakes would have been less. However, because the documentation of the number of disassemblies and the contamination levels are not available, unmonitored workers may be assigned an intake that is the same as the intake from the 1991 to 2000 period. Hence, the bounding intake for the period from 1958 to 1991 for this period is also 2,900 pCi, acute intake, per year of employment in the high-risk task.

ORAUT-TKBS-0013-5 also addresses assigning doses for the workers involved in the 1961 Cell Incident, which produces the bounding doses for those specific workers.

Thorium: Thorium at Pantex exists as thorium metal, thorium alloys, or materials impregnated with a thorium compound (see Section 5.2.1.4). Workers handle these forms during assembly and disassembly of certain weapons. Because of the relative hazard of thorium, Pantex has used and continues to use strict workplace monitoring practices, such as smear checks of components, to verify the integrity of the thorium components. It is assumed that workers could have encountered oxidized thorium components during disassembly of weapons. Pantex has never conducted machining of components containing thorium.

From 1980 to present, the methods for assigning intakes of thorium are the same as for plutonium because of similar workplace conditions. Specifically, there were fewer disassemblies containing thorium; thus, the plutonium methods are claimant favorable for thorium. The following summarizes the method provided in ORAUT-TKBS-0013-5 for bounding doses from thorium for this period. For workers who had the highest possibility of intake for each year from 1980 to 1991, a single acute intake of 40 DAC-hr (48 pCi) of Th-232 (in equilibrium with progeny) was assumed. For Category 2 workers in Table 5-2 of ORAUT-TKBS-0013-5, 0.1 times the intake was assigned. These intakes are modes of triangular distributions with a minimum of zero and a maximum of 10 times the mode to account for the possibility of more than one intake per year and the possibility that the air-sampling system is not representative.

A check on the reasonableness of the above estimates was made by analyzing Th-232 bioassay results. Two hundred fifty-eight worker urine samples were analyzed between 1992 and 1996 (Excel, 1991-2005). Only one result arguably exceeded the detection level; the median of the distribution was 0.000 pCi/L and the 95th percentile was 0.004 pCi/L (less than detectable). One hundred fifty-one worker fecal samples were analyzed between 1996 and 2000 (Excel, 1991-2005). About half were above the analytical detection level, but only four exceeded the expected natural excretion of approximately 0.32 pCi/d (ICRP, 1975). An acute intake of 48 pCi would result in less than 0.32 pCi/d excretion over about six days after the intake, so the intake estimate above and the fecal data agree reasonably well.

Prior to 1980 there is evidence of one disassembly involving thorium in a similar manner as DU. Because DU contamination and thorium contamination would have been in the oxide form and behaved similarly in the workplace on a mass basis (including mass loading in the air), it was assumed that the bounding intakes for inhalation Type S and insoluble ingestion of thorium oxide were the same as the bounding intakes for DU on a mass basis. When default Type S DU inhalation intake of 19 pCi/d is converted to mass, equated to the mass of Th-232, and converted to the activity of Th-232, the intake of Type S Th-232 is 5.2 pCi/d. Similarly the ingestion intake of insoluble Th-232 is 12 pCi/d. Equilibrium of progeny with the Th-232 is assumed. Because thorium components were rarer than DU components, the assumption of daily intake is bounding.

Radon: The assessment of radon doses looked at actual measurements taken at Pantex in 1969 and 1990 (McFall, 1969; UNC Geotech, 1990). The 1990 data resulted in slightly higher values than the 1969 data; thus, the 1990 data were used for the assessment. The equilibrium factor was revised as described below.

A value of the equilibrium factor *F* is often an assumed value of 0.4 in homes, as recommended by the ICRP (1981) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1993). UNSCEAR (1988, Annex A) reports an extensive analysis of equilibrium factors, noting that at more than 0.6 air changes per hour, the average was 0.33, while for less than 0.6 air changes per hour, the average was 0.51. UNSCEAR (1988) also reports that equilibrium factor drops dramatically with decreasing ambient aerosol concentration, so that the cleaner the air, the lower the equilibrium factor. This lower equilibrium factor is correlated with higher unattached fractions, which lead to rapid plate-out (UNSCEAR, 1988). The DOE reviewed equilibrium factors outdoors and in homes, workplaces, underground uranium mines, and other underground mines (DOE, 1999). The only non-mine workplaces reported there were turbine buildings at nuclear power plants, which had relatively low equilibrium factors of 0.30. Uranium mines had average equilibrium factors of 0.27, but have high air-exchange rates to minimize radon concentrations. Non-uranium mines had average factors of 0.55, ranging from 0.3 to 0.7.

Air exchange rates in cells and bays were not made available to NIOSH, nor are there any measurements of equilibrium factors at Pantex in the 1969 and 1990 surveys. The clean air needed for the kind of work performed in underground cells and bays at Pantex would argue for a low equilibrium factor. However, in the absence of any Pantex-specific information, a conservatively high value of equilibrium factor must be chosen. The Pantex-measured radon concentrations were converted to equilibrium-equivalent concentrations by multiplying the radon concentration by an equilibrium factor of 0.8, greater than almost any observed indoor value. The remote possibility that *F* could be greater than 0.8 is accounted for in the use of a lognormal uncertainty with a geometric standard deviation (GSD) of 3.

Workers in earthen or underground buildings were assigned radon intakes using the median value for earthen or underground buildings from the higher 1990 measurements, 0.8 for the equilibrium factor, with a GSD of 3 which exceeds the measured GSD of 2.5. Using actual measurement data combined with conservative assumptions provides a method to bound the intakes from radon for workers in earthen or underground buildings.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

Based on available data and the re-evaluation of the hundreds of documents in the SRDB related to Pantex, specifically in the area of internal dose, NIOSH concludes that the methods described in ORAUT-TKBS-0013-5 provide reasonable approaches to conservatively bound doses for all members of the class under evaluation. New information, revealed since the TBD was issued, confirms that internal dose assessment was performed on an appropriate, as-needed basis. As proven based on the available program documentation, the Pantex Plant operations were performed under strict radiological cleanliness controls and continually performed workplace monitoring to determine whether contaminated weapons were brought onsite or in the case of an inadvertent release of radioactive materials.

7.3 Evaluation of Bounding External Radiation Doses at the Pantex Plant

ATTRIBUTION: Section 7.3 and its related subsections were completed by Jerome Martin, Dade Moeller and Associates. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The principal sources of external radiation doses for members of the proposed class were plutonium pits and depleted uranium and thorium components. Secondary sources of external exposure included other radioactive materials present in smaller quantities (typically microcurie levels) as calibration sources or in larger quantities (up to curie levels) as radiography sources (ORAUT-TKBS-0013-2).

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 Operational External Monitoring Data

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

7.3.1.1 Personnel Dosimetry Data

As required by AEC/ERDA/DOE regulations, Pantex provided dosimeters for measuring external radiation exposures to workers (AEC, 1958). Pantex Safety Standard 321 specified that dosimeters be assigned to all workers who had the potential to exceed 10% of the Radiation Protection Guideline (RPG) in effect at the time (Phillips, 1963; Personal Communication, April 7, 2008; Personal Communication, October 8, 2003). The dosimeters that were assigned were considered state-of-the-art dosimeters that were supplied by a qualified commercial service (National Bureau of Standards, 1955). Dosimetry records documented the names and/or badge numbers of the workers monitored along with their periodic exposure results. All of these records are maintained by the Radiation Safety Department, both in hardcopy and electronically in DoRMS (ORAUT-TKBS-0013-6).

Photon

Primary photon-emitting radioactive materials used at Pantex included uranium, thorium, americium, and plutonium.

Since first used, the film badges and TLDs assigned at Pantex have been capable of measuring photon exposures in the workplace with sufficient accuracy to permit the calculation of bounding photon exposures. There is strong evidence that workers who had the highest potential for radiation exposure were monitored with state-of-the-art dosimeters (National Bureau of Standards, 1955) and the measured photon doses were reasonably accurate and complete (ORAUT-TKBS-0013-6). Dosimetry records maintained by the Radiation Safety Department have been independently reviewed by the HERS project to verify accuracy and to ensure complete documentation (Rawlston, 1991).

The dosimeter technology and the dosimeter responses as a function of photon energy are described in Section 6.5.2 of ORAUT-TKBS-0013-6, where NIOSH demonstrates that the responses adequately support dose calculations for the energies associated with the work performed at Pantex. Table 6-17 of ORAUT-TKBS-0013-6 lists the maximum individual photon dose by year. If these maximum doses are adjusted for missed dose and the dosimeter uncertainty correction factor, they represent the bounding photon doses. As discussed in the available Pantex radiological monitoring program documentation, personnel with the potential for exposures to exceed AEC exposure guidelines, as described in Pantex Radiation Protection procedures, were selected for monitoring; therefore, NIOSH has concluded that these doses will serve to bound any potential external exposures to unmonitored workers at Pantex. It is NIOSH's view, based on the previously stated information regarding the Pantex monitoring program and available data, that sufficient data are available to support the establishment of bounding photon doses to the proposed class in this evaluation.

Beta

The film badges and TLD used at Pantex were designed to detect beta exposures through the open window of the badge holder. Beta doses measured in the workplace were generally low, unless very close work was being performed (ORAUT-TKBS-0013-6). The main reason that higher beta doses were not recorded is that beta dose rates decrease rapidly with distance from a source and dosimeters were worn on the upper torso, approximately one foot or more from the source. It is possible that beta doses to the hands and arms were higher than those recorded for the whole-body for some workers in some circumstances. Therefore, the recorded beta doses are not necessarily bounding. A method for estimating bounding beta doses is addressed in Section 7.3.4 of this evaluation.

Neutron

Plutonium and highly-enriched uranium pits emit fast neutrons. The neutron emission rate is a function of the mass of fissionable material and specific design features. Neutron radiation fields are discussed in more detail in Section 6.5.4.3 of ORAUT-TKBS-0013-6.

Prior to 1977, neutron doses were measured by NTA film; however, NTA film underestimates, and therefore does not reliably measure, neutrons with energies less than 500 keV. The six-element in-house TLD system used from 1977 to 1980 responded well to thermal neutrons, but it under-responded to neutrons above 10 keV (DOE, 1977); thus, this system did not measure a significant fraction of the neutrons in the Pantex workplace during that timeframe. The response of the Panasonic UD-802 TLD to thermal and fast neutrons was measured (Robertson, 1983) using a bare and moderated californium-252 source. These measurements showed that the UD-802 significantly under-responded to fast neutrons. The data currently available to NIOSH does not permit quantification of the amount that neutron doses are underestimated in these cases/situations for the many varied neutron radiation fields and spectra during the associated time periods. Therefore, all available personnel monitoring neutron doses measured before 1993 are likely to underestimate the associated neutron exposure and therefore are not considered reliable for the purpose of dose reconstruction under this radiological dose reconstruction program. The Department of Energy Laboratory Accreditation Program (DOELAP) accredited the Panasonic UD-809/UD-812 TLD system in 1993 for all neutron categories applicable at Pantex. Neutron doses measured at Pantex since this time with this new system are considered reliable for use in this radiological dose reconstruction program, and these measurements provide a basis for using neutron-to-photon dose ratios to permit estimating worker neutron doses for the periods prior to the accreditation. Based on NIOSH's review and evaluation of the weapons systems handled at Pantex, and the assembly of the list that permits comparison across all times associated with this evaluation, NIOSH is able to establish that the neutron-to-photon dose ratios, applied to bounding photon doses, result in calculated neutron doses that are considered bounding across all time periods. The method used to bound neutron doses is addressed in Section 7.3.4.

7.3.1.2 Area Monitoring Data

Beginning in 1959, area monitor film badges were used to continuously measure radiation exposure doses in specific areas of concern, including assembly cells and vaults. The use of area monitor dosimeters continued for many years and the records from these dosimeters are available in the Radiation Safety Department files. The data from these dosimeters were used by the Radiation Safety Department to help determine which work areas had potential for significant exposure to workers. Area monitoring dose data represent an option to estimate unrealistically high bounding personnel radiation doses.

7.3.2 Evaluation of Bounding Ambient Environmental External Doses

A thorough evaluation of the ambient environmental dose, applicable to the performance of individual dose reconstructions, for Pantex has been provided in ORAUT-TKBS-0013-4. However, for the purpose of this SEC evaluation, the Pantex ambient environmental dose would be accounted for, and bounded from, the occupational monitoring data for personnel working at the Pantex site; therefore, further evaluation of ambient environmental dose is not necessary or included in this evaluation.

7.3.3 Pantex Plant Occupational X-Ray Examinations

Pantex required pre-employment and routine physical examinations as part of its Occupational Health and Safety program. The Medical Department maintained a log for each worker of what appears to be all X-ray examinations. An inspection of the logs for selected long-term workers showed that there were no consistent patterns in the frequency of their examinations. Based on this inspection, practices apparently varied among workers, probably based on occupation and job responsibilities. Table 7-2 summarizes these variations and makes conservative assumptions that give bounding doses. Additional details are provided in ORAUT-TKBS-0013-3.

Table 7-2: Pantex Plant Worker X-ray Examinations

Time Period	Examination Type	Frequency	Default Dose Reconstruction Recommendation
1952-1981	Posterior-anterior (PA) Chest	For all workers, pre-employment and annually	The log of X-ray examinations can be used to identify occupation-related examinations for PA chest, AP lumbar spine, and LAT lumbar spine examinations. If specific log data is not available, pre-employment PA chest, AP lumbar spine, and LAT lumbar spine examinations, as well as annual PA chest examinations will be assumed.
	Anterior-posterior (AP) Lumbar spine	For male workers, pre-employment	
	Lateral (LAT) Lumbar spine	For male workers, pre-employment	
1982 - 2004	PA Chest	For all workers, pre-employment and every 5 years.	The log of X-ray examinations can be used to identify occupation-related PA chest examinations. If specific log data are not available, pre-employment PA chest and an examination every 5 years will be assumed.

7.3.4 Methods for Bounding External Dose at the Pantex 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

Photon Dose

Photon doses for monitored workers have been measured with state-of-the-art dosimeters throughout the history of Pantex (see section 7.3.1.1 of this evaluation). Additionally, Pantex employees performing duties with the highest exposure potentials have consistently been monitored when performing their duties (Personal Communication, April 7, 2008; Personal Communication, October 8, 2003). The resultant monitoring data have been retained over the entire course of the evaluated class timeframe, and as such, these data permit estimation of bounding photon doses for the NIOSH-evaluated class.

As discussed, the available data associated with monitored workers can be used to bound the unmonitored workers because unmonitored workers had lower exposure potential positions. NIOSH has, however, analyzed the database of monitored worker photon dose data (Strom, unknown date) to provide statistically valid dose values that can be assigned to unmonitored workers, who would have been monitored by today's standards. It is recommended that doses be assigned to unmonitored workers that are equal to the arithmetic mean dose for monitored workers for each year of employment, as the results of this analysis can be used to assign doses that are more precise than a bounding value for unmonitored workers.

Beta Dose

Monitored workers exposed to beta-emitting components could have received external beta doses that would have been measured by film badges and TLDs. However, the beta dose from depleted uranium decreases rapidly with distance from the surface, so that in many cases the beta dose measured may have been less than the limit of detection (LOD). If a claimant's records show zero or no reported dose for a monitoring period, a missed dose can be assigned based on the LOD/2 method (OCAS-IG-001).

As discussed above for beta and photon dose, the available data associated with monitored workers can be used to bound the unmonitored workers because unmonitored workers were not monitored due to their lower exposure-potential positions. As was the case in the photon evaluation, NIOSH has analyzed the database of monitored worker beta dose data (Strom, unknown date) to provide statistically valid dose values for assignment to unmonitored workers. Beta doses equal to the arithmetic mean of beta doses for monitored workers can be assigned to unmonitored workers for each year of employment, as the results of this analysis can be used to assign doses that are more precise than a bounding value for unmonitored workers.

Neutron Dose

Photon doses (with appropriate corrections for lead apron use and dosimeter response uncertainty) were reliably measured from 1994 forward and can be used with a neutron-to-photon dose ratio of 1.7 to calculate neutron doses for the years prior to 1994 (ORAUT-TKBS-0013-6; Strom, unknown date). The average neutron-to-photon dose ratio determined from reliable collective neutron and photon doses measured since 1994 is only 0.25 (see Table 6.1 in ORAUT-TKBS-0013-6). Thus, this method for calculating neutron doses prior to 1994 will result in average neutron doses to workers that are approximately 6.8 times the expected doses, which will be bounding (ORAUT-TKBS-0013-6) for the class evaluated in this report.

Typically, there should not be a significant neutron exposure to unmonitored workers. However, for an unmonitored worker with some evidence of potential neutron exposure, neutron doses can be estimated by applying a median neutron-to-photon dose ratio of 0.8 as determined by the log probability analysis of grouped Pantex and neutron dosimeter data, as determined by Strom. This median value, when applied to the assigned photon dose for monitored workers, will yield a bounding neutron dose to unmonitored workers.

An alternate method has been developed for conservatively estimating missed neutron doses. Neutron and gamma dose-rates associated with various weapon configurations are available for LANL and LLNL-designed nuclear weapons systems handled at Pantex. Dose-rate data for individual weapons have been located at Pantex to cover the weapon configurations encountered during assembly and disassembly operations. These dose-rate data, coupled with the exposure times derived from time-and-motion studies of the nuclear explosive operations, allow the calculation of exposure-time weighted neutron-to-photon dose ratios. Using the neutron-to-photon dose ratios, the missed neutron doses can be estimated based on the measured photon doses and assigned to the personnel performing the nuclear explosive operations. These data allow determination of bounding neutron doses.

7.3.5 External Dose Reconstruction Feasibility Conclusion

The data sources for photon, beta, and neutron doses, as well as occupational X-ray examinations and ambient environmental external doses (ambient environmental dose accounted for in the available personnel monitoring data), have been examined and found to be adequate for bounding external doses for the Pantex proposed worker class evaluated in this report. The measured photon dose data, with appropriate corrections for lead apron use and dosimeter response uncertainty, provide reliable, bounding photon doses. The available beta-dose data can also be used to calculate/establish bounding beta doses. A conservative neutron-to-photon dose ratio, based on reliable neutron monitoring data and information regarding the weapons systems over the years of Pantex operation, and coupled with the application of the bounding photon doses, permit bounding the neutron doses. The available medical X-ray information, monitoring types, and monitoring frequencies support the ability to bound the medical X-ray dose. The bounding doses for monitored workers can be used with co-worker study statistics to assign bounding doses to unmonitored workers because the monitored workers are considered the maximally exposed work group within the proposed worker class (based on historical Pantex radiological program documentation). The combination of these dose calculation methods makes it feasible to bound the external dose (reconstruct the dose with sufficient accuracy) for the Pantex proposed worker class evaluated in this report.

7.4 Evaluation of Petition Basis for SEC-00068

The following subsections evaluate the assertions made on behalf of petition SEC-00068 for the Pantex Plant.

7.4.1 Unmonitored Workers

ATTRIBUTION: Section 7.4.1 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

SEC-00068: *One argument we make is that too few workers were monitored for statistical purposes for generalizations to the rest of the workforce to be valid. Until 1979 the majority of the Pantex workforce went completely unmonitored. The assumption that the most exposed workers were monitored was found not to be valid at IAAP, as above, and is likely not valid at Pantex.*

NIOSH has obtained credible information stating that prior to 1988, Pantex issued dosimeters only to workers likely to receive 10% or more of the radiation protection guidance. There is also strong evidence that a majority of the workforce was not exposed to radiological sources during that time period. From 1952 through 1957 the number of badged workers was particularly low, as industrial radiography and medical X-rays were the only significant sources of radiation exposure onsite during that time. Variations in the number of badged radiation workers from 1958 through 1988 reflect changes in weapons productions rates and the quantity of radioactive materials present onsite. Reviews conducted of the Pantex Plant health protection and monitoring programs have repeatedly found that monitoring levels are consistent with exposure potentials. Interviews with Pantex safety officers and health physicists working within the class timeframe also supported a proper correlation between exposure potentials and monitoring levels.

7.4.2 Effectiveness of the Health Protection and Industrial Health Programs

ATTRIBUTION: Section 7.4.2 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

SEC- *00068: ... real questions regarding the efficacy of the HP and IH programs at this site as reflected by workers' histories and the Tiger Team report.*

Excerpts from a 1990 'Tiger Team" report at the Pantex Plant relayed information related to (and critical of) the following: health physics support staffing levels and training; questions regarding quality assurance for radiation monitoring data; health and safety program inadequacies; the control of radioactive sources; maintenance of employee exposure records; contamination reports; and discussion of pre-employment or new employee baseline bioassay monitoring.

Although the report contains information which indicated that the Pantex Plant radiological program was deficient in implementing DOE Order 5480.11 requirements, the report did not find that radiation exposures and radiation doses were not monitored, either through personal or area monitoring. With the exception of neutron monitoring, the Tiger Team review did not indicate that occupational exposure monitoring data obtained were deficient, inaccurate, or unsuitable for use in bounding doses to Pantex workers.

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

ATTRIBUTION: Section 7.5 was completed by Tim Adler, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

During the feasibility evaluation for SEC-00068, an additional issue was identified that needed further analysis and resolution. The issue and its current status are:

- ISSUE: Due to inadequacies in measuring devices used, all neutron doses measured before 1993 are likely to be underestimated and unreliable.

  RESPONSE: Neutron doses measured at Pantex with a new system since 1994 are reliable and these measurements are suitable for use in bounding the doses received by Pantex workers. Photon doses (with appropriate corrections for lead apron use and dosimeter response uncertainty) were reliably measured and can be used with a neutron-to-photon dose ratio to calculate conservatively-bounding neutron doses for the years prior to 1994 (ORAUT-TKBS-0013-6).

7.6 Summary of Feasibility Findings for Petition SEC-00068

This report evaluates the feasibility for completing dose reconstructions for employees at the Pantex Plant from January 1951 through December 1991. 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 7-3 summarizes the results of the feasibility findings at Pantex Plant for each exposure source during the time period of January 1, 1951 through December 31, 1991.

Table 7-3: Summary of Feasibility Findings for SEC-00068
January 1951 through December 1991

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal[1]	**X**	
- Uranium	X	
- Tritium	X	
- Plutonium	X	
- Thorium	X	
- Radon	X	
External	**X**	
- Gamma/Photon	X	
- Beta	X	
- Neutron	X	
- Occupational Medical X-ray	X	

Notes:
[1] Internal includes an evaluation of available urinalysis (in vitro), airborne dust, and lung (in vivo) data.

As of August 1, 2008, a total of 357 claims have been submitted to NIOSH for individuals who worked at the Pantex Plant and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for 244 individuals (~68%).

8.0 Evaluation of Health Endangerment for Petition SEC-00068

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

NIOSH's evaluation determined that it is feasible to estimate radiation dose for members of the proposed class with sufficient accuracy based on the sum of information available from various resources. Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is not required.

9.0 NIOSH-Proposed Class for Petition SEC-00068

Based on its research, NIOSH accepted the petitioner-proposed class with a slight modification of the petitioner-requested definition (i.e., "worked in all facilities" was changed to "worked in any facility/location") to define a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees who worked in any facility/location at the Pantex Plant in Amarillo, Texas, from January 1, 1951 through December 31, 1991.

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-00068. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science.

Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining that it would be feasible to reconstruct the dose for the class proposed in this petition.

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Attachment One—SRDB Data for Bounding Internal Doses

Potential SRDB Data to be Used for Bounding Internal Doses													
	Internal Dose, Bioassay Data				Air Monitoring			Contamination Monitoring		Radiation Surveys		Environmental	
Year	H^3	Th	U	Pu	High Volume	Cell Air	Lapel	Alpha	H^3	Gamma	Neutron	Reports	Sampling
1959			25358		13944								
‘59			14537										
1960			14118	25306	13944								
1961				14226	13944			11088	14205				
‘61				14304				14226					
‘61				14330									
‘61				25342									
‘61				25306									
‘61				25358									
1962	14333				13944								14163
‘62	25391												
1963	25391		14329	14330						14319	14319		14163
‘63			25358	25358									
‘63				14537									
1964	25391				13944	25292							14163
1965	25391		25358		13944	25292							14163
‘65			14537										
1966	25391			14330	13944	25292							14163
‘66			25358	25358									
1967	25391		14537		13944	25292							14163
1968	25391		14537	14330		25292				14217	14217		14163
1969	25391					25286							14163
1970	25391					25286							14163
1971	14101					25286							14163
‘71	25391												
1972	14331		**25314		25293	25286		25291		25776			
‘72													
1973					14174							13085	**25433
‘73					25293								**25516
1974	**25316		**25316	**25316		25279						13087	**25432
‘74													**25433
‘74													**25516
1975						25297				25440		12551	**25432
‘75						25436						13097	**25435

Potential SRDB Data to be Used for Bounding Internal Doses													
	Internal Dose, Bioassay Data				Air Monitoring			Contamination Monitoring		Radiation Surveys		Environmental	
Year	H^3	Th	U	Pu	High Volume	Cell Air	Lapel	Alpha	H^3	Gamma	Neutron	Reports	Sampling
‘75													**25438
1976			**25314			25297				25440		13322	**14284
‘76	**25316		**25316	**25316						25782		13713	
1977						25301				25440		13321	
‘77	**25316		**25316	**25316						25786			
1978	**14194		**14194	**25314	14119	25301		25324		25440		13714	**14194
‘78			**14312	**14312									
‘78			**25314	25337									
‘78	**25316		**25316	**25316									
1979			14296	14296		25301		14252	14207	14207	14207	13684	14243
‘79						25305		25281	25281				
‘79								14296					
1980						25305				25440		13084	**14211
‘80										25776		13715	**25335
1981			**25314	**25314		25283				25511		13716	
‘81						25305				25783			
1982						25303				25513		13717	
1983	14331	17084	14537			25303				14148	14148	13718	
‘83	14334					25466		25466		25440	25466		
1984						25303				25779		13433	
1985						25298		14207	14207	25472		13089	**14213
‘85										25779			14265
1986						25298				14158	14158	13434	
‘86										25439	25439		
1987						25298				14129	14129	13086	
‘87										25471	25471		
1988													14231
1989	14654						14197	14207	14207	14157		13436	
‘89	14656							14208	14208	20761	20761		
1990	25362		14187							25468	25508	13440	
‘90			14196							25472		13685	
‘90			14206							25511			
‘90			14531							25513			
‘90			19642							25780			
1991	25351		19642		25360		25359		25484			13706	

Potential SRDB Data to be Used for Bounding Internal Doses													
	Internal Dose, Bioassay Data				Air Monitoring			Contamination Monitoring		Radiation Surveys		Environmental	
Year	**H^3**	**Th**	**U**	**Pu**	**High Volume**	**Cell Air**	**Lapel**	**Alpha**	**H^3**	**Gamma**	**Neutron**	**Reports**	**Sampling**
‘91							25483						

Notes:
** indicates that the data are CEP data