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

<table>
<tr><th>Time Period</th><th>Examination Type</th><th>Frequency</th><th>Default Dose Reconstruction Recommendation</th></tr>
<tr><td rowspan="3">1952-1981</td><td>Posterior-anterior (PA) Chest</td><td>For all workers, pre-employment and annually</td><td rowspan="3">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.</td></tr>
<tr><td>Anterior-posterior (AP) Lumbar spine</td><td>For male workers, pre-employment</td></tr>
<tr><td>Lateral (LAT) Lumbar spine</td><td>For male workers, pre-employment</td></tr>
<tr><td>1982 - 2004</td><td>PA Chest</td><td>For all workers, pre-employment and every 5 years.</td><td>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.</td></tr>
</table>

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