ORAU TEAM
Dose Reconstruction Project for NIOSH

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Document Title:	Document Number:	ORAUT-TKBS-0013-1
Pantex Plant – Introduction	Revision:	02
	Effective Date:	05/11/2007
	Type of Document:	TBD
	Supersedes:	Revision 01

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☐ New ☒ Total Rewrite ☐ Revision ☐ Page Change

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
02/18/2004	00	First approved issue. Initiated by Jerome B. Martin.
07/27/2006	01	Constitutes a total rewrite of document. Revised as a result of the biennial document review. Incorporates NIOSH formal review comments. Approved issue of Revision 01. This revision results in no change to the assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Jerome B. Martin.
05/11/2007	02	Approved revision initiated to include Attribution and Annotation section. Constitutes a total rewrite of the document. Incorporates formal internal review comments. This revision results in no change to the assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Jack J. Fix.

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ACRONYMS AND ABBREVIATIONS

AP	anterior–posterior
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DU	depleted uranium
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
IFI	in-flight insertable
L	liter
MeV	megaelectron-volt, 1 million electron-volts
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
PA	posterior–anterior
pCi	picocurie
TBD	technical basis document
U.S.C.	United States Code
§	section

1.1 INTRODUCTION

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historic background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH staff in the completion of the individual work required for each dose reconstruction.

In this document, the word “facility” is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an “atomic weapons employer facility” or a “Department of Energy [DOE] facility” as defined in the Energy Employees Occupational Illness Compensation Program Act [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA defines a DOE facility as “any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)” [42 U.S.C. § 7384l(12)]. Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled “Exposure in the Performance of Duty.” That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer “shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the POC [probability of causation[1]] guidelines established under subsection (c) …” [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation) define “performance of duty” for DOE employees with a covered cancer or restrict the “duty” to nuclear weapons work.

As noted above, the statute includes a definition of a DOE facility that excludes “buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program” [42 U.S.C. § 7384l(12)]. While this definition contains an exclusion with respect to the Naval Nuclear Propulsion Program, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled “Exposure in the Performance of Duty”] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all occupationally derived radiation exposures at covered facilities in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external dosimetry monitoring results are considered valid for use in dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction. NIOSH, however, does not consider the following exposures to be occupationally derived:

- radiation from naturally occurring radon present in conventional structures;
- radiation from diagnostic X-rays received in the treatment of work-related injuries.

[1] The U.S. Department of Labor is ultimately responsible under the EEOICPA for determining the POC.

1.2 PURPOSE

The purpose of this TBD is to provide a Pantex Plant site profile that contains technical basis information used by the Oak Ridge Associated Universities (ORAU) Team to evaluate the total occupational dose for EEOICPA claimants. This section provides an executive summary of the Pantex Plant TBDs.

1.3 SCOPE

This site profile is a specific support mechanism to the ORAU Team about the documentation of historical practices in relation to dose reconstruction at the Pantex Plant. This document provides supporting technical data, with assumptions that include a scientifically reasonable benefit of the doubt to claimants, to evaluate the total occupational radiation dose that can reasonably be associated with Pantex Plant worker exposures. This dose results from exposure to external and internal radiation sources in Pantex facilities, to Pantex occupationally required diagnostic X-ray examinations, and to on-site environmental releases. The discussion includes the doses that workers could have incurred while not monitored or that could have been missed.

Dose reconstructors should use the information in this TBD to evaluate both internal and external dosimetry data for unmonitored and monitored workers. In addition, the document serves as a supplement to, or a substitute for, individual monitoring data.

Over the years, new and more reliable radiation protection measures, as well as improved techniques and equipment for radiation detection and measurement, have been developed. The methods needed to account for these changes are identified in this document.

The doses are to be evaluated using the NIOSH Interactive RadioEpidemiological Program and the Integrated Modules for Bioassay Analysis computer programs. Information on measurement uncertainties is an integral component of the NIOSH approach. This document describes how the uncertainty for Pantex exposures and dose records is to be evaluated.

The site profile consists of the latest revisions of six sections: this Introduction, Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dosimetry. Some sections are accompanied by attachments that provide the critical data for the dose reconstructors.

Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 1.5.

1.4 EXECUTIVE SUMMARY

Section 2.0, Site Description (ORAUT 2006a), briefly describes the facilities and processes that have been used in the assembly and disassembly of nuclear weapons since U.S. Atomic Energy Commission operations began at Pantex in December 1951. Between 1952 and 1954, the primary mission at Pantex was to machine precision high-explosive castings and send them to Sandia National Laboratory in Albuquerque, New Mexico, for assembly. Between 1954 and 1958 during the use of the in-flight insertable (IFI) design, the only nuclear components handled at Pantex were depleted uranium (DU) cases and tritium reservoirs; during this time there was no processing of nuclear material. In 1958, the sealed-pit design replaced the IFI design and sealed plutonium pits were delivered to Pantex for assembly.

The nuclear weapon assembly process was highly standardized and consistent. Rigorous procedures were followed to ensure product quality and uniformity. Most of the parts for nuclear weapons were manufactured by the nuclear weapons complex of government-owned sites or by contracted vendors. Pantex received those parts as completed major components. These components supported one of three major processes: high-explosives assembly, physics package assembly, or mechanical assembly. The physics package operation involved the mating of the high explosives with the nuclear components. Completed and packaged weapons were staged for shipment to the U.S. Department of Defense (DoD).

From 1951 to 1987, weapons were shipped between Pantex and the DoD sites primarily by specially designed and built railcars escorted by DOE couriers. From 1977 to the present, weapons have moved between Pantex and DoD sites in specially designed and built tractor-trailers, also escorted by DOE couriers (ORAUT 2006a).

The facilities at Pantex are primarily those for assembly and disassembly of weapons and the special purpose and nuclear staging facilities that have handled complete nuclear weapons and components. Bays and Gravel Gertie cells are the facilities used for assembly and disassembly. The principal function of the bays is the assembly and disassembly of nuclear explosives, particularly the mechanical portion, which includes the electrical components and tritium reservoirs.

Physics package assembly and disassembly, where bare pit and high-explosive operations occur, take place in the cells. During the process of assembly of a nuclear explosive, operations begin in an assembly cell and then move to an assembly bay for completion. The reverse is true for disassembly. Disassembly of weapons has occurred in bays only when insensitive high explosives were present.

Gravel Gertie cells are round structures with a gravel and earth cover supported by a cable system. The design is based on experiments that showed that the mounded gravel roof over the round room would lift and vent the gas pressures produced in an accidental explosion. Plutonium would be filtered from the vented gases by the gravel, and releases to the environment would be minimized.

Special purpose facilities at Pantex include the Paint Facility, the Separation Testing Facility, the Mass Properties Facility, the Weapons Aging Facility, and the Weapons Transfer Station. Nuclear staging facilities include the Zone 4 igloos for staging or interim storage of weapons, weapon components, and other process-related materials. Zone 12 staging facilities include pit vaults, warehouses, and facilities for special nuclear material components (ORAUT 2006a).

Section 3.0, Occupational Medical Dose (ORAUT 2007a), provides information about the dose that individual workers received from X-rays that were required as a condition of employment. These X-rays included preemployment chest and lumbar spine X-rays and annual chest X-rays during physical examinations.

Pantex required preemployment and annual physical examinations as part of its occupational health and safety program. These medical examinations typically included annual diagnostic posterior–anterior (PA) chest X-rays from the beginning of operations in 1952, with a change in frequency to every 5 years beginning in 1982 (ORAUT 2007a). In addition, Pantex required a single set of preemployment lumbar spine radiographs, both anterior–posterior (AP) and lateral views, for men (but not for women) from 1952 to 1982 (ORAUT 2007a).

Both the X-ray equipment and the techniques used for taking X-rays covered by this TBD have changed over the years. These factors have been taken into account in determining the dose that a worker would have received from an X-ray. When there was a doubt about the technique used, assumptions that contain a scientifically reasonable benefit of the doubt to claimants have been made to ensure that the dose is not underestimated. The investigated parameters include the tube current and voltage, exposure time, filtration, source-to-skin distance, the view (PA or lateral), and any other factor that could affect the dose received by the worker.

The organ doses from the X-rays have been calculated. The calculated dose takes into account the uncertainty associated with each of the parameters mentioned above. Tables list the doses received by the various organs for convenient reference by the dose reconstructors.

Section 4.0, Occupational Environmental Dose (ORAUT 2004), applies to workers who were not routinely monitored for external or internal radiation exposure. The environmental dose is the dose unmonitored workers could have received when working on the site but outside the buildings from inhalation of radioactive materials in the air, direct radiation from plumes, contact with particles on the skin, and from direct exposure to radionuclides in the soil.

Exposure to these sources can result in an internal dose to the whole body or body organs from inhalation of the radioactive materials as well as a whole- or partial-body external dose from deposited radionuclides or submersion in a cloud of radioactive material (ORAUT 2004). .

Radionuclides present at the Pantex Plant have included tritium, uranium (primarily ^{238}U), plutonium, and thorium. The primary radionuclides of concern are tritium and DU. There were no noble gas releases at the Pantex site, and there have been no environmental releases of plutonium or thorium. A significant release of tritium occurred in May 1989, but environmental doses were minimal. Chronic low-level releases of DU have been monitored and are characterized in this section.

Section 5.0, Occupational Internal Dose (ORAUT 2007b), describes the internal dosimetry program at Pantex Plant. Internal dose at Pantex has occurred primarily from intakes of radioactive material during assembly and disassembly of nuclear weapons and potentially during radioactive waste management activities. Between 1980 and 1990, there was a large disassembly effort, but controls to limit airborne contamination were not fully implemented. During this period there was a higher likelihood of radionuclide intakes [1]. Before 1980, most work was assembly of new clean components, so the potential for intakes was lower [2]. In addition to the radionuclides used at Pantex that can result in worker intakes, this section addresses occupational internal dose from radon in the workplace. This section also addresses potential missed internal dose (ORAUT 2007b).

There was no routine bioassay program at Pantex before 1972 (ORAUT 2007b); bioassay was performed only for specific events. There are only four radionuclides handled at Pantex that are of concern for occupational intakes: Tritium, uranium, thorium, and plutonium.

There is no specific data to substantiate any specific releases of tritium or uptakes of tritium before 1972 (ORAUT 2007b). Tritium dose records assign doses to only a few workers out of over 2000 monitored between 1971 and 1980 (ORAUT 2007b). Default doses were assigned to exposed workers for the 1956 to 1971 period based on the few non-zero doses in 1972. Around 1980, disassembly of nuclear weapons was performed more often than assembly, and releases of tritium were more likely to occur (ORAUT 2007b). The TBD describes a method for assigning chronic intake of tritium to workers who have handled tritium reservoirs from 1972 to the present based on the dose records. In addition the large accidental release of tritium in 1989 is discussed. Four workers received intakes; one significantly, requiring medical treatment (ORAUT 2007b).

Uranium contamination at Pantex is either uranium metal or air-oxidized uranium (ORAUT 2007b). During disassembly, aged components can have uranium oxide and uranium metal in the form of *black dust*, which is potentially present as airborne contamination that exhibits type S aerosol behavior. Bioassay data collected in 1990 for a group of 305 workers were analyzed to determine the potential magnitude of doses from occupational intakes of uranium, the probabilistic corrections for nonoccupational intakes of uranium, and the use of isotope ratios to distinguish occupational intakes from environmental intakes. The TBD describes a method to determine default intake values for workers exposed to uranium contamination during disassembly of nuclear weapons.

Thorium and plutonium have been handled at Pantex, but no machining or other processing has been conducted. The potential for removable contamination and uptakes by workers has been very low. A few small uptakes of thorium have been recorded since 1999 (ORAUT 2007b). No intakes of plutonium have occurred except for workers who could have been involved in a 1961 incident and its subsequent cleanup (ORAUT 2007b).

Occupational internal dose from elevated radon in the Pantex workplace was assessed. A DOE complex-wide survey of radon levels was performed in 1990. There were 137 locations sampled at Pantex with duplicate measurements made at 13 locations. There were eight buildings at Pantex with radon concentrations above 4 pCi/L, which is the U.S. Environmental Protection Agency's reference point for considering remedial action for indoor radon activity. The TBD provides recommendations for assessment of potential radon exposures and effective dose to workers (ORAUT 2007b).

Section 6.0, Occupational External Dosimetry (ORAUT 2006b), discusses the Pantex program for measuring whole-body, skin, and extremity doses to the workers. The methods for evaluating external doses to workers have also evolved over the years as new techniques and equipment have been developed. In addition, concepts in radiation protection have changed. The TBD discusses the dose reconstruction parameters, Pantex practices and policies, and dosimeter types and technologies for measuring the dose from the different types of radiation. The evaluation of doses measured from exposure to beta, gamma, and neutron sources is addressed. Tables list results for various dosimeters exposed to different exposure geometries and radiation energies.

The primary sources of external radiation exposure at Pantex have been plutonium pits, DU, and thorium components (ORAUT 2006b). Plutonium pits, which emit X-rays, gamma rays, and neutrons, have been the major source of exposure to Pantex radiation workers (ORAUT 2006b). Direct handling of pits can result in relatively high extremity dose rates [3]. Workers wear lead aprons during pit-handling work, which substantially reduces the low-energy photon doses to the torso. Dosimeters are usually worn under the lead apron; this location for the dosimeter captures the reduced torso dose but underestimates the dose to the head (thyroid, lens of eye). Neutron doses measured under the lead apron can also be underestimated (ORAUT 2006b). Beta and photon exposures have occurred during handling of DU or thorium components. Exposures to thorium have included the penetrating 2.6-MeV photons from ^{208}Tl (ORAUT 2006b).

Sources of bias, workplace radiation field characteristics, responses of the different beta/gamma and neutron dosimeters in the workplace fields, and the adjustments to the recorded dose measured by these dosimeters during specific years are discussed in detail.

There are sources of potential dose that could have been missed because of the limitations of dosimetry systems and the methods of reporting low doses (ORAUT 2006b) This missed dose is discussed as a function of facility location, dosimeter type, year, and energy range.

1.5 ATTRIBUTIONS AND ANNOTATIONS

Where appropriate in this document, bracketed callouts have been inserted to indicate information, conclusions, and recommendations provided to assist in the process of worker dose reconstruction. These callouts are listed here in the Attributions and Annotations section, with information to identify the source and justification for each associated item. Conventional References, which are provided in the next section of this document, link data, quotations, and other information to documents available for review on the Project's Site Research Database.

Jerome Martin serves as a Site Expert for this document. As such, he is responsible for advising on site-specific issues and incidents as necessary and ensures the completeness and accuracy of the document. Because of his prior work experience at the site, he possesses, or is aware of information that is relevant for reconstructing radiation doses experienced by claimants who worked at the site. In all cases where such information or prior studies or writings are included or relied upon by the document owner, those materials are fully attributed. Mr. Martin's Disclosure Statement is available at www.oraucoc.org.

[1] Martin, Jerome B. ORAU Team. Health Physicist. March 2007.
More extensive engineering controls to limit airborne contamination were implemented in the 1990s. During the disassembly campaign of the 1980s, when contamination controls were limited, the potential for uptakes was greater.

[2] Martin, Jerome B. ORAU Team. Health Physicist. March 2007.
Prior to 1980, the emphasis was on assembly of new weapons and relatively few disassemblies were done. New weapon components were clean (not oxidized) and routine contamination smears revealed very little removable contamination. Thus, the potential for uptakes was lower than for the disassembly period in the 1980s.

[3] Martin, Jerome B. ORAU Team. Health Physicist. March 2007.
The radiation dose rates at the surface of a pit are much higher than that measured at a distance of 1 foot. If a pit was directly touched with the hands, the extremity doses were about a factor of 10 higher than that measured by a dosimeter worn on the chest.

REFERENCES

ORAUT (Oak Ridge Associated Universities Team), 2004, *Technical Basis Document for the Pantex Plant – Occupational Environmental Dose*, Rev. 00, Oak Ridge, Tennessee, August 24.

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ORAUT (Oak Ridge Associated Universities Team), 2007b, *Pantex Plant – Occupational Internal Dose*, Rev. 00 PC-1, Oak Ridge, Tennessee, February 8.