ORAU TEAM
Dose Reconstruction
Project for NIOSH

Oak Ridge Associated Universities | Dade Moeller | MJW Technical Services

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ACRONYMS AND ABBREVIATIONS

AP	anterior-posterior
AWE	atomic weapons employer
DHHS	U.S. Department of Health and Human Services
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DU	depleted uranium
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
IFI	in-flight insertable
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
SEC	Special Exposure Cohort
SRDB Ref ID	Site Research Database Reference Identification (number)
TBD	technical basis document
U.S.C.	United States Code
§	section or sections

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 historical background information and guidance to assist in the preparation of dose reconstructions at particular Department of Energy (DOE) or Atomic Weapons Employer (AWE) facilities or categories of DOE or AWE facilities. They will be revised in the event additional relevant information is obtained about the affected DOE or AWE facility(ies). These documents may be used to assist NIOSH staff in the evaluation of Special Exposure Cohort (SEC) petitions and the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used to refer to an area, building, or group of buildings that served a specific purpose at a DOE or AWE facility. It does not mean nor should it be equated to an "AWE facility" or a "DOE facility." The terms AWE and DOE facility are defined in sections 7348l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), respectively. An AWE facility means "a facility, owned by an atomic weapons employer, that is or was used to process or produce, for use by the United States, material that emitted radiation and was used in the production of an atomic weapon, excluding uranium mining or milling." 42 U.S.C. § 7384l(5). On the other hand, a DOE facility is defined 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 [DOE] (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)," and with regard to which DOE has or had a proprietary interest; or "entered into a contract with an entity to provide management and operation, management and integration, environmental remediation services, construction, or maintenance services." 42 U.S.C. § 7384l(12). The Department of Energy (DOE) determines whether a site meets the statutory definition of an AWE facility and the Department of Labor (DOL) determines if a site is a DOE facility and, if it is, designates it as such.

Accordingly, a Part B claim for benefits must be based on an energy employee's eligible employment and occupational radiation exposure at a DOE or AWE facility during the facility's designated time period and location (i.e., covered employee). After DOL determines that a claim meets the eligibility requirements under EEOICPA, DOL transmits the claim to NIOSH for a dose reconstruction. EEOICPA provides, among other things, guidance on eligible employment and the types of radiation exposure to be included in an individual dose reconstruction. Under EEOICPA, eligible employment at a DOE facility includes individuals who are or were employed by DOE and its predecessor agencies, as well as their contractors and subcontractors at the facility. Unlike the abovementioned statutory provisions on DOE facility definitions that contain specific descriptions or exclusions on facility designation, the statutory provision governing types of exposure to be included in dose reconstructions for DOE covered employees only requires that such exposures be incurred in the performance of duty. As such, NIOSH broadly construes radiation exposures incurred in the performance of duty to include all radiation exposures received as a condition of employment at covered DOE facilities in its dose reconstructions for covered employees. For covered employees at DOE facilities, individual dose reconstructions may also include radiation exposures related to the Naval Nuclear Propulsion Program at DOE facilities, if applicable. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction.

NIOSH does not consider the following types of exposure as those incurred in the performance of duty as a condition of employment at a DOE facility. Therefore these exposures are not included in dose reconstructions for covered employees (NIOSH 2010):

- Background radiation, including radiation from naturally occurring radon present in conventional structures
- Radiation from X-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons

1.1.1 PURPOSE

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

1.1.2 SCOPE

This site profile documents 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 (favorable 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 occupationally required diagnostic X-ray examinations, and to onsite environmental releases. The discussion includes the doses that workers could have incurred while not monitored or that could have been missed.

Dose reconstructors may use the information in this TBD to evaluate both internal and external dosimetry data for unmonitored and monitored workers. In addition, the site profile 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 necessary to account for these changes are identified in this site profile.

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. Each section of this site profile, as appropriate, 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: Introduction, Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dose. 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 1.3.

1.1.3 SPECIAL EXPOSURE COHORT

January 1, 1958 through December 31, 1983
On December 21, 2011, the Secretary of the U.S. Department of Health and Human Services (DHHS) designated the following class of employees as an addition to the SEC (Sebelius 2011):

> *All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Pantex Plant in Amarillo, Texas, during the period from January 1, 1958 through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the SEC.*

As stated in Sebelius (2011), while it was concluded that it is feasible to reconstruct all external radiation doses including medical X-ray dose for the period, DHHS finds that it lacks sufficient personnel or area monitoring data, source term data, and operational information to support reconstructing internal dose from intakes of uranium with sufficient accuracy from January 1, 1958, through December 31, 1983, at the Pantex Pant in Amarillo, Texas. Reconstruction of thorium intakes with sufficient accuracy is not feasible for all workers during the same period since the proposed method for estimating those intakes depends on the reconstruction of uranium intakes. However, reconstruction of doses from radon is feasible based on workplace measurements. Plutonium and thorium intakes can be reconstructed for individuals who have specific monitoring results for those radionuclides. Tritium doses can be reconstructed based on tritium bioassay results from monitored workers. Although DHHS found that it is not possible to completely reconstruct internal radiation doses for the proposed class, NIOSH can use any internal monitoring data that might become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Pantex Plant, during the period from January 1, 1958, through December 31, 1983, but who do not qualify for inclusion in the SEC, can be performed using these data as appropriate to support a partial dose reconstruction.

January 1, 1984, through December 31, 1991
On September 30, 2013, the Secretary of DHHS designated the following class of employees as an addition to the SEC (Sebelius 2013):

> *All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Pantex Plant in Amarillo, Texas, during the period from January 1, 1984 through December 31, 1991, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the SEC.*

As stated in Sebelius (2013), while it was concluded that it is feasible to reconstruct all external radiation doses including medical X-ray dose for the period, DHHS finds that it lacks sufficient information to reconstruct internal radiation doses adequately for all Pantex Plant employees from intakes of uranium and thorium with sufficient accuracy from January 1, 1984, through December 31, 1991, at the Pantex Pant in Amarillo, Texas. Specifically, DHHS found that the available monitoring data, as well as available process and source term information for the Pantex Plant was inadequate to estimate with sufficient accuracy the internal doses from potential exposures to uranium during the period 1984 through 1990, and to thorium from January 1, 1984, through December 31, 1991. However, tritium internal doses can be reconstructed for the period based on the available tritium bioassay data. Although DHHS found that it is not possible to completely reconstruct internal radiation doses for the proposed class, NIOSH can use any internal monitoring data that might become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Pantex Plant during the period from January 1, 1984, through December 31, 1991, but who do not qualify for inclusion in the SEC, can be performed using these data as appropriate to support a partial dose reconstruction.

1.2 SUMMARY

Section 2.0, *Site Description* (ORAUT 2015a), 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 Laboratories in Albuquerque, New Mexico, for assembly. Between 1954 and 1958 during the use of the in-flight insertable (IFI) design, the only nuclear components Pantex handled 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, and/or specially designed and built tractor-trailers, also 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.

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 that are 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 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 that would be 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.

Section 3.0, *Occupational Medical Dose* (ORAUT 2014a), 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 1971. 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 1970.

Both the X-ray equipment and the techniques for taking X-rays that this TBD covers 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 doubt about the X-ray technique used, assumptions favorable 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, AP, or lateral), and any other factor that could affect the dose the worker received.

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

Section 4.0, *Occupational Environmental Dose* (ORAUT 2014b), 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 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 when working on the site but outside the buildings.

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.

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 Pantex, 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 2015b), 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.

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

There are no specific data to substantiate any specific releases of tritium or uptakes of tritium before 1972. Tritium dose records assign doses to only a few out of over 2,000 monitored workers between 1971 and 1980. Default doses were assigned to exposed workers for 1956 to 1971 based on the few nonzero doses in 1972. Around 1980, disassembly of nuclear weapons was performed more often than assembly, and releases of tritium were more likely to occur. Section 5.0 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 was significant and required medical treatment.

Uranium contamination at Pantex is either uranium metal or air-oxidized uranium. 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.

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. No intakes of plutonium have occurred except for workers who could have been involved in a 1961 incident and its subsequent cleanup.

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 sampling locations with duplicate measurements at 13 locations. There were eight buildings at Pantex with radon concentrations above 4 pCi per liter, which is the U.S. Environmental Protection Agency’s reference point for considering remedial action for indoor radon activity. Section 5.0 provides recommendations for assessment of potential radon exposures and effective dose to workers.

Section 6.0, *Occupational External Dose* (ORAUT 2015c), 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. Section 6.0 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 measured doses from exposure to beta, gamma, and neutron sources is addressed. Tables list results for various dosimeters that were 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. Plutonium pits, which emit X-rays, gamma rays, and neutrons, have been the major source of exposure to Pantex radiation workers. 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 (e.g., thyroid, lens of eye). Neutron doses that are measured under the lead apron can also be underestimated. 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 208Tl.

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 as 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. This missed dose is discussed as a function of facility location, dosimeter type, year, and energy range.

1.3 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 (SRDB).

Jerome Martin served as a Site Expert for this document. As such, he was responsible for advising on site-specific issues and incidents as necessary to ensure the completeness and accuracy of the document. Because of his work experience at the site, he possessed or was aware of information that is relevant for reconstructing radiation doses experienced by claimants who worked at the site. In all cases where such information, studies, or writings are included or relied upon by the document owner, those materials are fully attributed.

[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.
Before 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. The potential for uptakes was thus lower than for the disassembly period in the 1980s.

[3] Martin, Jerome B. ORAU Team. Health Physicist. March 2007.
The measured radiation dose rates at the surface of a pit are much higher than those 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

NIOSH (National Institute for Occupational Safety and Health), 2010, *Radiation Exposures Covered for Dose Reconstructions Under Part B of the Energy Employees Occupational Illness Compensation Program Act*, DCAS-IG-003, Rev. 1, Division of Compensation Analysis and Support, Cincinnati, Ohio, October 5.

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ORAUT (Oak Ridge Associated Universities Team), 2014b, *Pantex Plant – Occupational Environmental Dose*, ORAUT-TKBS-0013-4, Rev. 02, Oak Ridge, Tennessee, January 3.

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Sebelius, K., 2011, *HHS Designation of Additional Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000, Designating a Class of Employees from Pantex Plant, Amarillo, Texas*, U.S. Department of Health and Human Services, Office of the Secretary, Washington, D.C., December 21. [SRDB Ref ID: 116796]

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