ORAU TEAM
Dose Reconstruction Project for NIOSH

Oak Ridge Associated Universities | Dade Moeller | MJW Technical Services

DOE Review Release 12/15/2015

Pantex Plant – Site Description	ORAUT-TKBS-0013-2	Rev. 03
	Effective Date:	12/08/2015
	Supersedes:	Revision 02

Subject Expert(s): Dale D. Thomas III

Document Owner Approval:	Signature on File Dale D. Thomas III, Document Owner	Approval Date:	12/03/2015
Concurrence:	Signature on File John M. Byrne, Objective 1 Manager	Concurrence Date:	12/03/2015
Concurrence:	Signature on File Edward F. Maher, Objective 3 Manager	Concurrence Date:	12/03/2015
Concurrence:	Vickie S. Short Signature on File for Kate Kimpan, Project Director	Concurrence Date:	12/07/2015
Approval:	Signature on File James W. Neton, Associate Director for Science	Approval Date:	12/08/2015

FOR DOCUMENTS MARKED AS A TOTAL REWRITE, REVISION, OR PAGE CHANGE, REPLACE THE PRIOR REVISION AND DISCARD / DESTROY ALL COPIES OF THE PRIOR REVISION.

☐ New ☒ Total Rewrite ☐ Revision ☐ Page Change

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
03/30/2004	00	New Technical Basis Document for the Pantex Plant – Site Description. First approved issue. Initiated by Jerome B. Martin.
07/27/2006	01	Constitutes a total rewrite of the document. Revised as a result of the biennial document review. Incorporates NIOSH formal 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 Jerome B. Martin.
05/08/2007	02	Approved revision initiated to add Attributions and Annotations, Purpose and Scope Sections. 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.
12/08/2015	03	Revision initiated to incorporate information on the approved Special Exposure Cohort classes for the Pantex Plant. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Dale D. Thomas III.

TABLE OF CONTENTS

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
CAM	continuous air monitor
CFR	Code of Federal Regulations
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
FM	farm-to-market
ft	foot
HE	high explosive(s)
hr	hour
IFI	in-flight insertable
IHE	insensitive high explosive(s)
keV	kiloelectron-volt, 1 thousand electron-volts
lb	pound
LINAC	linear accelerator
MeV	megaelectron-volt, 1 million electron-volts
mi	mile
mm	millimeter
mrad	millirad
mrem	millirem
NELA	nuclear explosive look-alike
NEOP	nuclear explosive operating procedures
NDE	nondestructive examination
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities Team
POC	probability of causation
RAMS	radiation alarm monitoring system
SEC	Special Exposure Cohort
SNM	special nuclear material
SRDB Ref ID	Site Research Database Reference Identification (number)
TBD	technical basis document
TLD	thermoluminescent dosimeter
U.S.C.	United States Code

yr	year
μCi	microcurie
§	section or sections

2.1 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

2.1.1 PURPOSE

The purpose of this technical basis document (TBD) is to provide a Pantex Plant site description 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 document provides information on Pantex Plant facilities and operations.

2.1.2 SCOPE

The Pantex Plant has played an important role in the U.S. nuclear weapons program. Operations have included the fabrication of high explosives (HE) and the assembly and disassembly of nuclear weapons. This TBD contains supporting information to assist in the evaluation of worker doses from Pantex Plant operations. Additional guidance is found in OCAS-IG-001, *External Dose Reconstruction Implementation Guideline* (NIOSH 2007) and OCAS-IG-002, *Internal Dose Reconstruction Implementation Guideline* (NIOSH 2002).

The methods Pantex used to measure radiation exposure to workers have evolved since the beginning of operations. An objective of this TBD is to provide supporting technical data to assist in the evaluation of the total Pantex occupational dose that can reasonably be associated with worker radiation exposure as covered under EEOICPA. This dose includes occupational external and internal exposures in Pantex facilities, occupationally required diagnostic X-ray examinations, and onsite exposures to Pantex environmental releases in accordance with the guidance in ORAUT-TKBS-0013-6, *Pantex Plant – Occupational External Dose* (ORAUT 2015a).

Section 2.2 of this TBD provides a general description of the Pantex Plant and its location. Section 2.3 describes site activities, including early Pantex Plant operations and weapon assembly and disassembly processes. Section 2.4 describes specific Pantex facilities including bays, cells, special-purpose facilities, and nuclear staging facilities. The Pantex radiation protection program is described in Section 2.5. General radiation exposure characteristics are described in Section 2.6. Dose reconstructors would use these data only if monitoring data were unavailable and other methods were not appropriate for dose reconstruction.

Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 2.7

2.1.3 SPECIAL EXPOSURE COHORT

Required section for TKBS if there is an SEC class for the site

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 Special Exposure Cohort (SEC) (DHHS 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 DHHS (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 because the proposed method for estimating those intakes depend 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 who were 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 (DHHS 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 DHHS (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 from 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 who were 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.

2.2 SITE DESCRIPTION

The Pantex Plant (Figure 2-1) is approximately 17 mi northeast of Amarillo in Carson County (in the Texas panhandle). The Plant site is bounded on the north by Texas Farm-to-Market (FM) Road 293, on the east by FM 2373, and on the west by FM 683. To the south, DOE-owned property extends to within 1 mi of U.S. Highway 60.

2.3 SITE ACTIVITIES

2.3.1 EARLY PANTEX PLANT OPERATIONS

Pantex Plant was one of the last plants built during World War II to load, assemble, and pack ordnance. The plant began operations in September 1942 only 9 months after groundbreaking. By the end of the War, Pantex had three loading lines running full time, which produced 500-lb bombs, 105-mm howitzer shells, and 23-lb fragmentation bombs. Operations at Pantex stopped the week after the War ended on August 14, 1945 (Mitchell 2003).

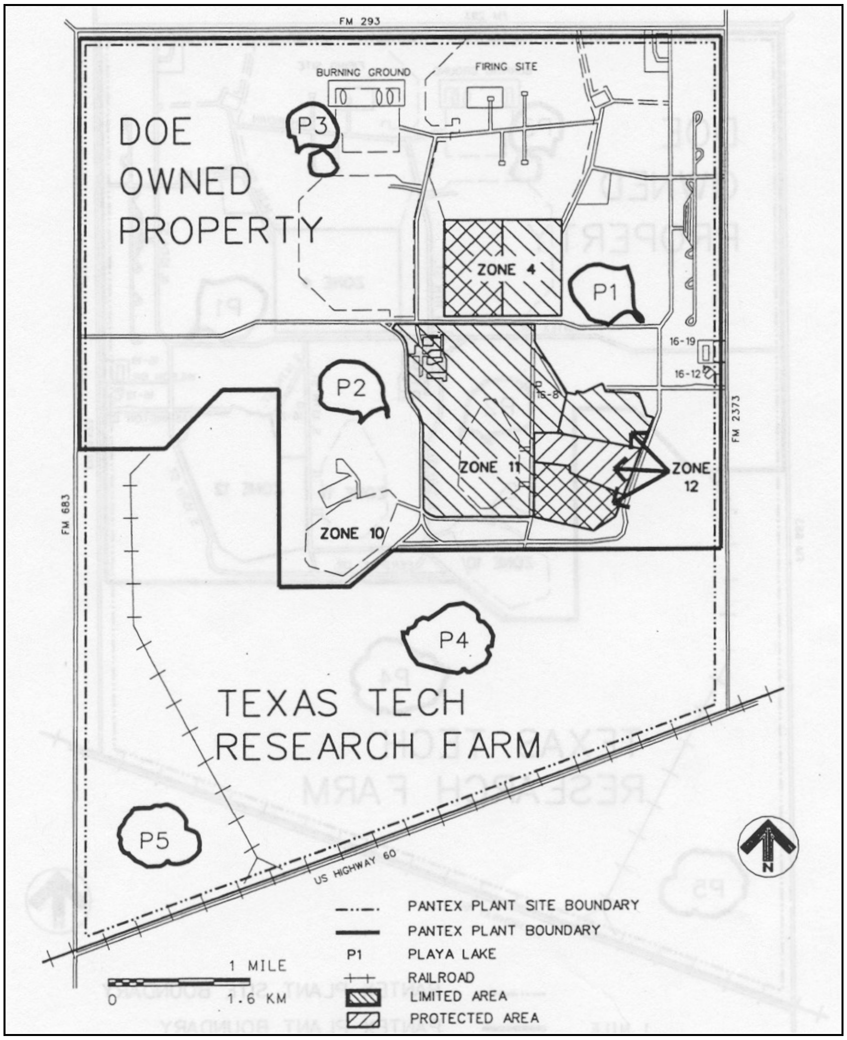

Figure 2-1. Map of Pantex Plant (BWXT Pantex 2001, p. 56).

In 1951, when the U.S. Atomic Energy Commission (AEC) was looking for a new high explosives (HE) fabrication plant, the unused 6 yr-old HE loading line at Pantex was attractive. AEC contracted Silas Mason Company for the construction of 10 new buildings and modification of 3 others, and construction began on April 13, 1951 (Mitchell 2003). Pantex completed its first HE operations in December 1951. By mid 1952, Pantex was at full production and was responsible for HE fabrication, assembly of nonnuclear components, retrofits, modifications, and disassembly for retirements. The 10 facilities included explosives-manufacturing facilities that did not process Special Nuclear Material (SNM).

Beginning in 1948, the in-flight insertable (IFI) design was used in nuclear weapons. In this design, nuclear and nonnuclear components were kept separate until the time of use. The nuclear capsule did not require additional assembly, so military technicians could complete the final weapon assembly en route to the target by inserting the nuclear capsule into the mechanical assembly (Mitchell 2003).

Between 1952 and 1954, the primary mission at Pantex was to precision-machine HE castings and send them to Sandia National Laboratory in Albuquerque, New Mexico, for assembly. From 1956 to 1958, with the IFI design, the only nuclear components that were handled at Pantex were depleted uranium (DU) cases and tritium reservoirs; during this time there was no processing of nuclear material (ORAUT 2003a). Because these DU components were new at the time of assembly, this analysis assumed that removable DU oxide contamination on the components was minimal. In similar fashion, the potential for significant removable tritium contamination was minimal because the tritium reservoirs had to meet rigorous shipping requirements. The only other sources of radiation exposure at Pantex during this period were industrial radiography and medical X-rays (ORAUT 2003a) [1].

In the late 1950s, the sealed-pit design replaced the IFI design and delivery of sealed plutonium pits to Pantex became routine in 1958 (Mitchell 2003). New facilities were required for the sealed-pit design, which involved encapsulated SNM; six gravel gertie cells were completed in 1958.

By 1966, all the older IFI weapons were dismantled, and most of the SNM was recycled into the new sealed-pit weapons. In 1964, the weapon surveillance and repair mission was assigned to Pantex, while both Pantex and Burlington shared the retrofits and modifications mission. Pantex renovated facilities for HE development in the early 1960s and completed the separated-bay weapon assembly facility in 1970. Since 1975, Pantex has been the only DOE center for weapons assembly, disassembly, retrofit, and modification (Mitchell 2003).

2.3.2 WEAPON ASSEMBLY AND DISASSEMBLY PROCESSES

The nuclear weapon assembly process was highly standardized and consistent. Rigorous procedures were followed to ensure product quality and uniformity. Classified records documented every step of assembly and disassembly of every weapon including the badge number or inspection stamp of the person completing the step (ORAUT 2003b). With the advent of the sealed-pit design in 1958, all assembly and disassembly work was on complete sealed-pit weapons (Mitchell 2003).

Most parts for nuclear weapons assembly were manufactured within the nuclear weapons complex of government-owned/contractor-operated facilities. Pantex received those parts as completed major components (DOE 1997). These components supported one of three major processes: HE subassembly, physics package assembly, or mechanical assembly. A process called palletizing involved pulling the required parts for one weapon from warehouse stock into one or two large baskets or pallets, which were delivered at the appropriate time to the bay or cell where assembly would take place (BWXT Pantex 2001).

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

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

Figure 2-2 is a schematic illustration of the weapon assembly process at Pantex. The shaded steps are those with the highest potential for radiation exposure. The following sections characterize the radiation source(s), the geometry of exposure situations, and the typical duration of exposures associated with these steps.

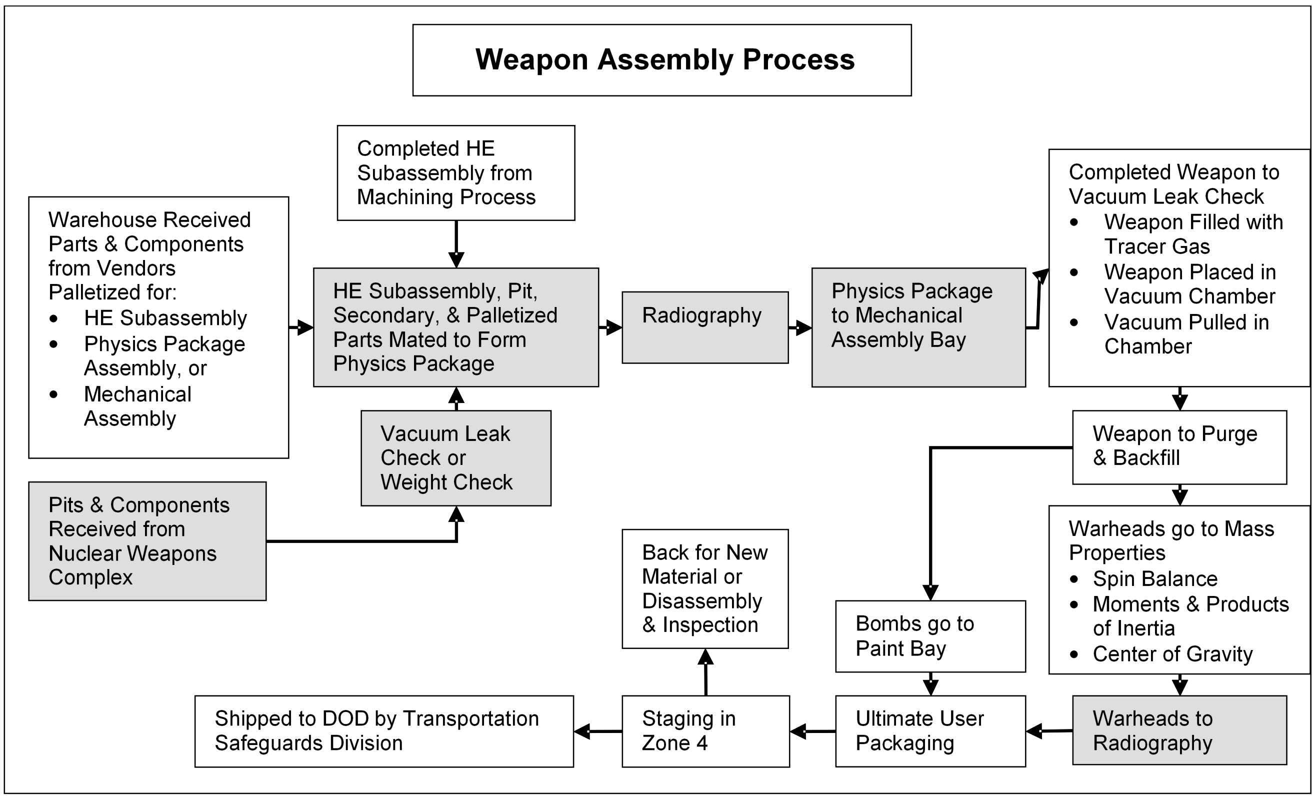

Figure 2-2. Pantex nuclear weapon assembly process (Mitchell 2003).

Figure 2-3 shows how the dismantlement of nuclear weapons at Pantex is basically the reverse of the assembly process.

From 1951 to 1987, weapons were shipped between Pantex and DOD sites (primarily by rail in specially designed and built railcars) escorted by DOE couriers but also by 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 (Mitchell 2003).

2.4 SITE FACILITIES

Figure 2-1 shows the locations of the major Pantex Plant activities in Zone 4 and Zone 12. Major operations with radioactive materials included staging of SNM in Zone 4 and assembly and disassembly of nuclear weapons in Zone 12 South (BWXT Pantex 2001).

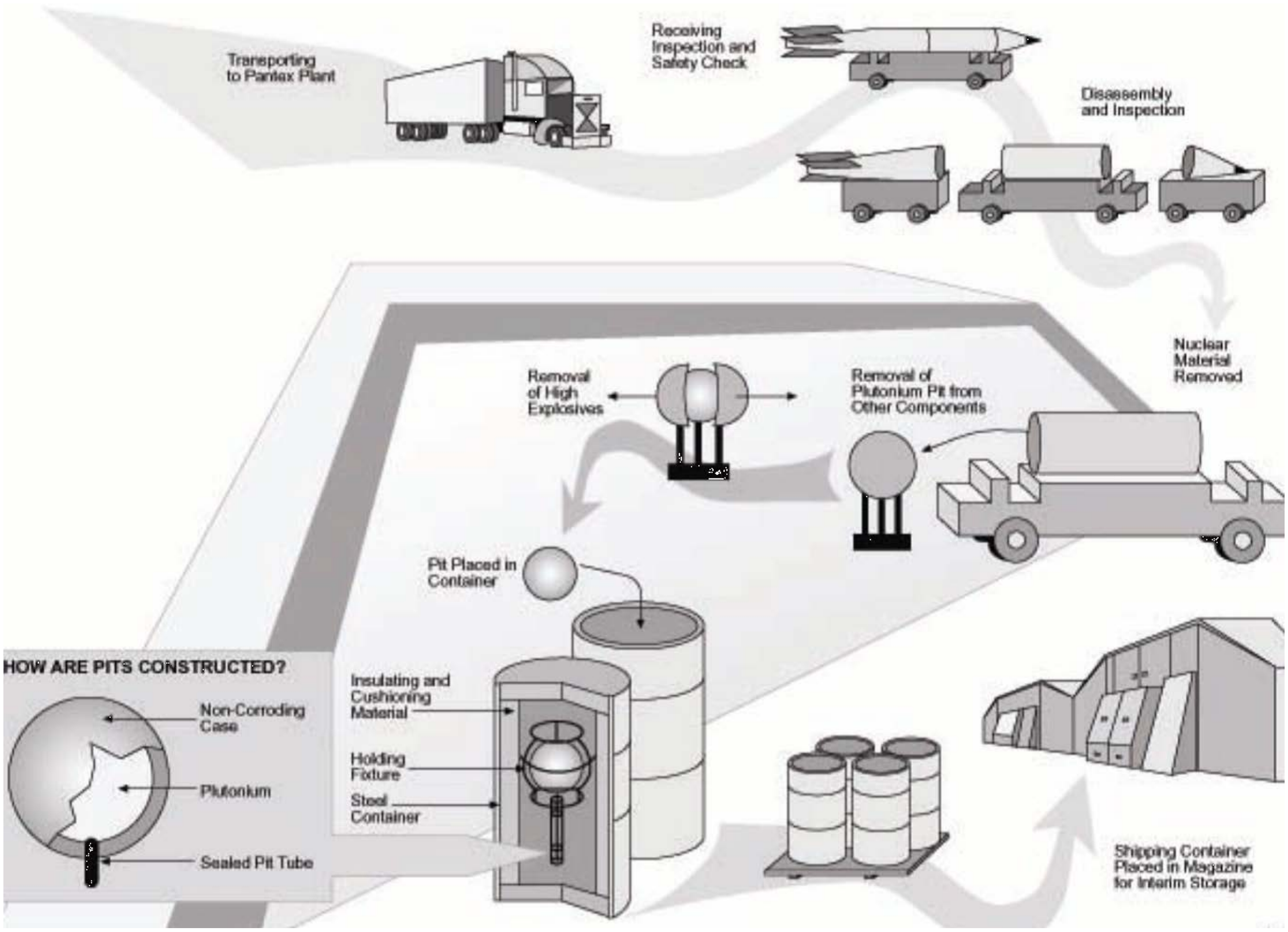

Figure 2-3. Weapons dismantlement and pit storage at Pantex Plant (Mitchell 2003).

The moderate-hazard facilities at Pantex are primarily those for assembly and disassembly and the special-purpose and nuclear staging facilities that have handled complete nuclear weapons (nuclear explosives) and components (BWXT Pantex 2001). The following sections describe the bays, cells, special-purpose facilities, and nuclear staging facilities at Pantex.

2.4.1 BAYS

Figure 2-4 shows a generic bay situated off a ramp or hall for transport of a weapon or weapon component into the bay. The bay is accessed through a pair of interlocked blast-proof doors, which prevent one door from opening unless the other door is closed. A pair of double doors (also with an interlocking system) is used to bring equipment into the bay. A special work stand occupies the middle of the floor space for weapons work. Appropriate electrical, pneumatic, and safety alarm systems are permanently installed in the bay. In addition, an elaborate communication system is in place for monitoring the nuclear explosive operating procedures (NEOPs) and tracking the SNM.

Redundant and diverse fire protection systems are in place, and strict control of combustible material is enforced. Certain operations require that the production technicians be electrically grounded to the weapon to avoid static discharge. In addition, operations are discontinued during lightning warnings (BWXT Pantex 2001).

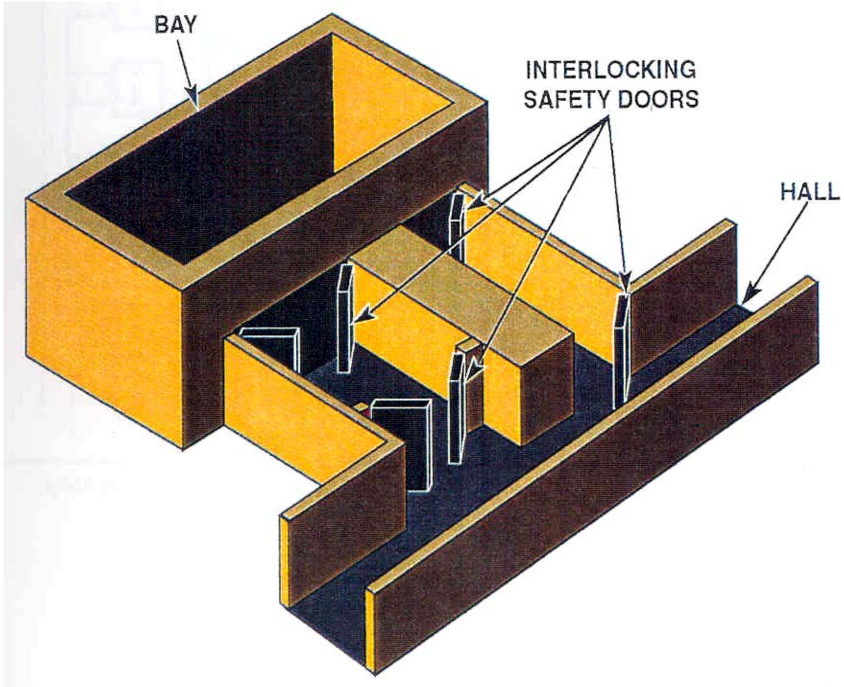

Figure 2-4. Generic representation of a nuclear explosive bay (Mitchell 2003).

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 (BWXT Pantex 2001). The major operations in these bays are the partial assembly or disassembly of nuclear weapons containing HE and the complete assembly and disassembly of nuclear weapons containing insensitive high explosives (IHE).

Physics package assembly and disassembly, which involves bare pit and HE operations, take place in the cells. During the assembly process 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 for HE weapons begins in a bay and concludes in a cell. Disassembly of weapons with IHE occurs only in a bay.

Alpha and beta continuous air monitors (CAMs) connected to the Pantex Radiation Alarm Monitoring System (RAMS) are used to detect airborne radiological contamination in the bays and cells (BWXT Pantex 2001). The radiation safety system in the radiography bays provides interlocking safety devices to protect workers from accidental exposures (BWXT Pantex 2001, p. 13). Additional safety measures include interlocks between the operating controls; gamma radiation detectors; panic switches; warning lights, chimes, and horns; passageway door switches; RAMS alarms; and fire alarms.

Nuclear explosives, nuclear components, radioisotopic thermoelectric generators, HE, and IHE are transferred to and from the bays using electric forklifts or manually operated transfer carts (BWXT Pantex 2001). Only weapons containing IHE main charges can be completely assembled or disassembled in the bays. For pit-HE-IHE disassembly, employees wear lead-lined aprons, safety glasses, and vinyl gloves to handle bare pits. In addition, a safety net is used during pit-HE-IHE disassembly for some operations. All assembly and disassembly operations are performed in the designated bay in accordance with the written NEOPs and the operations and instructions standards specific to a weapons program.

Radiographic inspections and certifications of nuclear explosive assemblies and subassemblies are performed in the radiography bays, which currently house an 8-MeV linear accelerator (LINAC) and a 9-MeV LINAC (BWXT Pantex 2001). Each LINAC has the capability to examine completed nuclear explosives in addition to components and subassemblies. The radiography bays contain manipulator systems, turntables, alignment lasers, and closed-circuit television systems. The control room areas for the two radiography bays include a process/service room that provides development and processing of film from LINAC operations as well as film storage, viewing, and interpretation areas. In addition to the large fixed LINAC units, a portable X-ray machine can be used in the bays to radiograph pits.

Process flow is similar in the two radiography bays (BWXT Pantex 2001). Assemblies are brought to the bay in fixtures that allow radiography, or they are removed and placed in suitable fixtures. The operator positions the film behind the unit, perpendicular to the beam in relation to the LINAC and the unit. During operation of the LINAC, the operator moves to the control room to make the radiographic exposure. All personnel remain in the control room during the exposure. There are numerous emergency stop switches on the walls inside the radiography bays, which disable or prevent the operation of the radiography equipment in the event personnel are accidentally trapped in the bay. The control room is isolated from the LINAC room such that exposure rates to personnel follow as low as is reasonably achievable principles and do not exceed 0.25 mrem/hr. During operation of the portable unit, the operator would occupy the vestibule portion of the bay where exposure rates to personnel do not exceed 0.25 mrem/hr (BWXT Pantex 2001, p. 82). The portable X-ray machine is operated via a control console connected to it by cables. The operator, after making the radiographic exposure, develops the film in the process/service room. The operator views the film, makes the appropriate verifications of internal structure, and completes the necessary forms to release the unit for work by other departments.

The generic-use bays in these buildings can be configured for staging operations. Weapons and components are held in staging bays in preparation for use in assembly, special testing, or transportation off the site.

2.4.2 CELLS

The mounded earth and gravel cover over a cell is supported by a cable catenary system. The cables are suspended from the top of a cell's round room wall. The cell roof consists of the support cables, layers of wire mesh, gravel and earth coverings, and a Gunite or concrete cap. Figure 2-5 shows a generic cell design from Mitchell (2003).

The design of the cells is based on gravel gertie experiments that show that the structure largely dissipates blast pressures (BWXT Pantex 2001). The mounded gravel roof over the round room is designed to lift and vent gas pressures that would be produced in an accidental explosion. Plutonium would be filtered from the vented gases by the gravel material and release to the environment would be minimized. The equipment passageway doors are designed to remain intact in the event of accidental detonation, and the doors are interlocked so only one door can be open at a time. The two blast doors are also interlocked.

The cell facilities consist of a round room, staging cubicles, a corridor area, and an equipment/mechanical room. All of these areas are inside the blast-resistant cell structure and are protected from external events, including external explosions, winds, and tornados. The principal function of the cells is the assembly and disassembly of nuclear explosives, particularly operations on the physics packages of nuclear explosives that contain HE (BWXT Pantex 2001). Work on nuclear explosives that contain IHE can be done in the bays. In the future, most of the operations in the cells are expected to involve the dismantlement of retired stockpile weapons.

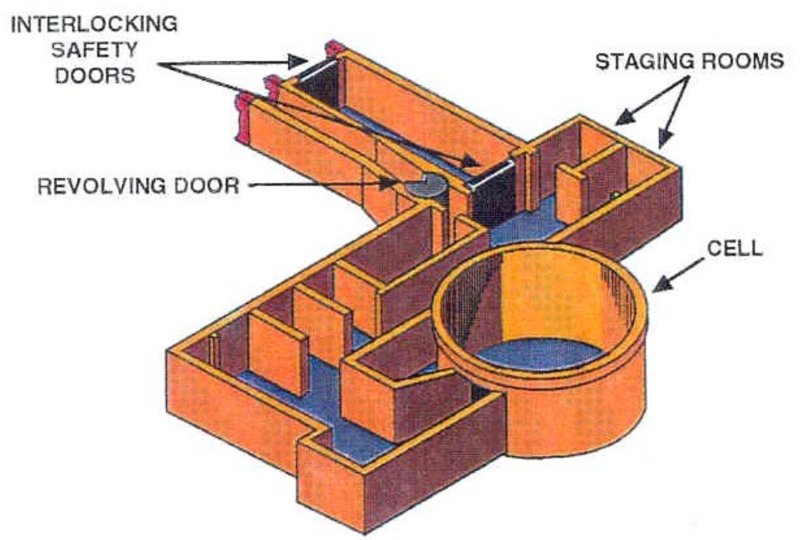

Figure 2-5. Generic representation of a nuclear explosive cell (Mitchell 2003).

The cells were designed as assembly/disassembly and inspection areas with the capability to process HE and nuclear explosive components that contain plutonium (BWXT Pantex 2001). The major operations are pit-HE assembly, pit-HE disassembly, and complete nuclear explosive assembly and disassembly. A number of specialized operations support quality assurance for these activities.

To comply with DOE and Pantex Plant requirements, plutonium-HE assembly and disassembly operations must be conducted in a cell-type structure where the design features of the facility afford an added margin of safety (DOE 2001). Partial assembly can be performed in a cell to the point where the HE component is considered cased. In this configuration, completion of the assembly process is typically performed in the bay facilities.

Components for a particular weapon are sent to the operating cell in which workers perform the assembly (BWXT Pantex 2001). Assembly operations are performed in designated cells in accordance with NEOPs and other written procedures specific to a nuclear weapons program. Inspections and audits are performed to confirm that design specifications are met. Acceptance inspections are performed by DOE inspectors. During all phases of assembly, procedures specific to nuclear explosives are followed and checklists are initialed as each procedural step is completed. Once the nuclear explosive assembly is complete, it is sent to radiography (if required) to verify the presence of SNM and to confirm the position of the safing device. If required, the weapon is then sent to the vacuum chambers for final inspection and testing.

During a limited (or partial) assembly, pits are transferred to the cells from the designated SNM staging facility at Pantex Plant. HE comes from an in-process staging facility for HE. Partial assembly in a cell typically results in a cased nuclear explosive assembly that contains a pit that is mated with HE, which is then sent to an assembly bay facility for final assembly into a nuclear explosive.

Cells are also used extensively for the disassembly or partial disassembly of nuclear explosives that have been returned to DOE by DOD (BWXT Pantex 2001). Many of these nuclear explosives were designed and built without the added safety benefit of IHE. Therefore, disassembly operations must be completed in a cell after other component disassembly operations have been completed in other facilities.

Plutonium pit-HE assemblies are brought to the cells from other facilities in Zone 12 (BWXT Pantex 2001). Special tools and equipment are supplied from warehouse stocks. Some disassembly operations require a portable glovebox or other specialized equipment. For plutonium pit-HE disassembly, personnel must use a safety net, safety latches, special tooling, lead aprons, safety glasses, and approved gloves. Some operations require that portions of the round room floor be covered with a barrier paper taped to the floor. In the event of an accident or unanticipated contamination, this barrier paper can be peeled from the floor and disposed of as contaminated waste, which aids containment and cleanup.

During disassembly, suspect components must be checked for radioactive contamination. If components are contaminated, decontamination procedures are performed before the components are transported.

2.4.3 SPECIAL-PURPOSE FACILITIES

The 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 (BWXT Pantex 2001). The following statements about typical maximum annual exposures are based on routine annual analyses of exposure data in relation to worker assignments that are done to ensure proper assignment of radiation worker status and the type of dosimeter that is provided.

The Paint Facility is used to spray-paint weapons, components, and supporting container and transportation hardware. Radiation exposure rates to workers in the Paint Facility are comparable to those of transportation workers who move weapons that contain nuclear materials, which are typically less than 100 mrem/yr. The Paint Facility is restricted to nuclear explosive look-alike (NELA) assemblies. The presence of HE (or IHE) and SNM at the same time is not allowed in the paint bay.

Operations in the Separation Testing Facility involve functional separation tests of selected reentry body assemblies, which is a continuing requirement of the Weapons Surveillance Program. Separation tests are conducted remotely with authorized personnel in the control booth during the entire test. Worker exposures to the weapons at the beginning and end of each test are brief, and cumulative radiation exposures are typically less than 100 mrem/yr.

The Mass Properties Facility has two bays and a remote control room. One of the bays has a spin-balancing machine that works much like a machine for balancing automobile tires. The weapon is placed in the machine and spun to measure any out-of-balance forces. The correct placing of balance weights on the weapon is determined from the results of the test. The center of gravity and the moment and product of inertia of the weapon are measured in another bay. Worker exposures to the weapons at the beginning and end of each test are brief, and cumulative radiation exposures are typically less than 100 mrem/yr.

The Weapons Aging Facility places the weapon or related component in a specialized controlled facility that maintains the temperature such that the weapons and components are aged artificially over an accelerated timeframe. As in the case of the Mass Properties and Separation Test Facilities, the operations are observed and controlled from a remote control room. Worker exposures to the weapons at the beginning and end of each test are brief, and cumulative radiation exposures are typically less than 100 mrem/yr.

The Weapons Transfer Station is used for loading and unloading weapons, components, and explosives. It is a completely enclosed high dock that accommodates over-the-road trailers and forklifts.

2.4.4 NUCLEAR STAGING FACILITIES

Zone 4 facilities are for staging or interim storage for weapons, components, and other process-related materials (BWXT Pantex 2001). Periodic inspection of the pits is required; process technicians and radiation safety technicians perform this operation. Personnel are exposed isotropically to radiation sources during this work.

Zone 12 staging facilities, including pit vaults, warehouses, and SNM component staging facilities, are where nuclear explosive components without HE are staged (BWXT Pantex 2001), including pits, radioisotopic thermal generators, and tritium reservoirs. Pits are encapsulated components that are packaged in specially designed containers for staging and transportation between facilities. Radioisotopic thermoelectric generators are small, self-contained, sealed 238Pu sources of thermally generated electricity. Tritium reservoirs are small metal bottles filled with tritium gas.

2.5 PANTEX RADIATION PROTECTION PROGRAM

The radiation protection program at Pantex evolved gradually over time, with a major expansion after a tritium release incident in May 1989. A radiation dosimetry program was established at Pantex in 1952 by the manager of the radiography group. The technology of the program has evolved over the past 50 years from simple film badges to sophisticated thermoluminescent dosimeter (TLD) systems. Figure 2-6 shows the steps in the evolution and a cumulative plot of annual photon and neutron recorded dose. ORAUT-TKBS-0013-6, *Technical Basis Document for the Pantex Plant – Occupational External Dosimetry* (ORAUT 2015a) describes these steps in detail.

The radiation protection program was focused on workers who were most likely to be exposed to radiation, which included production technicians, material handlers, transportation workers, radiography technicians, quality control technicians, and warehouse production workers. ORAUT (2015a) describes these workers and their exposure potentials. All other workers at Pantex had little occasion to enter radiological areas, and their potential for radiation exposure or intakes of radioactive material is considerably less [2].

From 1951 to about 1980, nuclear weapons assembly operations were generally free of contamination [3]. Occasional checks for removable contamination generally demonstrated negative results, so few precautions were taken in relation to personal protective equipment and clothing. There was no evidence of any intakes of radioactive materials by Pantex workers (ORAUT 2003a) [4]. The major emphasis was on monitoring external radiation exposure by the methods shown in Figure 2-6.

In 1972, a modest bioassay program was begun for monitoring worker exposures to tritium; in 1976, the program was expanded to a 4-year period with generally negative results (ORAUT 2003a) [5]. In the early 1980s, with the increasing disassembly of weapons that had been in various environments, DU contamination became a greater concern and additional radiation protection measures were applied to contamination control [6]. In 1988, an extensive bioassay program for workers who were exposed to DU contamination was implemented. ORAUT-TKBS-0013-5, *Pantex Plant – Occupational Internal Dose* (ORAUT 2015b) describes the bioassay programs in detail.

Airborne contamination is monitored with alpha CAMs and tritium monitors. The air monitoring system was installed in the early to mid-1970s [7]. The alpha CAM system frequently responds to elevated radon concentrations, but it has rarely detected airborne concentrations of uranium, thorium, or plutonium [8]. The tritium monitors frequently respond to minor local releases of tritium gas. The few occasions when airborne contamination has been detected are documented in incident reports as described in ORAUT (2015b).

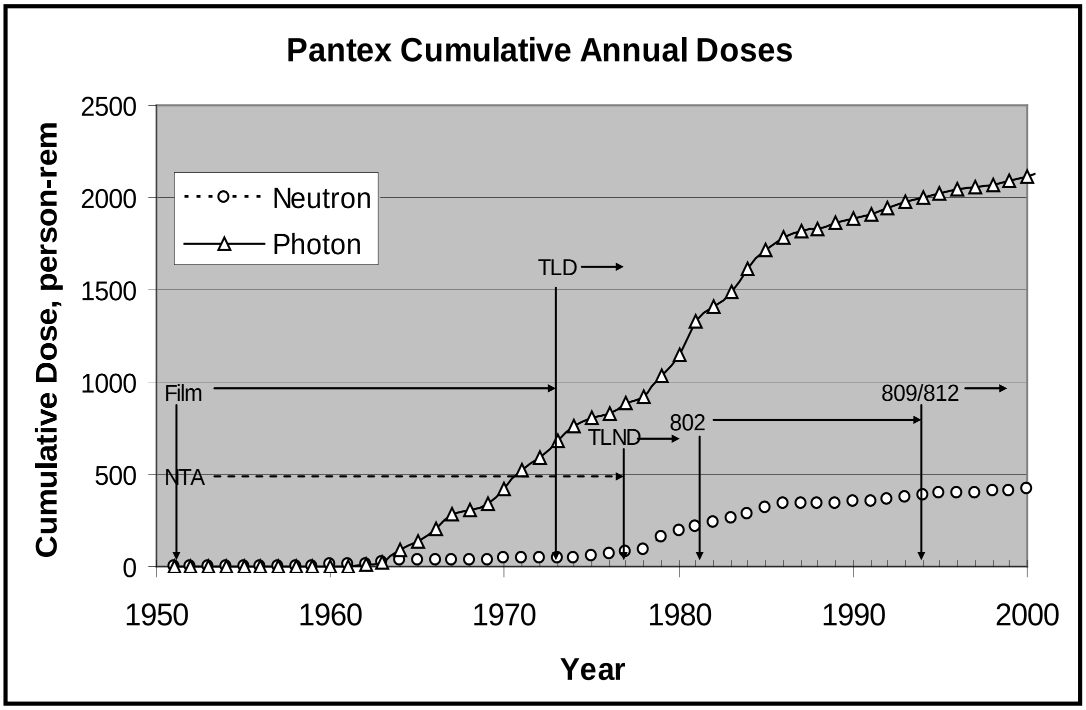

Figure 2-6. Evolution of external dosimetry at Pantex and a cumulative plot of annual photon and neutron recorded dose.

After the tritium release incident in May 1989, the radiation protection program expanded rapidly. In May 1989 there were only seven staff members in the Radiation Safety Department; by mid-1991 the staff had expanded to 50 and new facilities and modern equipment were added.

2.6 GENERAL RADIATION EXPOSURE CHARACTERISTICS

The general radioactive source terms have been consistent throughout the history of Pantex, with few exceptions. From 1951 to the present, DU and tritium have been present at Pantex. During assembly, the DU was relatively clean and there was minimal removable contamination [9]. The tritium was received in sealed reservoirs, and leakage was not a concern during assembly [10]. Minor leakage occurred during disassembly. From 1958 to the present, sealed plutonium pits and enriched uranium components have been received, handled, and stored at Pantex. With two minor exceptions, plutonium has always been contained by the pit cladding [11]. Some thorium components were assembled into weapons in the 1960s and disassembled during the 1990s. These source terms are approximately the same for Zones 4 and 12. There are, and have been, a few other radioactive materials present in small quantities as calibration sources or in larger quantities as radiography sources. ORAUT (2015a) discusses those source terms in more detail.

Radiation exposures occur at Pantex when workers are involved in operations with radioactive materials, such as the assembly or disassembly of nuclear weapons. The primary sources of external radiation exposure are plutonium pits and DU or thorium components. The primary sources of radioactive contamination (which can lead to intake) are DU oxide and tritium (ORAUT 2003a) [12].

Plutonium pits are sealed to prevent surface contamination problems [13]. Enriched uranium components are solid, hermetically sealed units. The pits emit the X-rays, gamma rays, and neutrons that are the major source of exposure to Pantex radiation workers. Direct handling of pits can result in relatively high dose rates [14]. Workers wear lead aprons during pit-handling work, which substantially reduce low-energy photon doses to the torso [15]. 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 including the thyroid and eye lens doses [16]. Neutron doses that were measured under the lead apron can be underestimated [17]. Beta and photon exposures occur during handling of DU or thorium components. The rule-of-thumb beta dose rate of approximately 200 mrad/hr at the surface of a DU slab can be used to estimate worker exposures. Exposures to thorium include penetrating 2.6-MeV photons from 208Tl.

The major radioactive contamination concern is DU oxide during disassembly operations. DU components tend to oxidize while in the field, and this oxide is present as a readily dispersible powder during disassembly. ORAUT (2015b) discusses this contaminant. Contamination on thorium components is much less significant [18]. In addition, tritium contamination is a concern; minor tritium intakes occur routinely but with very little whole-body dose [19]. The one exception is the Cell 1 incident in 1989, which is discussed in detail in ORAUT (2015b).

2.7 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 formerly served as a Site Expert for this document. He was responsible for advising on site-specific issues and incidents. Because of his prior work experience at the site, he possessed, or was aware of information that is relevant for reconstructing radiation doses experienced by Energy Employees 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.

[1] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
The statements about the radiation sources at Pantex are based on ORAUT (2003a) and on personal knowledge.

[2] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
Radiation exposure of worker groups at Pantex is routinely analyzed to validate the identification of radiation workers. All workers who are not identified as radiation workers have a lower potential for radiation exposure.

[3] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
The period from 1951 to about 1980 can be characterized as an "assembly period" when relatively few disassemblies were conducted. Assemblies involved new, clean components that were generally free of radioactive contamination. Tests for removable contamination were routinely done on new components and results were usually negative.

[4] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A review of the radiation incident report files revealed there were no significant intakes of radioactive materials by Pantex workers before 1989.

[5] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A review of tritium bioassay records indicated the frequency of bioassay sampling and the generally negative results. This subject is addressed in detail in ORAUT (2015b).

[6] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A review of radiation incident report files revealed the increased incidence of DU contamination cases beginning in about 1980. Corrective actions included more frequent contamination surveys and bioassay sampling.

[7] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
The dates of installation of the air monitoring system were established from equipment installation records during the planning for an upgrade to the system conducted in 1994.

[8] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A review of radiation incident report files revealed numerous alpha CAM alarms that were due to elevated radon concentrations. Very few incidents involved airborne concentrations of uranium, thorium, or plutonium. Airborne contaminants are addressed in detail in ORAUT (2015b).

[9] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
The period from 1951 to about 1980 can be characterized as an “assembly period” when relatively few disassemblies were conducted. Assemblies involved new, clean components that were generally free of radioactive contamination. Contamination tests were routinely done on new components and results were usually negative.

[10] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
The installation of tritium reservoirs involved connections that did not release any tritium gas. However, during disassembly, the disconnection of a tritium reservoir frequently involved a minor release of tritium gas that had collected within the system during several years of storage.

[11] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A review of radiation incident report files revealed that only three incidents at Pantex (one in 1961, one in 1978, and one in 1992) involved minor plutonium contamination. In all other cases, plutonium has been effectively contained by the pit cladding.

[12] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A review of radiation incident report files revealed that the most common sources of radioactive contamination that leads to intakes by workers are DU and tritium.

[13] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
The purpose of cladding on plutonium pits is to prevent oxidation and spread of contamination.

[14] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
During handling of pits, the worker’s hands are in direct contact and the torso is within about 1 ft where the radiation dose rates to personnel are the highest.

[15] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A major source of radiation exposure during pit-handling work is the 60-keV photons from 241Am. A lead apron is very effective in reducing the exposure to the torso from these low-energy photons.

[16] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
Pantex procedures require the positioning of dosimeters under the lead apron. The dosimeter then records the reduced torso dose, but underestimates the dose to the unshielded portions of the body (i.e., head, thyroid, and lens of eye). This subject is addressed in detail in ORAUT (2015a).

[17] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
Dosimeters are calibrated for neutrons by mounting a dosimeter on a phantom and measuring the albedo effect from the phantom. A dose algorithm is used to carefully determine the neutron dose from the response of the individual TLD chips. A lead apron can adversely affect the response of a dosimeter to neutron radiation by blocking some of the incident radiation and disrupting the albedo effect.

[18] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
A review of radiation incident report files revealed numerous cases of DU contamination, but only one involving thorium. Routine contamination tests on thorium surfaces are usually negative. This subject is addressed in detail in ORAUT (2015b).

[19] Martin, Jerome B. ORAU Team. Senior Health Physicist. July 2006.
The calculated whole-body dose from a minor uptake of tritium is very low (e.g., a 1-μCi intake of tritium results in a committed dose of only 0.07 mrem).

REFERENCES

BWXT Pantex, 2001, *Safety Information Document in Support of the National Environmental Policy Act Documents for Pantex Plant*, Amarillo, Texas, October. [SRDB Ref ID: 21859]

DHHS (U.S. Department of Health and Human Services), 2011, *DHHS 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*, Office of the Secretary, Washington, D.C., December 21. [SRDB Ref ID: 116796]

DHHS (U.S. Department of Health and Human Services), 2013, *DHHS 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 the Pantex Plant, Amarillo, Texas*, Office of the Secretary, Washington, D.C., September 30. [SRDB Ref ID: 128051]

DOE (U.S. Department of Energy), 1997, *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences*, DOE/EM-0319, Office of Environmental Management, Washington, D.C., January. [SRDB Ref ID: 11930]

DOE (U.S. Department of Energy), 2001, *Safety of Nuclear Explosive Operations*, DOE O 452.2B, Washington, D.C., August 7. [SRDB Ref ID: 24848]

Mitchell, K. C., 2003, *Rhetoric to Reality: A Cold War Context Statement for the Pantex Plant, 1951-1991*, BWXT Pantex, Pantex Plant, Amarillo, Texas. [SRDB Ref ID: 24171]

ORAUT (Oak Ridge Associated Universities Team), 2003a, “Personal communication,” memorandum to file, Oak Ridge, Tennessee, September 24. [SRDB Ref ID: 11083]

ORAUT (Oak Ridge Associated Universities Team), 2003b, “Personal communication,” memorandum to file, Oak Ridge, Tennessee, September 24. [SRDB Ref ID: 11078]

ORAUT (Oak Ridge Associated Universities Team), 2015a, *Pantex Plant – Occupational External Dose*, ORAUT-TKBS-0013-6, Rev. 02, Oak Ridge, Tennessee, November 24.

ORAUT (Oak Ridge Associated Universities Team), 2015b, *Pantex Plant – Occupational Internal Dose*, ORAUT-TKBS-0013-5, Rev. 04, Oak Ridge, Tennessee, June 1.

NIOSH (National Institute for Occupational Safety and Health), 2007, *External Dose Reconstruction Implementation Guideline*, OCAS-IG-001, Rev. 3, Office of Compensation Analysis and Support, Cincinnati, Ohio, November 21.

NIOSH (National Institute for Occupational Safety and Health), 2002, *Internal Dose Reconstruction Implementation Guideline*, OCAS-IG-002, Rev. 0, Office of Compensation Analysis and Support, Cincinnati, Ohio, August 1.

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.

GLOSSARY

depleted uranium (DU)

Uranium with a percentage of ^{235}U lower than the 0.7% found in natural uranium. As examples, spent (used) fuel elements, byproduct tails, residues from uranium isotope separation, and some weapons materials contain DU. DU can be blended with highly enriched uranium to make reactor fuel or used as a raw material to produce plutonium. Pantex lists the isotope activity fractions for use in nuclear weapons components as:

Isotope	Activity fraction
^{234}U	0.0840
^{235}U	0.0145
^{238}U	0.9015

gravel gertie

Facility with the distinguishing characteristic of having blow-out roof panels overlain with gravel to dissipate the pressure surge and energy of a conventional high-explosive detonation. This design was developed to allow the energy of the blast to be dissipated while minimizing the spread of contamination of any radioactive material present. Also called gertie.

high explosive (HE)

Chemical compound or mechanical mixture that, when subjected to heat, impact, friction, shock, or other initiation stimulus, undergoes a rapid chemical change resulting in large volumes of highly heated gases that exert pressure in the surrounding medium. See insensitive high explosive.

insensitive high explosive (IHE)

High explosive that is so insensitive that there is negligible probability of accidental initiation or transition from burning to detonation. See high explosive.

nuclear explosive look-alike (NELA) assembly

At Pantex, model of the basic configuration of a nuclear explosive that does not contain radioactive material. Alternatively, the NELA may contain actual fissile material without the actual required HE assembly.

pit

Package at the center of an implosion weapon that contains the machined fissile material that begins the fission chain reaction. Also called primary.

special nuclear material (SNM)

Plutonium or uranium enriched to a higher-than-natural assay including ^{239}Pu, ^{233}U, uranium containing more than the natural abundance of ^{235}U, or any material artificially enriched in one of these isotopes.

tritium reservoirs

Gas-tight metal containers for storage of tritium gas.