



**ORAU TEAM  
Dose Reconstruction  
Project for NIOSH**

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**Site Profile for Clarksville Modification  
Center with Supplementary Guidance for the  
Medina Modification Center**

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**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
11/14/2006	00	New Site Profile for Clarksville Base Weapons Storage Area and Modification Center with Supplementary Guidance for Medina. First approved issue. Incorporated responses to internal formal review comments. Added sections 5.2.2 and 6.5 covering guidance for 1966-67 after operations had ceased. Changes made in response to NIOSH formal review comments including: use of “favorable to claimants” throughout; removal of HT-to-HTO conversion factor for all sections dealing with tritium; Sections 4.0 and 5.1.1 – use of Pantex 1989 accident doses as surrogate for Clarksville tritium release accident; Section 5 – clarification of operation years and postoperative years, also added to Glossary; Section 5.2.1 – revised DU intakes during weapons disassembly to include room ventilation and 8-hr shift; Section 5.2.3 – added DU intake from burning contaminated HE; Section 5.3 – added intake from alpha contamination on capsules or pits; Section 6.1 – added description of roles of SNL, AEC, and military personnel; Section 6.4 – clarified that the dose rate from Pu metal is sum of photons and neutrons; Section A1.1 – added to description of Medina site and operation; Section A2.0 – extended period of medical X-rays to October 1958; Section A3.2.2 – clarified dates soil samples were taken; Section A5.0 – enhanced the description of the radiography source incident. There is an increase in assigned dose and a PER is required. Training required: As determined by the Task Manager. Initiated by Donald E. Bihl.
10/05/2012	01	Revision initiated to incorporate Special Exposure Cohort (SEC) Petitions SEC-00202 and SEC-00203. Added Section 1.3 to incorporate the SEC class definition. Revised Section 5.0 and deleted subsections in accordance with dose reconstruction limitations per SEC-00202. Added Section A.1 to incorporate the SEC class definition. Revised Section A.4 in accordance with dose reconstruction limitations per SEC-00203. 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.
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01/04/2017	03	Revision initiated to update external dose reconstruction guidance due to revisions in ORAUT-TKBS-0013-6, <i>Pantex Plant – Occupational External Dose</i> . Revised Sections 6.2, 6.2.1, 6.2.2.2, 6.2.5.1, 6.3, 6.3.1, 6.3.2 and added Attachment B. Updated Table B-1 to incorporate values from Tables A-1 through A-3, <i>Pantex Plant – Occupational External Dose Technical Basis Document (ORAUT-TKBS-0013-6, Rev. 03)</i> , and updated references. 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.

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**ACRONYMS AND ABBREVIATIONS**

AEC	U.S. Atomic Energy Commission
AFB	Air Force Base
AP	anterior-posterior
AWE	atomic weapons employer
CD	compact disk
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter
CONEX	container express
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
dpm	disintegrations per minute
DU	depleted uranium
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
FGR	Federal Guidance Report
ft	foot
gal	gallon
GSD	geometric standard deviation
HE	high explosive
HEPA	high-efficiency particulate air
HEU	highly enriched uranium
hr	hour
HT	elemental tritium (tritiated gas)
HTO	tritiated water vapor
ICRP	International Commission on Radiological Protection
in.	inch
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron-volt
kg	kilogram
LAT	lateral
lb	pound
LLRW	low-level radioactive waste
LOD	limit of detection
MeV	megaelectron-volt, 1 million electron volts
MHSMC	Mason & Hanger-Silas Mason Company
MRD	minimum recordable dose
mrad	millirad
mrem	millirem
NCRP	National Council on Radiological Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health

NTA nuclear track emulsion, type A

ORAU Oak Ridge Associated Universities

PA posterior-anterior

PER program evaluation report

PM<sub>10</sub> particulate matter in the air with an aerodynamic diameter less than or equal to 10 micrometers

SEC Special Exposure Cohort

SNL Sandia National Laboratories

SRDB Ref ID Site Research Database Reference Identification (number)

TLD thermoluminescent dosimeter

TNT trinitrotoluene

U.S.C. United States Code

UST underground storage tank

WSA weapons storage area

yr year

Z atomic number

§ section or sections

## 1.0 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 7384I(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. § 7384I(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. § 7384I(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 2010a):

- 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 PURPOSE

This site profile provides information about U.S. Atomic Energy Commission (AEC) operations at Clarksville Modification Center at Fort Campbell in Tennessee pertaining to radiation exposures for monitored or unmonitored workers. Because the Medina Modification Center in Texas was similar in purpose and operation to Clarksville Modification Center, Attachment A of this document contains information about Medina.

## 1.2 SCOPE

Section 2.0 describes the Clarksville site, operations with potential for possible radiation exposures, and source terms. Section 3.0 provides guidance for determining occupational medical dose. Section 4.0 provides guidance for determining dose to workers outside radiological facilities due to releases of radioactive materials to the environment. Section 5.0 provides guidance for determining intakes of radionuclides inside facilities. Section 6.0 provides guidance for determining external doses from measured doses or for periods when records of measured doses are missing. Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 7.0.

## 1.3 SPECIAL EXPOSURE COHORT

On August 23, 2012, as provided for under 42 U.S.C. 7384q(b), the Secretary of Health and Human Services designated the following class of employees as an addition to the SEC (Sebelius 2012a):

*All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors, who worked at the Clarksville Modification Center, Ft. Campbell, in Clarksville, Tennessee, from August 1, 1949 through December 31, 1967, 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 Special Exposure Cohort.*

In its evaluation (NIOSH 2012a), NIOSH found it lacks sufficient information to reconstruct internal radiation doses adequately for all Clarksville Modification Center employees for all potential radiation exposures. Specifically, this includes internal personnel monitoring data, air monitoring data, process data, and radiological source term information that would allow NIOSH to estimate with sufficient accuracy potential internal exposures to uranium, plutonium, and tritium. However, NIOSH has determined that the occupational medical dose and external doses can be reconstructed based on available data. Based on the occupational medical and external data available and the available dose reconstruction methods, NIOSH believes that it is possible to either (1) estimate the maximum external dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or (2) estimate the external doses to members of the class more precisely than a maximum dose estimate. Although NIOSH found that it is not possible to reconstruct internal radiation doses completely for the proposed class, it intends to 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 employees at Clarksville Modification Center during the period from August 1, 1949, through December 31, 1967, but who do not qualify for inclusion in the SEC, can be performed using these data as appropriate to support a partial dose reconstruction.

## 2.0 SITE DESCRIPTION AND OPERATIONAL HISTORY

### 2.1 SITE DESCRIPTION

The Clarksville Modification Center was one of 13 weapons storage areas (WSAs) created under the Armed Forces Special Weapons Project. The Clarksville Base was constructed on the Fort Campbell Military Reservation in the mid- to late 1940s (the first weapon components arrived in July 1949) and was supported by Sandia Corporation for the AEC and the U.S. Navy. [The Sandia site became Sandia National Laboratories (SNL); for convenience, this site profile uses SNL throughout.] SNL, AEC, and the Navy were all active at Clarksville Modification Center from 1949 until 1958 performing maintenance and quality assurance on nuclear components of weapons. From 1958 until 1965, Mason & Hanger-Silas Mason Company (MHSMC) operated Clarksville Modification Center for the AEC as a weapons modification and disassembly facility (Lamb and Halliburton 1996; ORAUT 2006a; Mitchell 2003).

Clarksville Base was originally separate from Fort Campbell, which was operated by the U.S. Army. In 1965, AEC activities transferred elsewhere, although AEC was responsible for the Base through 1967. The Base was returned to the Army and incorporated into Fort Campbell in 1969 (Last, Gilmore, and Bronson 1998). It is unclear what activities occurred between 1967 and 1969, but storage of nuclear materials had ceased.

During AEC tenure, nuclear weapons and weapon components were stored by AEC and maintained by SNL and military personnel at the WSAs. WSAs consisted of storage buildings that housed nuclear capsules, maintenance structures, waste burial sites, and bunkers for storage of weapons casings. SNL personnel worked at Clarksville Modification Center under contract to the AEC until early 1962 (Lamb and Halliburton 1996; Last, Gilmore, and Bronson 1998; ORAUT 2006a).

Storage of nuclear capsules at Clarksville Modification Center was in an underground complex known as the ABC Structure. The ABC Structure consisted of the A Structure, which was the nuclear capsule storage area that was secured behind a bank-type locking vault door at the end of a 600-ft-long tunnel; the C Structure, which was used for nuclear materials inspection and maintenance; and the B Structure, which was a backup facility for the C Structure but was used only as a medical wing. C Structure activities involved dismantling the nuclear assembly system, checking the activity of the fissile material, and replacing the Po-Be initiators (Lamb and Halliburton 1996; Last, Gilmore, and Bronson 1998; ORAUT 2006a). Figure 2-1 is an overall plan view of the ABC Structure. Figure 2-2 shows a close-up plan view of the A Structure, and Figure 2-3 shows a cross-sectional view. Figure 2-4 shows a plan view of the B and C Structures. The figures refer to "Fort Campbell" because the ABC Structure was inactive in 1998; however, at the time of use they were the Clarksville WSA.

A second C Structure, constructed in 1957, was an aboveground brick building AEC used only to service nonnuclear components. Once this structure opened, operations at the original C Structure ceased due to moisture intrusion. In addition, the Clarksville WSA included a gravel gertie for weapons maintenance and modification. The newer C Structure and gravel gertie had large overhead rails to support weapon subassemblies during maintenance. Standard aboveground igloos were used for storage, including the storage of sealed weapons. No nuclear maintenance activities occurred in these igloos (Lamb and Halliburton 1996; Last, Gilmore, and Bronson 1998; ORAUT 2006a).

Some of the claimant interviews refer to the "bird cage." This term was used officially to describe the criticality-safe framework around a nuclear package (see Figure 2-5); however, the term appears to have been used unofficially to refer to the entire Clarksville Modification Center, meaning the fenced, heavily guarded area where an AEC Q-level clearance was required (more than just the tunnel complex).

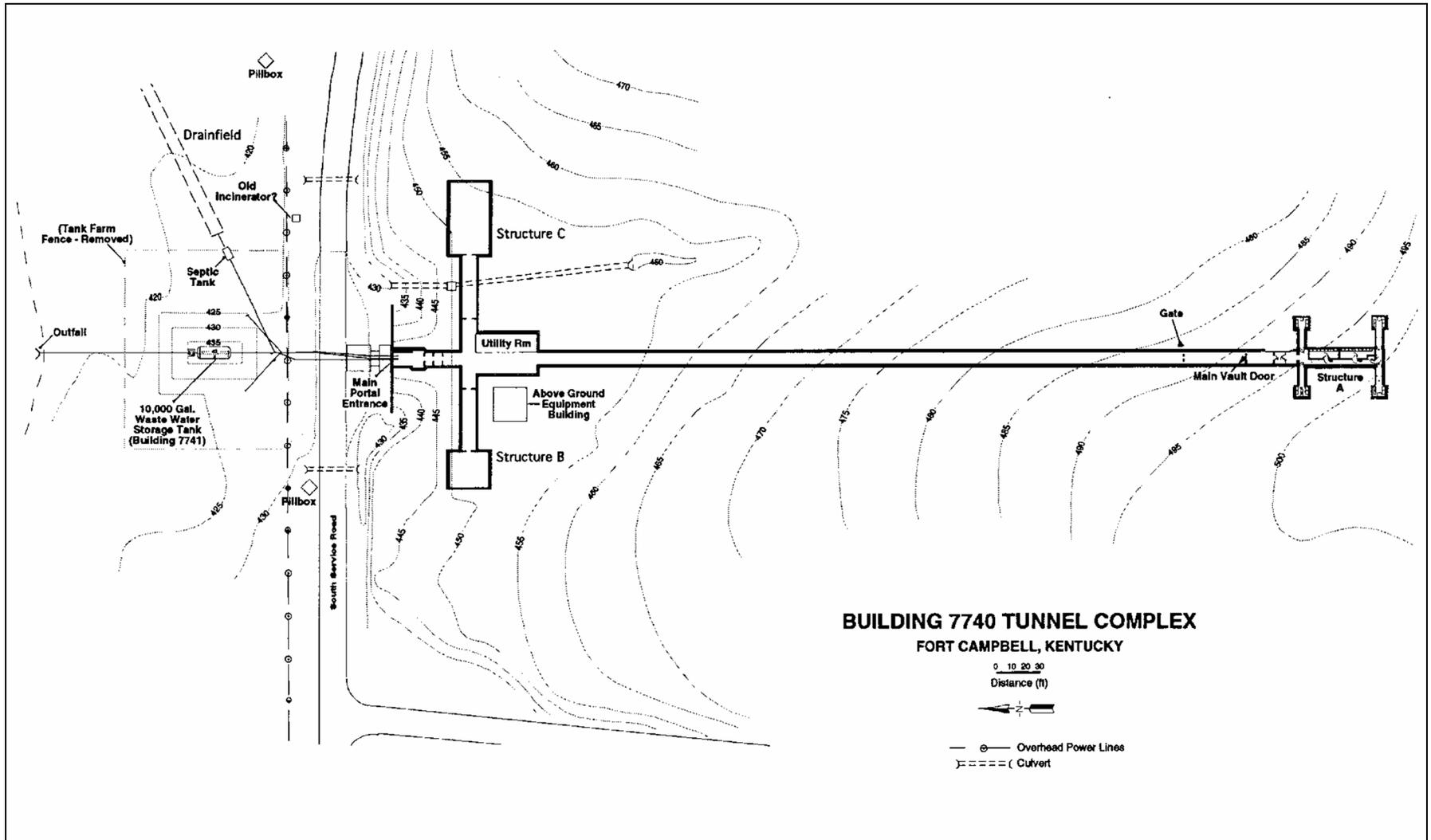


Figure 2-1. General plan view of ABC Structure (Last, Gilmore, and Bronson 1998).

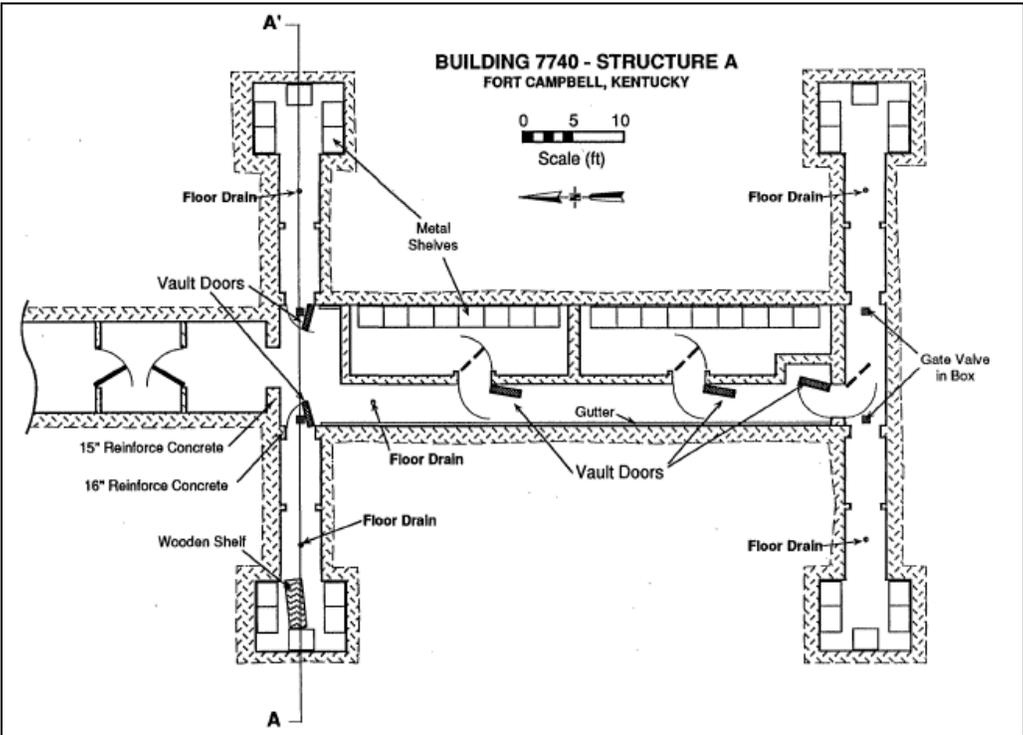


Figure 2-2. Plan view of the A Structure (Last, Gilmore, and Bronson 1998).

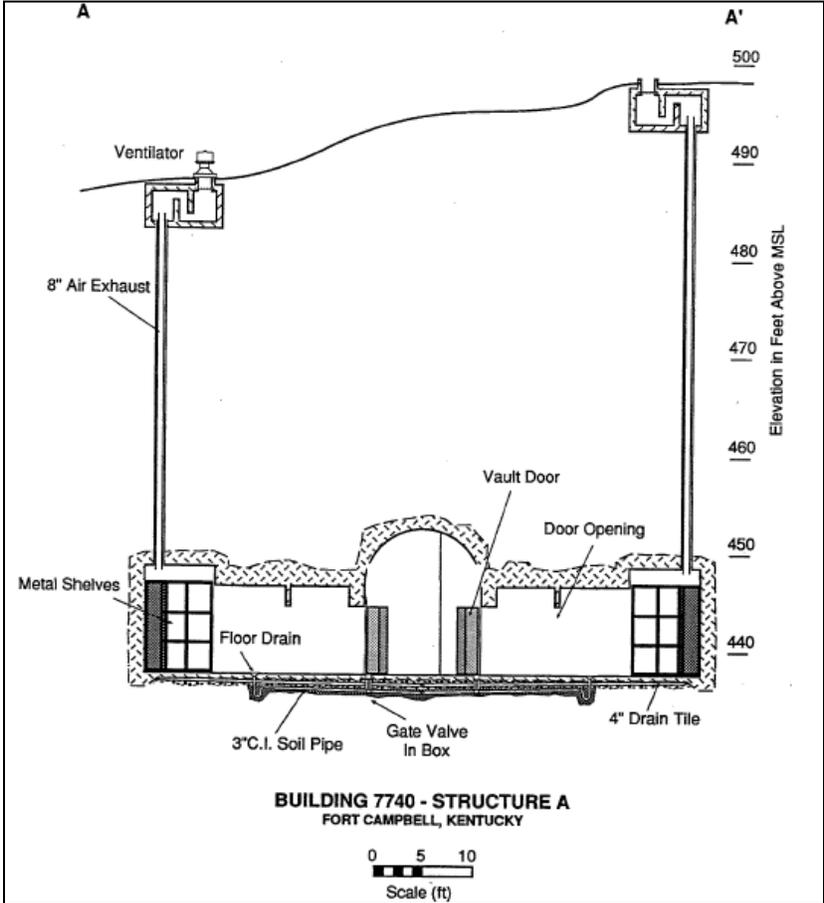


Figure 2-3. Cross-sectional view of the A Structure (Last, Gilmore, and Bronson 1998).

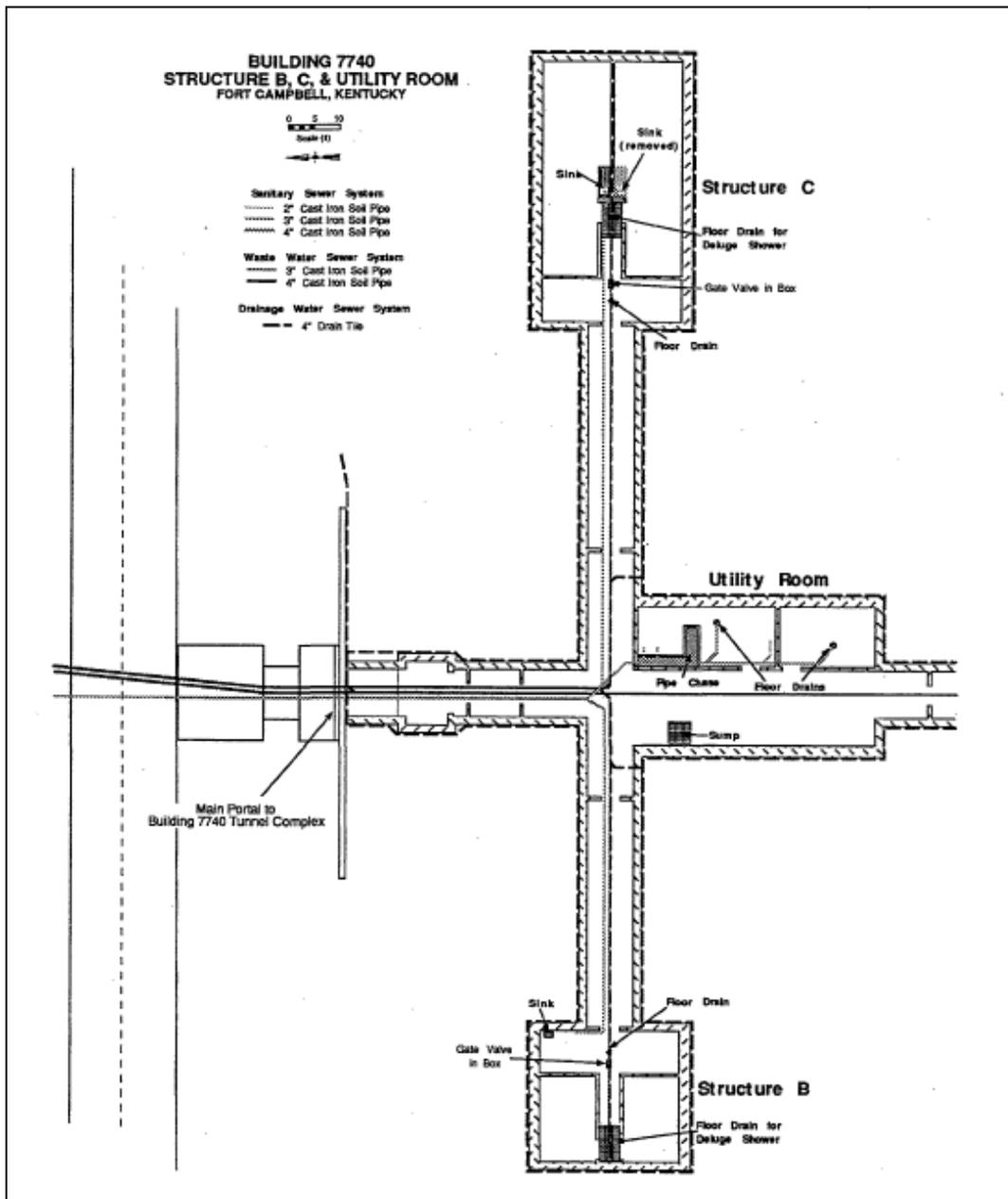


Figure 2-4. Plan view of the B and C Structures in the tunnel complex (Last, Gilmore, and Bronson 1998).

## 2.2 SOURCE TERMS

Early weapon designs were in-flight insertables. Weapons of this type had removable nuclear capsules (also known as the physics package or pit) and were stored in a bird cage. The bird cage ensured storage in a criticality-safe manner. The capsules were pressure-sealed. Figure 2-5 shows a typical bird cage. The bird cage held the nuclear capsule, which contained plutonium, highly enriched uranium (HEU), and a Po-Be initiator. Periodic maintenance was required on these early weapon pits to exchange the Po-Be initiators due to the short half-life of  $^{210}\text{Po}$ . This required disassembly of the weapon pit to remove the initiator, which was at the pit center.



Figure 2-5. Typical bird cage.

Later weapon designs were not in-flight insertables and did not have Po-Be initiators, which eliminated the need to disassemble the weapon pit for modification. The Po-Be initiators were phased out over time, until 1956, and replaced by external neutron generators. The weapon pits are referred to as sealed pit designs. These designs included the potential for exposure to tritium. The introduction of tritium could have occurred as early as 1954 (ORAUT 2006a; Mitchell 2003).

Another source of radioactive material in early nuclear weapons was the spark gap tube. These tubes, which were part of the firing circuits, were used to switch large amounts of electrical current. A small amount of  $^{137}\text{Cs}$  was used in spark gap tubes to stabilize the electrical properties. These tubes, which were manufactured of thick glass to prevent breakage, were a minor exposure pathway (ORAUT 2006a).

As part of the maintenance activities, Clarksville personnel performed radiographs of the weapon components using a large  $^{60}\text{Co}$  source. The exact location of this source was not discovered, but the newer C Structure is a likely candidate (ORAUT 2006a).

In summary, the radioactive materials of interest at Clarksville Modification Center are tritium as a gas, weapons-grade plutonium, HEU, depleted uranium (DU; also used in weapons construction),  $^{210}\text{Po}$  in a Po-Be neutron initiator, a  $^{60}\text{Co}$  radiograph source, and small activities of  $^{137}\text{Cs}$ .

## 2.3 JOB DESCRIPTIONS

Table 2-1 lists job descriptions from the claims files or interviews of former employees (ORAUT 2006b, 2006c).

Table 2-1. Job categories.

<b>Title</b>	<b>Description</b>
Material handler	Moved nuclear devices to and from storage and disassembly areas or among magazines; unloaded devices from trucks, railcars, and aircraft and drove them to storage areas.
Production operator, operator, operator trainee	Assembled and disassembled nuclear devices.
Inspector, quality control specialist, quality control inspector	Nuclear components inspectors observed assembly and disassembly, recorded condition of components, and ensured correct assembly of components; it is possible these workers performed gamma/X-ray inspections of devices. Not all inspectors were responsible for nuclear components; some would have had only incidental exposure to complete weapons. The latter should be considered in same category as material handlers.
Warehouseman	Received, stored, shipped nuclear devices; conducted inventory of nuclear devices. One claimant interview indicated a warehouseman worked in storage igloos for 1 week conducting inventory about every 6 months.
Safety/security inspector	Performed security inspection and control of all buildings including magazines; probably spent some time in all secure locations but did not handle nuclear devices.
Mechanic	Repaired equipment, moved nuclear devices; mechanics might have been responsible for replacing filters in ventilation systems including contaminated filters; spent time in igloos when necessary.
Truck driver, heavy equipment operator	Probably involved with transporting nuclear devices to and from railcars and airport.
Firemen	Firemen were present with a fire extinguisher during disassemblies.
Sheet metal worker, electrician, refrigerator/cooling mechanic, janitor	Probably worked anywhere and might have had some exposure in igloos.
Clerk-typist	Worked in offices in Bird Cage; might have entered disassembly areas to deliver messages.
Accountant	Had office in Bird Cage; occasionally entered igloos.
Bus driver, grounds laborer, power plant operator, sewage disposal operator	Probably did not have any exposure except environmental.

### 3.0 OCCUPATIONAL MEDICAL DOSE

It is not known if medical X-rays were required for all workers or selected workers as a condition of employment. No documentation on X-ray policies, procedures, or equipment has been found. An SNL safety engineer familiar with work at WSAs did not recall X-rays being part of medical examinations at any of the WSAs during the period when SNL was the principal AEC contractor (ORAUT 2006a). Records on Clarksville workers from Pantex do not list any X-rays before 1960, even for workers who continued employment into the years when MHSMC was the principal AEC contractor. A review of the claims information revealed that, for employment between 1960 and 1965, 53% of the workers had at least one chest X-ray and 35% had at least one lumbar spine X-ray. Most of the X-rays are either labeled as preemployment or occurred in the first year of employment. The pattern does not support additional routine X-rays; only four workers had more than one chest X-ray and only one had a second lumbar spine X-ray. In terms of job categories, no pattern was evident in relation to who had preemployment X-rays and who did not. For instance, the records for the two claims showed one chest X-ray each, whereas some craft workers had no record of X-rays.

Based on the limited information available for workers during 1960 through 1967 with no X-ray records, the dose reconstructor should assume one chest X-ray and one lumbar spine examination for the entire employment period (not each year). As described below, a lumbar spine examination is assumed to consist of four exposures. The dose from X-rays should be assigned in 1960 or the first year of employment after 1960, but not for employment before 1960.

No information about X-ray equipment manufacturers, models, examination techniques, or exposure rates for the X-rays has been found. Therefore, assumptions that are favorable to claimants and guidance in ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures* (ORAUT 2011), were used. The actual film was not sent to the Pantex Plant for archiving, only the information that an X-ray occurred, the type, and the date. The film size and therefore type of radiography are not known. For small DOE sites, conventional chest X-rays are assumed.

Lumbar spine X-rays at the Pantex Plant were given only to men. None of the lumbar spine X-rays in the Clarksville claim files were given to women, but the number of female workers among the Clarksville claims is small. Nevertheless, because lumbar spine X-rays were given to screen for back injuries that might preclude heavy lifting, and considering that heavy lifting was culturally a man's job in the workplace in the 1960s, it is reasonable to assign the default lumbar spine X-ray only to men.

#### **Organ Dose Calculations**

ORAUT (2011) organ doses should be used because no site-specific information is available for Clarksville. Dose reconstructors should use the most recent update of that document. Dose reconstructors should assume that a posterior-anterior (PA) chest projection was performed on Clarksville workers. Organ dose equivalents for chest projections for all periods are in Table A-7 of ORAUT (2011), and skin doses from chest projections are in Tables A-8 and A-9 of that document.

According to ORAUT (2011), two anterior-posterior (AP) and two lateral exposures should be assumed for lumbar spine examinations when the site-specific protocol is not known. However, the doses in ORAUT (2011) include only one exposure per projection. The organ doses for lumbar spine X-rays in ORAUT (2011) for one exposure per projection are listed in Table A-10 of that document. Dose reconstructors should double these doses when assuming two exposures per projection for Clarksville claims (see footnote b to Table A-10). Skin doses from lumbar spine projections are in Table A-11 of ORAUT (2011). These values should also be doubled when assuming two exposures per projection. Enter the doubled values from ORAUT (2011) into the Interactive RadioEpidemiological Program (IREP) as an acute dose due to photons with energies between 30 and 250 keV. Assume a normal distribution with a standard deviation of  $\pm 30\%$ .

#### **4.0 OCCUPATIONAL ENVIRONMENTAL DOSE**

Occupational environmental dose refers to the dose received by workers outside normal production facilities. These doses can be internal or external (e.g., from effluents or scattered radiation through building walls or ceilings). No records on environmental releases from Clarksville Modification Center have been discovered. Before 1959, complete disassemblies were not performed at Clarksville Modification Center, only storage, maintenance, and inspection. Maintenance included replacement of major components.

Plutonium and enriched uranium sources in the weapons were always sealed, as were polonium in the initiators and other radionuclides in the radiography sources. There was risk of DU oxide contamination in the cells. The underground C Structure had exhaust vents at the top of the hillside under which the tunnel was located (Last, Gilmore, and Bronson 1998). Whether the exhaust passed through high-efficiency particulate air (HEPA) filters is not known. According to a former employee, portable gloveboxes with HEPA-filtered exhausts were used to contain oxidized DU when weapons underwent inspections, maintenance, and refurbishment during the SNL years (ORAUT 2006a). The DU was cleaned from the nuclear components and deposited as solid waste on cleaning rags.

The same employee mentioned that the DU contamination came from spalling, which produced large nonrespirable particles. Environmental intake of DU was insignificant because (1) the likelihood of a significant release outside the tunnel was small and (2) the location of the exhaust vent made it unlikely that DU that might have exhausted from the C Structure would have returned to occupied areas (ORAUT 2006a).

After tritium reservoirs became part of the weapons, leaks of tritium into the disassembly cell and out the cell exhaust duct were possible. The employee was not aware of any releases of tritium from the disassembly cells, but most handling of the tritium reservoirs occurred during the years MHSMC operated the facility (ORAUT 2006a). No documentation about tritium releases into the cells or through exhaust stacks has been found. Tritium in the reservoirs was in the form of tritiated gas, which has essentially no significance for intakes. Tritium gas converts slowly to tritiated water vapor as it mingles with humid air. Not all the gas would convert to water vapor during the time workers would be exposed (Peterson and Davis 2002), but it is favorable to claimants to assume 100% water vapor.

Based on similar work at the Pantex Plant, the release of tritium from the reservoirs during normal operations does not produce airborne concentrations that could result in intakes that result in annual organ doses of greater than 0.001 rem (ORAUT 2015). Therefore, with the exception of 1962 as described below, environmental intakes of tritium and the resultant internal dose for the Clarksville Modification Center should not be assigned.

A Clarksville worker described an accident involving a damaged weapon that was sent to Clarksville Modification Center from the military (ORAUT 2006b). The accident was corroborated in a claimant interview. At the time of the accident, both individuals were told the damaged weapon was leaking tritium. No documentation of the accident or information about the amount of tritium that might have leaked has been found. The interview indicated that the accident occurred in 1962.

Because the worker was told that they had been exposed to tritium while moving the weapon from the airport to the storage igloo, it is assumed that the tritium leak had been occurring for some time before its discovery. The reservoirs were under considerable pressure, so most of the contents would have leaked before arrival at Clarksville. However, there was sufficient leakage still occurring to set off the tritium monitors the next day when the weapon was taken into the cell, according to the claimant interview.

An accidental release of tritium during a disassembly occurred at the Pantex Plant in 1989 (ORAUT 2015). This was a major release that caused severe contamination of a cell. Workers were present at the initiation of the release and therefore subject to the highest release rate. All of the release occurred at Pantex, whereas most of the 1962 leak probably did not occur at Clarksville. It is unlikely that the accidental release at Clarksville was worse than the Pantex release. Clarksville workers stopped the leak within a few hours of its discovery, whereas the release at Pantex was so significant no attempt was made to stop the leak until it had run its course. Therefore, it is reasonable to conclude that the amount of tritium release at Clarksville was much less than the amount during the 1989 Pantex accident. Therefore, because NIOSH has concluded that it lacks sufficient information, which includes monitoring data, sufficient air monitoring information, or sufficient process and radiological source information, that would allow it to estimate the intakes of tritium to which the proposed class may have been exposed, no internal dose for intakes of environmental airborne concentrations should be assigned for the Clarksville Modification Center.

External radiation dose greater than the ambient rate outside a building where frequent radiography was performed might have occurred via direct radiation penetration through walls or from scattered radiation. Dose rates are usually quite small in noncontrolled areas near radiography sources. For instance, at the Hanford Radiological Calibration Facility, the total annual dose as measured by thermoluminescent dosimeters (TLDs) on the outside of an interior wall at about 25 ft from a 20-Ci <sup>137</sup>Cs source (662-keV gamma ray), which was used almost daily, was 7 mrem. A <sup>60</sup>Co radiography source would be expected to have less activity, but the gamma radiation strength of <sup>60</sup>Co (1,173- and 1,332-keV gamma rays) is about 4 times that of <sup>137</sup>Cs. Assuming a smaller activity <sup>60</sup>Co source produces about the same annual dose rate outside the radiography building as the 20-Ci <sup>137</sup>Cs source and, assuming an environmental occupancy factor outside the building of 0.5, dose reconstructors should assign a 4-mrem whole-body dose per year from external radiation (see Table 4-1). Assume a 100% 30- to 250-keV photon energy category. Calculate organ doses of interest using OCAS-IG-001, *External Dose Reconstruction Implementation Guideline* (NIOSH 2007). Because this dose rate was made by inference from a similar situation, rather than by direct measurement, an uncertainty factor of 2 is reasonable.

Table 4-1. Summary of environmental external dose.

Period of application	Annual whole-body dose	Photon energy category	Distribution
July 1949–1965	4 mrem	30–250 keV	GSD = 2
1966–1967	0 mrem	Not applicable	Not applicable

## **5.0 OCCUPATIONAL INTERNAL DOSE**

NIOSH has concluded that it is not possible to reconstruct internal doses completely for any period at the Clarksville Modification Center. Therefore, in the absence of monitoring data for an individual claim, no occupational internal doses should be assigned. For claims in which individual internal monitoring data are available, the internal dose should be reconstructed based on interpretation of the monitoring data using existing NIOSH dose reconstruction processes and procedures.

## **6.0 OCCUPATIONAL EXTERNAL DOSE**

### **6.1 INTRODUCTION**

Workers at Clarksville Modification Center were employed by either SNL or MHSMC, but not both. A few SNL workers (fewer than 20) performed the maintenance operations involving nuclear components between July 1949 and September 1958 (ORAUT 2006a). A similar number of MHSMC workers performed inspections and modifications on nuclear weapons from 1959 to September 1965 (Mitchell 2003).

Work activities at Clarksville Modification Center undoubtedly varied over time. Analysis of historical information showed that maintenance activities at Clarksville began in 1949, which corresponds to the first record of personnel monitoring (ORAUT 2006a). The nature of the radiation fields a Clarksville worker could have encountered depends on the type of weapon on which work occurred. Nuclear weapons components emit alpha and beta particles, X- and gamma rays, and neutrons, but doses to workers depend strongly on the configuration (i.e., material and shielding) of the source of radiation and the work performed (Oxley 2001).

There were three major groups of workers at Clarksville. AEC employees served primarily in oversight positions and generally did not perform hands-on work. SNL and (later) MHSMC employees were responsible for maintenance of the weapons and would likely have the highest doses. Military personnel would likely receive doses that were less than the SNL or MHSMC employees; the military primarily loaded the weapons on airplanes and performed in-flight operations that were necessary.

### **6.2 EXTERNAL RADIATION DOSIMETERS AND RECORDS**

External dosimetry records for Clarksville Modification Center are sparse, and the connection between the dose record and the worker might be missing. Statistical analysis of doses known to have been received at Clarksville cannot be performed with the few records found to date.

Dosimetry data for several Clarksville workers were found and incorporated into the site research database and subsequently linked to individual claimant records. SNL dosimetry records spanned 1949 through 1959. Until 1953, specific nuclear components present in the WSAs contained  $^{210}\text{Po}$ . The presence of these components accounts for approximately 10 annual doses (from all WSAs) of nominally 1 rem. After 1953, the maximum annual dose from the aggregate of all WSAs was nominally 0.100 rem (ORAUT 2006a). The Pantex Plant maintains a limited database for MHSMC workers at Clarksville Modification Center that contains weekly dose information for a few workers from October 1960 to 1965. Although MHSMC began its management of Clarksville Modification Center in early 1959, no dosimetry records were found for 1959 through September 1960. Annual dose reports to AEC for 1960 to 1965 included individual whole-body dose equivalent from photons and neutrons. At Clarksville, dosimeters were issued to only a few workers who had direct contact with nuclear weapon components.

The first dosimetry records found for MHSMC workers are from October 1960. Commercial film badge service was supplied by Tracerlab from 1960 to 1965. During this period, a small number of workers (from 3 to 27) were monitored with the results mostly less than the minimum recordable dose (MRD). Of approximately 5,900 individual weekly film badges, only about 40 results were at or above the MRD. The highest annual dose to a worker from film data was less than 200 mrem in a year. Eastman Kodak nuclear track emulsion, type A (NTA) film was probably added for neutron dosimetry in January 1960; the exact date has not been determined. A former employee thought the first use of neutron dosimetry might have been 1959. Pantex Plant dosimetry data show that NTA film was in use by January 1960 (ORAUT 2006a). Because Clarksville and Pantex were operated by the same

contractor, it is reasonable to assume that identical dosimetry service was provided for both sites. Only one positive (12-mrem) result was reported from nearly 3,900 individual weekly film badges (Tracerlab 1965).

### 6.2.1 Historical Administrative Practices

Clarksville Modification Center started monitoring workers for radiation exposure in July 1949. SNL provided the dosimeters at that time. Table 6-1 summarizes the monitoring technique, exchange frequency, and values for one-half the limit of detection (LOD/2). The SNL MRD for nonpenetrating skin and penetrating whole-body dose was probably similar to the minimum detection levels (MDLs) determined by others (Wilson 1960, 1987; NIOSH 1993; NRC 1989; Wilson et al. 1990). Dosimeters were supplied by Tracerlab from October 1960 to 1965 for MHSMC workers. No dosimetry records were found for 1959 through September 1960. The Tracerlab MRDs were 30 and 10 mrem, respectively (Tracerlab 1965). Actual MDLs are typically higher because of additional uncertainty in field use and the use of dose recording thresholds.

Table 6-1. Dosimeter LOD values (mrem) for dose reconstruction by period (ORAUT 2016a).<sup>a</sup>

Dosimeter type–provider	Period	Exchange frequency	Skin LOD	Deep LOD	Neutron LOD
Beta-gamma film–SNL	07/1949–1959	Monthly	30	10	Not applicable
Beta-gamma film–Tracerlab	10/1960–1963	Weekly	30	10	15
Beta-gamma, NTA film–Tracerlab	1964–1966	Weekly	40	10	20

a. Adapted from Table 6-3 of ORAUT (2016a).

The routine practice at Clarksville Modification Center appears to have required assigning dosimeters to designated radiation workers who could receive an external radiation dose greater than 10% of the radiation protection guidelines in effect. Dosimeters were exchanged on a routine schedule. However, from 1960 to 1965 when Tracerlab provided film badges, individual worker names were not recorded with specific film badge numbers. In addition, dose components appear to be missing for some workers based on such designations as blanks or “damaged film” in records. These missing components can be reconstructed from other recorded dosimeter data by using recommended methods described below in this site profile.

### 6.2.2 Dosimetry Technology

SNL radiation workers were monitored by film badges provided by SNL. The film badge initially consisted of a piece of dental X-ray film in a plastic pouch with a pin for fastening to clothing. A lead filter was later added to the plastic pouch. The Oak Ridge metal film badge holder with three filters was used from 1957 through 1958. NTA film for neutron dosimetry was added in 1959 or 1960. Results from film badges were reported on “cardex” dosimetry records. However, records from these dosimeters have not been found in the SNL archives (ORAUT 2006a). The maximum reported radiation dose was as high as 1 rem/yr from 1949 to 1952 (ORAUT 2006a). After 1952, maximum radiation doses were about 100 mrem/yr (ORAUT 2006a).

The first commercial dosimeter MHSMC used at Clarksville was a two-element film badge from Tracerlab for measuring beta, X-ray, and gamma exposures (Tracerlab 1965). Beginning in July 1962, Clarksville used a multielement film badge that incorporated NTA film to measure beta, X-rays, gamma rays, and fast neutrons (Tracerlab 1965).

#### 6.2.2.1 Beta/Photon Dosimeters

Figure 6-1 shows the response of two film badges to photon radiation of different energies along with the *Hp(10)* response: one for a sensitive DuPont 502 emulsion in a two-element badge (Pardue,

Goldstein, and Wollan 1944), and one for a sensitive DuPont 555 emulsion in the multielement badge (Thornton, Davis, and Gupton 1961). The response of the sensitive Eastman Type 2 film in a multielement film badge is similar to that of the sensitive DuPont 555 emulsion. The film badges show an over-response at photon energies around 100 keV, due primarily to relatively high atomic numbers ( $Z$ ) [silver (47) and bromine (35)] in the film emulsions (in comparison with tissue). The film badges under-respond to lower energy photons, but the relative response of the two-element film badge to 60-keV photons from  $^{241}\text{Am}$  is nearly unity. The multielement film badge typically over-responds to 60-keV photons.

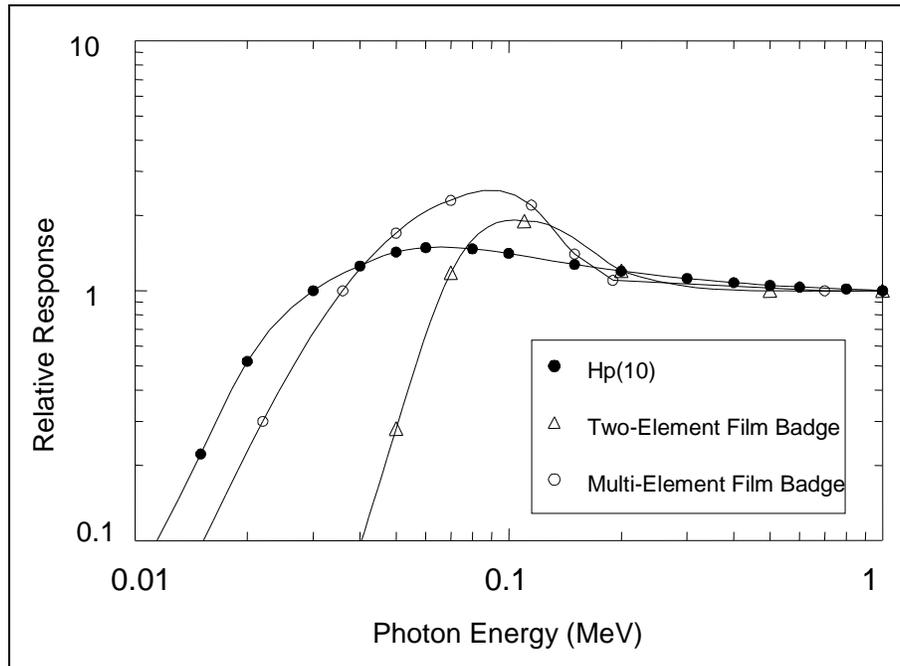


Figure 6-1. Comparison of  $H_p(10)$  for photons with energy responses for DuPont 502 emulsion in two-element film badge (Pardue, Goldstein, and Wollan 1944) and DuPont 555 emulsion in multielement film badge (Thornton, Davis, and Gupton 1961).

### 6.2.2.2 Neutron Dosimeters

The response of film dosimeters to neutron radiation was not good. NTA film was added to the holder for the Clarksville beta/gamma dosimeter in 1958 and from July 1962 through 1965 (ORAUT 2005). In general, the response of the NTA film decreases with decreasing neutron energies greater than a minimum threshold energy for laboratory studies, estimated to be about 500 keV (IAEA 1990). The minimum threshold energy for routine use in Clarksville mixed photon and neutron radiation fields is probably about 1 MeV. Results reported at the first AEC neutron dosimetry workshop indicated that laboratory dose measurements with NTA film were about one-half to one-fourth of those measured with other methods, including the neutron TLD (Vallario, Hankins, and Unruh 1969). Based on current knowledge of the general characteristics and response of NTA film, and the expected under-response in workplace conditions with significant scattering of neutrons, use of the film for personnel neutron dose monitoring can have biases. Testing of NTA film clearly showed that neutrons with energies below 500 keV were not measurable, and overall neutron doses were probably underestimated. Based on this, correction factors should be applied to the recorded NTA film results to account for threshold response (1.4), angular dependence (1.33), and uncorrected fading (1.56) (ORAUT 2016a). Combining these factors, the total correction factor of 2.9 should be applied to the NTA film results in addition to the International Commission on Radiological Protection (ICRP) correction factor (1.91) (ORAUT 2016a).

## **6.2.3 Dosimeter Calibration Procedures**

### **6.2.3.1 Beta/Photon Dosimeters**

Clarksville film badges were originally calibrated with  $^{226}\text{Ra}$  sources, with exposure measured by Victoreen R chambers. Deliberately irradiated film badges were sent periodically to SNL and Tracerlab, and reported doses were compared with measured doses for calibration (ORAUT 2006a).

### **6.2.3.2 Neutron Dosimeters**

An account of the historical aspects of the calibration of Clarksville neutron dosimeters is not available.

## **6.2.4 Workplace Radiation Fields**

The main workplace radiation fields at Clarksville Modification Center arose from the handling of nuclear weapon components containing plutonium, HEU, Po-Be initiators, and DU. The highest dose rates were encountered from the handling of bare pits and Po-Be initiators. The nuclides in the sealed nuclear weapon component pits emitted alpha, beta, X-, gamma, and neutron radiation. From an external dosimetry perspective, the radiations of concern are beta particles, photons (X- and gamma rays), and neutrons. Radiation exposure to workers depends significantly on the processes used in the preparation, design, and construction of the weapons.

With few exceptions, the following sections show that, for external dose reconstruction purposes, all beta radiation fields are greater than 15 keV, all photon radiation fields are between 30 and 250 keV, and all neutron fields are between 0.1 and 2 MeV. Presuming that 100% of the radiation fields are within these ranges is a simplifying, conservative assumption that is generally favorable to claimants. Table 6-2 summarizes the radiation energy categories.

Table 6-2. Beta, photon, and neutron radiation energies and percentages for Clarksville facilities.

Process/buildings	Description	Operations period	Radioactive material	Radiation type	Energy selection	Percent (notes)
Bays Cells Tunnel complex	Assembly/disassembly of nuclear weapons	1949–1965	DU	Beta	>15 keV	100 <sup>a</sup>
				Photons	30–250 keV	100 <sup>b</sup>
Bays Cells Tunnel complex	Assembly/disassembly of nuclear weapons	1958–1965	Tritium	Beta	<15 keV	100 <sup>c</sup>
Bays Cells Tunnel complex	Assembly/disassembly of nuclear weapons	1949–1965	Plutonium, HEU	Photons	30–250 keV	100
				Neutrons	0.1–2 MeV	100 <sup>d</sup>
Bays Cells Tunnel complex	Casual surveillance, minor maintenance	1966–1967	DU	Beta	>15 keV	100
				Photons	30–250 keV	100
Igloos	Staging of weapons and plutonium pits	1949–1965	Plutonium, HEU	Photons	30–250 keV	100
				Neutrons	0.1–2 MeV	100 <sup>d</sup>
Igloos	Casual surveillance, minor maintenance	1966–1967	DU	Beta	>15 keV	100
				Photons	30–250 keV	100
Transportation	Movement of weapons	1949–1965	DU, HEU, plutonium	Photons	30–250 keV	100 <sup>b</sup>
				Neutrons	0.1–2 MeV	100 <sup>d</sup>
Warehouse	Packaging components	1949–1965	Weapon components	Beta	>15 keV	100 <sup>a</sup>
				Photons	30–250 keV	100 <sup>b</sup>
				Neutrons	0.1–2 MeV	100 <sup>d</sup>
Warehouse	Packaging components	1954–1965	Tritium	Beta	<15 keV	100 <sup>c</sup>

- Workplace beta radiation has energy greater than 15 keV.
- Most photons from DU have energies greater than 30 keV; some have energies greater than 250 keV. If shielding materials are present, fewer photons are in the categories less than 30 keV or greater than 250 keV. The simplifying conservative assumption that 100% of the photons from DU are between 30 and 250 keV is recommended as generally favorable to claimants.
- Beta particles from tritium are classified in the less-than-15-keV category.
- The energy of neutrons in the workplace is predominately in one of two ranges: Between 0.1 and 2 MeV or between 2 and 20 MeV. In some cases, with significant moderating materials, some neutrons are less than 0.1 MeV. However, the simplifying conservative assumption that 100% of the neutrons are between 0.1 and 2 MeV is recommended as generally favorable to claimants.

#### 6.2.4.1 Depleted Uranium

Clarksville workers handled DU (primarily <sup>238</sup>U) during assembly and disassembly of weapon components and during maintenance operations. An important progeny nuclide for potential worker exposure in <sup>238</sup>U decay is <sup>234m</sup>Pa with a half-life of 24 days. In a few months after purification, DU components have <sup>234m</sup>Pa activities nearly equal to that of <sup>238</sup>U. Protactinium-234m emits beta radiation 98.6% of the time when it changes to its ground state with a maximum energy of 2.28 MeV and an average energy of 0.825 MeV (Shleien, Slaback, and Birky 1998; ICRP 1973). An additional source of exposure in the Clarksville workplace was from bremsstrahlung produced in high-Z materials from interactions with higher energy beta particles. Beta particles emitted by <sup>234m</sup>Pa excite both bremsstrahlung and characteristic X-rays in DU or <sup>238</sup>U.

Beta radiation from DU could have contributed to extremity and skin dose to workers unless precautions were taken to protect workers from the radiation. Protective clothing and gloves provide a protection factor of 2 or more, depending on the thickness. A bare slab source of natural uranium contributes an *Hp(0.07)* dose of approximately 230 mrad/hr at the surface in comparison with an

*Hp*(10) dose at 1 ft of approximately 2 mrad/hr (Kathren 1975). However, significant beta exposures to Clarksville workers were rarely detected by film badges, based on a review of shallow and deep dosimetry data.

#### **6.2.4.2 Photon Radiation**

Photon radiation in the workplace could have been readily measured at Clarksville Modification Center with available dosimeter technology during all years of operation. It is assumed that all photons at Clarksville were within the 30- to 250-keV range, similar to data from the Pantex Plant.

#### **6.2.4.3 Neutron Radiation**

The in-flight-insertable design of nuclear weapons required a neutron initiator source. The first initiator sources were <sup>210</sup>Po mixed which could be combined with beryllium to produce neutrons (ORAUT 2006a). The average energy of the neutrons was 4.2 MeV (Shleien, Slaback, and Birky 1998). The energies of the photons and neutrons were 0.8 and 4.45 MeV, respectively (Shleien and Terpilak 1984). Unfortunately, the half-life of <sup>210</sup>Po is only 138.4 days (Shleien, Slaback, and Birky 1998), so the initiator sources had to be exchanged frequently (ORAUT 2006a).

Until 1957, the primary radiological task was periodically changing the Po-Be initiators. Between 1954 and 1956, Po-Be initiators were gradually replaced with a newer type of sealed neutron generator that did not require routine replacement. Maintenance activities were reduced to annual disassembly of capsules to verify the integrity of fissile materials, and radiation exposures to workers were reduced (Lamb and Halliburton 1996).

### **6.2.5 Dosimeter Response to Radiation Fields**

#### **6.2.5.1 Beta/Photon/Neutron Film Dosimeter Response**

The dosimeters Clarksville used after 1957 contained an open window with little filtration, a lower energy window for allowing beta particles and lower energy photons to enter a film area with a plastic filter, and a film area with a metal (usually aluminum) filter. The open window enabled measurement of beta particles and lower energy photons. The plastic filter enabled measurement of intermediate energy photons and the metal filter enabled measurement of higher energy photons (1-cm depth).

Tracerlab provided commercial dosimetry services from October 1960 through 1965. The AEC tested film badges from Tracerlab with exposures to 40-, 70-, and 210-keV X-rays and <sup>60</sup>Co gamma rays, and mixed-energy exposures of all four radiations (AEC 1955). The film badges generally responded well "with a tendency to interpret most exposures too high." The over-response (in the 100- to 200-keV region) tended to yield conservatively high results.

The film badge dosimetry reports from Tracerlab are less than adequate because few names are recorded in relation to specific film badge numbers. Radiation doses to workers were probably low during this period, and many positive doses less than the MRD would have been recorded as zero. The weekly film badge exchange frequency increased the probability that low doses were truncated to zero. An uncertainty correction factor of 1.3 is a reasonable estimate of the uncertainty for recorded photon doses for organs other than the skin. The factor of 2.9 applied to recorded neutron doses accounts for uncertainties in dosimeter response.

#### **6.2.5.2 Neutron Dose Weighting Factor**

The coworker neutron doses for Clarksville were based on Pantex dosimeter readings. At Pantex, thermoluminescent neutron dosimeters were calibrated with measurements based on fluence-to-dose

conversion factors and quality factors similar to those from ICRP Publication 21 (ICRP 1973) and National Council on Radiation Protection and Measurement (NCRP) Report 38 (NCRP 1971). It is necessary to adjust the neutron dose to account for the change in neutron quality factors between historic and current scientific guidance, as discussed in NIOSH (2007). Table 6-3, excerpted from ORAUT (2015b), lists the correction factor to use.

Table 6-3. Neutron dose energies, percentages, and associated ICRP (1991) correction factors.

Process	Description	Neutron energy (MeV)	Default dose fraction <sup>a</sup> (%)	ICRP (1991)/NCRP (1971) correction factor
Nuclear weapons component assembly	Neutron exposure associated with weapons assembly and disassembly activities	0.1–2	100	1.91

a. From Table 6-2; assuming all neutron energies are between 0.1 and 2 MeV is favorable to claimants.

### 6.3 RECOMMENDATIONS FOR EXTERNAL DOSE RECONSTRUCTION, OPERATIVE YEARS

Dose reconstruction for Clarksville Modification Center workers is based on the foregoing information, which requires assessment of external dose considering these primary factors:

- Adjustments to recorded photon dose to account for dosimeter response uncertainty;
- Adjustment of neutron doses to account for energy dependence, angular response, and fading using a factor of 2.9;
- Multiplication of the calculated neutron dose by an ICRP (1991) neutron weighting factor adjustment of 1.91 for neutron energies between 0.1 and 2 MeV; and
- Adjustments to account for non-uniform fields for doses to the extremities and lower torso organs associated with workers performing pit maintenance operations with bare pits on the lap in a sitting position. This is discussed later in Section 6.4.

#### 6.3.1 Unmonitored External Dose

For Clarksville, the concept of “unmonitored worker” must be expanded to include “monitored but records not found.” Few dosimetry records have been found for Clarksville; those that have been found do not always identify the person who received the radiation dose. Therefore, it was necessary to estimate the radiation doses Clarksville workers might have received. To perform these estimates, four job categories with relative exposure potentials were identified (Table 6-4). Category 1 consists of individuals who worked with nuclear devices on a daily basis; these were considered full-time radiation workers who received the highest doses. Category 2 consists of individuals who routinely entered radiation work areas but were not in close contact with nuclear devices or were not exposed full time; they were assumed to be occupationally exposed, but to a lesser extent than those working with nuclear components. Category 3 consists of individuals who were only occasionally exposed and were not in close contact with nuclear components. Category 4 consists of individuals who did not enter radiation areas; they were assumed to have received only environmental dose.

Operations at Clarksville Modification Center between 1958 and 1965 were similar to those at the Pantex Plant; MHSMC operated both facilities. Therefore, the coworker doses in ORAUT-TKBS-0013-6, *Pantex Plant – Occupational External Dose* (ORAUT 2016a) are assumed to be representative for unmonitored workers at Clarksville for the MHSMC years. See Attachment B for unmonitored dose tables.

Table 6-4. Exposure categories and applicable job titles.

Exposure category	Conditions	Job titles
1	Extensive work with pits; full-time exposure (typically apply the 95th-percentile coworker dose).	Production operator, operator, operator trainee, nuclear inspector, nuclear quality control inspector
2	Worked predominantly in radiation areas but did not handle nuclear components routinely (typically apply the 50th-percentile coworker dose)	Material handler, warehouseman, safety/security inspector, fireman, nuclear quality control specialists, inspectors not associated with nuclear components
3	Infrequent entry into radiation areas (apply either the 50th-percentile coworker dose or onsite ambient dose depending on job description or statements in the interview).	All job categories not explicitly listed in this table
4	Did not enter radiation areas; exposure from environmental sources only (apply on-site ambient dose).	Bus driver, grounds laborer, power plant operator, sewage disposal operator

For the SNL years, 1949 to 1958, workers handled sealed components rather than performing intimate handling of pits, so doses would be expected to be smaller than those for MHSMC operations. Therefore, the assignment of unmonitored worker doses from Attachment B should be considered representative of the doses that the Clarksville workers likely received.

### 6.3.2 Recorded and Missed External Dose for Monitored Workers

The vast majority of records reflect only annual summary information. If external dose data are found in a worker's file, the dose reconstructor should assign the recorded annual dose along with missed dose based on the LOD/2s and the number of exchange periods from Table 6-1 for the respective dosimetry systems, using the guidance in Attachment A of ORAUT-PROC-0006, *External Dose Reconstruction* (ORAUT 2006d).

### 6.3.3 Radiation Dose Fraction

Table 6-2 summarizes the recommended energy fractions for Clarksville dose according to facilities, processes or activities, and energy categories required by IREP.

## 6.4 ORGAN DOSE, OPERATIVE YEARS

Once the *H<sub>p</sub>(10)* adjusted doses have been calculated for each year, the values are used to calculate organ doses of interest using the external dose reconstruction implementation guidelines (NIOSH 2007). Dose reconstructors should assume the use of the AP (front-to-back) geometry for the irradiation geometry and for conversion to organ dose. Multiply the calculated neutron doses by the neutron deep dose equivalent organ dose conversion factors for AP irradiation from Appendix B of NIOSH (2007). For photons applicable to Clarksville Modification Center (i.e., film badge era), use the conversion factor from exposure to organ dose.

Some workers at Clarksville Modification Center, generally production operators, operators, or operator trainees, might have handled unshielded pits with gloved hands or by holding the unshielded pits in their laps. If the individual has skin cancer on the hands and handled unshielded pits, dose reconstructors should apply the guidance in DCAS-TIB-0013, *Selected Geometric Exposure Scenario Considerations for External Dose Reconstruction at Uranium Facilities* (NIOSH 2010b). For cancers of the lower torso organs, the 95th-percentile glovebox correction factor in DCAS-TIB-0010, *Best Estimate External Dose Reconstruction for Glovebox Workers*, (NIOSH 2011) is recommended to ensure a result favorable to the claimant. This type of activity was generally limited to a relatively

small fraction of time during the average workday. Because of this, a scaling factor should be applied to the 95th-percentile glovebox correction. For example, the actual pit handling activity likely took no more than 1 to 2 hr/d. Assuming that the claimant actually performed pit handling maintenance operations for 1 hr/d 5 d/wk, the appropriate correction to apply would equate to the 95th-percentile correction multiplied by 0.125 (5 hr/d divided by the 40-hour work week).

In likely compensable cases that include cancers on the extremities, a more realistic dose estimate should be performed using actual surface dose rates, attenuation factors, or both. Further, it is unlikely that individuals would have contact with the bare metal for extended periods.

## 6.5 ORGAN DOSE, POSTOPERATIVE YEARS

External dose might have been received by persons doing minor maintenance or surveillance of the site after the facility was shut down in 1966 and 1967, due to possible residual DU contamination on floors or surfaces. A radiological survey in 1997 found no contamination above release criteria (Last, Gilmore, and Bronson 1998). The release criterion for combined fixed and removable contamination was 5,000 dpm/100 cm<sup>2</sup>. Organ dose rates were calculated assuming the following:

- A geometry of standing on a contaminated floor,
- 5,000 dpm/100 cm<sup>2</sup> of natural uranium, which would be favorable to claimants in relation to DU, and
- Progeny radionuclides after 5-year ingrowth

Calculations were based on dose factors provided in the compact disk (CD) supplement to Federal Guidance Report (FGR) No. 13 (Eckerman et al. 1999). The dose rates to the skin are averages over the entire phantom used for the calculations, and no credit for protective clothing or shoes was applied in the calculations. It was assumed that time spent in proximity to contaminated surfaces was limited to a few hours a month, so an occupancy factor of 0.02 was applied. The annual organ doses are listed in Table 6-5.

Because all measurements were reported as simply less than the release criterion, the above calculations are analogous with missed dose calculations. Therefore, a triangular distribution should be applied with a minimum of zero, a mode based on the surface contamination at one-half the release criterion, and a maximum based on the surface contamination at the release criterion. However, the doses are all less than 1 mrem/yr and can be ignored. They are provided in case a dose reconstructor believes it appropriate to use a larger occupancy factor. No neutron doses should be applied.

Table 6-5. Annual external dose (rem) to organs from natural uranium surface contamination at or below release criterion, 1966 to 1967.

<b>Organ</b>	<b>Mode</b>	<b>Maximum</b>
Adrenals	7.28E-07	1.46E-06
Bladder wall	7.98E-07	1.60E-06
Bone surface	2.08E-06	4.16E-06
Brain	7.58E-07	1.52E-06
Breasts	1.06E-06	2.12E-06
Esophagus	6.73E-07	1.35E-06
Stomach wall	7.95E-07	1.59E-06
Small intestine wall	7.46E-07	1.49E-06
Upper large intestine wall	7.68E-07	1.54E-06
Lower large intestine wall	7.74E-07	1.55E-06
Kidneys	8.07E-07	1.61E-06
Liver	7.96E-07	1.59E-06
Lungs	8.44E-07	1.69E-06
Muscle	1.00E-06	2.00E-06
Ovaries	7.41E-07	1.48E-06
Pancreas	7.10E-07	1.42E-06
Red marrow	8.27E-07	1.65E-06
Skin	2.80E-04	5.60E-04
Spleen	8.01E-07	1.60E-06
Testes	1.05E-06	2.10E-06
Thymus	7.86E-07	1.57E-06
Thyroid	8.78E-07	1.76E-06
Uterus	7.42E-07	1.48E-06

## **7.0 ATTRIBUTIONS AND ANNOTATIONS**

All information requiring identification was addressed via references integrated into the reference section of this document.

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## GLOSSARY

### absorption

In external dosimetry, process in which radiation energy is imparted to material. In internal dosimetry, movement of material to blood regardless of mechanism.

### absorption type

Categories for materials according to their rate of absorption from the respiratory tract to the blood, which replaced the earlier inhalation clearance classes. Defined by the International Commission on Radiological Protection, the absorption types are F: deposited materials that are readily absorbed into blood from the respiratory tract (fast solubilization), M: deposited materials that have intermediate rates of absorption into blood from the respiratory tract (moderate rate of solubilization), and S: deposited materials that are relatively insoluble in the respiratory tract (slow solubilization).

### activity

Amount of radioactivity. The International System unit of activity is the becquerel (1 disintegration per second); the traditional unit is the curie [37 billion ( $3.7 \times 10^{10}$ ) becquerels].

### acute exposure

Radiation exposure to the body delivered in a short period. See *chronic exposure*.

### alpha radiation

Positively charged particle emitted from the nuclei of some radioactive elements. An alpha particle consists of two neutrons and two protons (a helium nucleus) and has an electrostatic charge of +2.

### anterior-posterior (AP)

Physical orientation of the body relative to a penetrating directional radiation such that the radiation passes through the body from the front to the back. See *exposure geometry*.

### background radiation

Radiation from cosmic sources, naturally occurring radioactive materials including naturally occurring radon, and global fallout from the testing of nuclear explosives. Background radiation does not include radiation from source, byproduct, or Special Nuclear Materials regulated by the U.S. Nuclear Regulatory Commission. The average individual exposure from background radiation is about 360 millirem per year.

### beta radiation

Charged particle emitted from some radioactive elements with a mass equal to 1/1,837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is a positron.

### bird cage

- (1) Criticality-safe framework around a nuclear capsule in the in-flight insertable design;
- (2) common expression for Clarksville secured area.

### bremsstrahlung

Electromagnetic radiation released as a result of inelastic scattering of a moving charged particle within the nucleus of an atom. X-rays produced in a typical medical X-ray tube frequently originate from inelastic scattering of accelerated electrons in the anode material.

**chronic exposure**

Radiation dose to the body delivered in small amounts over a long period (e.g., days or years). See *acute exposure*.

**contamination**

Radioactive material in an undesired location including air, soil, buildings, animals, and persons.

**decay**

(1) Disintegration of atomic nuclei from spontaneous radioactivity including alpha, beta, and neutron radiation, often accompanied by gamma radiation. (2) Decrease in the amount of radioactive material over time due to nuclear transformation. See *half-life*.

**deep dose equivalent [ $H_p(10)$ ]**

Dose equivalent in units of rem or sievert for a 1-centimeter depth in tissue (1,000 milligrams per square centimeter). See *dose*.

**depleted uranium (DU)**

Uranium with a percentage of  $^{235}\text{U}$  lower than the 0.7% found in natural uranium.

**dose**

In general, the specific amount of energy from ionizing radiation that is absorbed per unit of mass. Effective and equivalent doses are in units of rem or sievert; other types of dose are in units of, rad, rep, or gray.

**dose equivalent**

In units of rem or sievert, product of absorbed dose in tissue multiplied by a weighting factor and sometimes by other modifying factors to account for the potential for a biological effect from the absorbed dose. See *dose*.

**dosimeter**

Device that measures the quantity of received radiation, usually a holder with radiation-absorbing filters and radiation-sensitive inserts packaged to provide a record of absorbed dose received by an individual. See *film dosimeter* and *thermoluminescent dosimeter*.

**dosimeter holder**

Plastic holder for a dosimeter card, which typically includes one or more metallic filters that modify the response of the phosphor to radiation.

**dosimetry**

Measurement and calculation of internal and external radiation doses.

**enriched uranium (EU)**

Uranium in which processing has increased the proportion of  $^{235}\text{U}$  to  $^{238}\text{U}$  to above the natural level of 0.7% by mass. Reactor-grade uranium is usually about 3.5%  $^{235}\text{U}$ ; weapons-grade uranium contains greater than 90%  $^{235}\text{U}$ .

**exchange period (frequency)**

Period (weekly, biweekly, monthly, quarterly, etc.) for routine exchange of dosimeters.

**exposure geometry**

Orientation (physical positioning) of a person or object in relation to a radiation source. This geometry is a factor in the radiation dose to various parts of the body. See *anterior-posterior*, *posterior-anterior*, and *lateral*.

**film**

(1) In the context of external dosimetry, radiation-sensitive photographic film in a light-tight wrapping. See *film dosimeter*. (2) X-ray film.

**film badge**

See *film dosimeter*.

**film dosimeter**

Package of film for measurement of ionizing radiation exposure for personnel monitoring purposes. A film dosimeter can contain two or three films of different sensitivities, and it can contain one or more filters that shield parts of the film from certain types of radiation. When developed, the film has an image caused by radiation measurable with an optical densitometer. Also called film badge.

**filter**

Material used (1) in a dosimeter to adjust radiation response to provide an improved tissue equivalent or dose response and (2) in an X-ray machine to selectively absorb photons from the beam to reduce unnecessary exposure of individuals or to improve radiographic quality.

**gamma radiation**

Electromagnetic radiation (photons) of short wavelength and high energy (10 kiloelectron-volts to 9 megaelectron-volts) that originates in atomic nuclei and accompanies many nuclear reactions (e.g., fission, radioactive decay, and neutron capture). Gamma photons are identical to X-ray photons of high energy; the difference is that X-rays do not originate in the nucleus.

**geometric standard deviation (GSD)**

In probability theory and statistics, the geometric standard deviation describes the spread of a set of numbers whose preferred average is the geometric mean.

**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.

**half-life**

Time in which half of a given quantity of a particular radionuclide disintegrates (decays) into another nuclear form. During one half-life, the number of atoms of a particular radionuclide decreases by one half. Each radionuclide has a unique half-life ranging from millionths of a second to billions of years.

**high-efficiency particulate air (HEPA) filter**

Dense filter that removes contaminants from air flows before return to the working environment or discharge to the outside air (exhaust).

**highly enriched uranium (HEU)**

Uranium enriched to at least 20% <sup>235</sup>U for use as fissile material in nuclear weapons components and some reactor fuels. Also called high-enriched uranium.

**igloo**

Earth-covered storage area for items that might explode, such as ammunition, high explosives, bombs, or bomb parts.

**in-flight insertable**

Historical weapons design in which final assembly of the nuclear and nonnuclear components of an air-drop weapon did not occur until just before use. Military technicians completed the assembly en route to the target by inserting the nuclear materials capsule into the mechanical assembly.

**lateral (LAT)**

Orientation of the body during an X-ray procedure in which the X-rays pass from one side of the body to the other. See *exposure geometry*.

**minimum detectable activity or amount (MDA)**

Smallest amount (activity or mass) of an analyte in a sample that can be detected with a probability  $\beta$  of nondetection (Type II error) while accepting a probability  $\alpha$  of erroneously deciding that a positive (nonzero) quantity of analyte is present in an appropriate blank sample (Type I error).

**neutron (n)**

Basic nucleic particle that is electrically neutral with mass slightly greater than that of a proton. There are neutrons in the nuclei of every atom heavier than normal hydrogen.

**neutron film dosimeter**

Film dosimeter with a nuclear track emulsion, type A, film packet.

**neutron radiation**

Radiation that consists of free neutrons unattached to other subatomic particles emitted from a decaying radionuclide. Neutron radiation can cause further fission in fissionable material such as the chain reactions in nuclear reactors, and nonradioactive nuclides can become radioactive by absorbing free neutrons. See *neutron*.

**neutron-to-photon dose ratio**

Ratio applied to the photon fraction to estimate the unmeasured neutron dose based on knowledge and measurements in a specified location.

**nuclear emulsion**

Thick photographic coating in which the tracks of various fundamental particles show as black traces after development. The number of tracks in a given area is a measure of the dose from that radiation. See *nuclear track emulsion, type A*.

**nuclear track emulsion, type A (NTA)**

Film sensitive to fast neutrons. Made by the Eastman Kodak Company, the developed image has tracks caused by neutrons that become visible under oil immersion with about 1,000-power magnification.

**open window**

Area of a film dosimeter that has little to no radiation shielding (e.g., only a holder and visible light protection). The open window measures nonpenetrating as well as penetrating dose, which minimizes the potential for beta radiation to contribute to the interpreted penetrating dose. See *film dosimeter*.

**operational years**

Period of U.S. Atomic Energy Commission responsibility during which the site had an active mission that involved handling or storing radioactive materials.

**personal dose equivalent [ $H_p(d)$ ]**

Dose equivalent in units of rem or sievert in soft tissue below a specified point on the body at an appropriate depth  $d$ . The depths selected for personal dosimetry are 0.07 millimeter (7 milligrams per square centimeter) and 10 millimeters (1,000 milligrams per square centimeter), respectively, for the skin (shallow) and whole-body (deep) doses. These are noted as  $H_p(0.07)$  and  $H_p(10)$ , respectively. The International Commission on Radiological Measurement and Units recommended  $H_p(d)$  in 1993 as dose quantity for radiological protection.

**photon**

Quantum of electromagnetic energy generally regarded as a discrete particle having zero rest mass, no electric charge, and an indefinitely long lifetime. The entire range of electromagnetic radiation that extends in frequency from  $10^{23}$  cycles per second (hertz) to 0 hertz.

**photon radiation**

Electromagnetic radiation that consists of quanta of energy (photons) from radiofrequency waves to gamma rays.

**PM<sub>10</sub>**

Particles less than 10 micrometers in aerodynamic median diameter that include both fine and coarse dust particles; essentially particles of respirable size.

**posterior-anterior (PA)**

Physical orientation of the body relative to a penetrating directional radiation field such that the radiation passes through the body from the back to the front. See *exposure geometry*.

**postoperative years**

Period of U.S. Atomic Energy Commission responsibility during which no active functions were performed that involved handling or storing radioactive materials. The period after the site was shut down and major radioactive materials were removed, but the site was still under Commission jurisdiction.

**progeny**

Nuclides that result from decay of other nuclides. Also called decay products and formerly called daughter products.

**radiograph**

Static images produced on radiographic film by gamma rays or X-rays after passing through matter. In the context of the Energy Employees Occupational Illness Compensation Program Act of 2000, radiographs are X-ray images of the various parts of the body used to screen for disease.

**radiography**

The process of producing images on film (or other media) with radiation.

**radon (Rn)**

Radioactive gaseous element with atomic number 86. Radon is a decay product (progeny) of other radioactive elements such as thorium and radium.

**shallow dose equivalent [ $H_p(0.07)$ ]**

Dose equivalent in units of rem or sievert at a depth of 0.07 millimeter (7 milligrams per square centimeter) in tissue equal to the sum of the penetrating and nonpenetrating doses.

**thermoluminescent dosimeter (TLD)**

Device for measuring radiation dose that consists of a holder containing solid chips of material that, when heated, release the stored energy as light. The measurement of this light provides a measurement of absorbed dose.

**U.S. Atomic Energy Commission (AEC)**

Federal agency created in 1946 to assume the responsibilities of the Manhattan Engineer District (nuclear weapons) and to manage the development, use, and control of nuclear energy for military and civilian applications. The U.S. Energy Research and Development Administration and the U.S. Nuclear Regulatory Commission assumed separate duties from the AEC in 1974. The U.S. Department of Energy succeeded the U.S. Energy Research and Development Administration in 1979.

**whole-body (WB) dose**

Dose to the entire body excluding the contents of the gastrointestinal tract, urinary bladder, and gall bladder and commonly defined as the absorbed dose at a tissue depth of 10 millimeters (1,000 milligrams per square centimeter). Also called penetrating dose. See *dose*.

**X-ray**

(1) See *X-ray radiation*. (2) See *radiograph*.

**X-ray radiation**

Electromagnetic radiation (photons) produced by bombardment of atoms by accelerated particles. X-rays are produced by various mechanisms including bremsstrahlung and electron shell transitions within atoms (characteristic X-rays). Once formed, there is no difference between X-rays and gamma rays, but gamma photons originate inside the nucleus of an atom.

**ATTACHMENT A  
GUIDANCE FOR THE MEDINA MODIFICATION CENTER**

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## **ATTACHMENT A GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

### **A.1 SPECIAL EXPOSURE COHORT**

On August 23, 2012, as provided for under 42 U.S.C. 7384q(b), the Secretary of Health and Human Services designated the following class of employees as an addition to the SEC (Sebelius 2012b):

*All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Medina Modification Center in San Antonio, Texas, from January 1, 1958 through December 31, 1966, 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 Special Exposure Cohort.*

In its evaluation (NIOSH 2012b), NIOSH found that it lacks sufficient information to reconstruct internal radiation doses adequately for all Medina Modification Center employees for all potential radiation exposures. Specifically, this includes internal personnel monitoring data, air monitoring data, process data, and radiological source term information that would allow NIOSH to estimate with sufficient accuracy potential internal exposures to uranium, plutonium, and tritium. However, NIOSH has determined that occupational medical and external doses can be reconstructed based on available data. Based on the occupational medical and external data available, and the available dose reconstruction methods, NIOSH believes it is possible to either: (1) estimate the maximum external dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the external doses to members of the class more precisely than a maximum dose estimate. Although NIOSH found that it is not possible to reconstruct internal radiation doses completely for the proposed class, NIOSH intends to 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 employees at Medina Modification Center, San Antonio, Texas, during the period from January 1, 1958, through December 31, 1966, but who do not qualify for inclusion in the SEC, can be performed using these data as appropriate to support a partial dose reconstruction.

### **A.2 SITE DESCRIPTION AND FUNCTIONS**

Medina Base, located on about 3,700 acres of Lackland Air Force Base (AFB) southwest of San Antonio, Texas, was one of 13 WSAs created under the Armed Forces Special Weapons Project. Medina Base was constructed by the U.S. Air Force and the AEC between 1953 and 1955, with the first weapons components arriving in 1955. It was supported by SNL for the AEC and the Air Force. SNL, AEC, and the Air Force were all active at Medina from 1955 until early 1959, performing maintenance and quality assurance on nuclear components of weapons (Mitchell 2003).

**NOTE: The approved dates for applicability under EEOICPA for this site are limited to 1958 through 1966 only.**

AEC stored nuclear weapons and components that were maintained by SNL and Air Force personnel at the Medina WSA, which consisted of storage buildings that housed nuclear capsules, maintenance structures, waste burial sites, and bunkers for storage of weapons casings. SNL personnel worked at Medina under contract to the AEC until early 1959 (ORAUT 2006e).

In 1958, MHSMC was chosen by the AEC to manage Medina Base, and construction of new facilities was undertaken. Three gravel gertie cells were constructed along with other specialized facilities that

## ATTACHMENT A GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)

made up the Medina Modification Center (Mitchell 2003). From April 1959 until 1966, MHSMC operated Medina for the AEC as a weapons modification and disassembly facility. The mission was to perform stockpile surveillance, modifications, retrofits, and weapon retirements (Carr ca. 1992). This work included inspections for corrosion and replacement of tritium reservoirs. Medina was operated by MHSMC until January 1966, when its mission was transferred to the Pantex Plant and Medina Base was transferred back to the Air Force.

### A.2.1 Site Description

Lackland AFB is in the San Antonio metropolitan area in Bexar County, Texas (Figure A-1). Commercial and residential developments border Lackland AFB on the north, west, and south sides, and Kelly AFB borders it on the east. The western portion of Lackland AFB was the Medina Base, which is now the Lackland Training Annex. The Medina Base consisted of four main areas: the 200 Area (general shops and stores), 300 Area (operations and storage), 400 Area (Plants 1 and 2, main production operations), and 500 Area (igloos and storage facilities). Two additional areas were the Burning Ground and the Railhead (Figure A-2) (Lamb and Halliburton 1995).

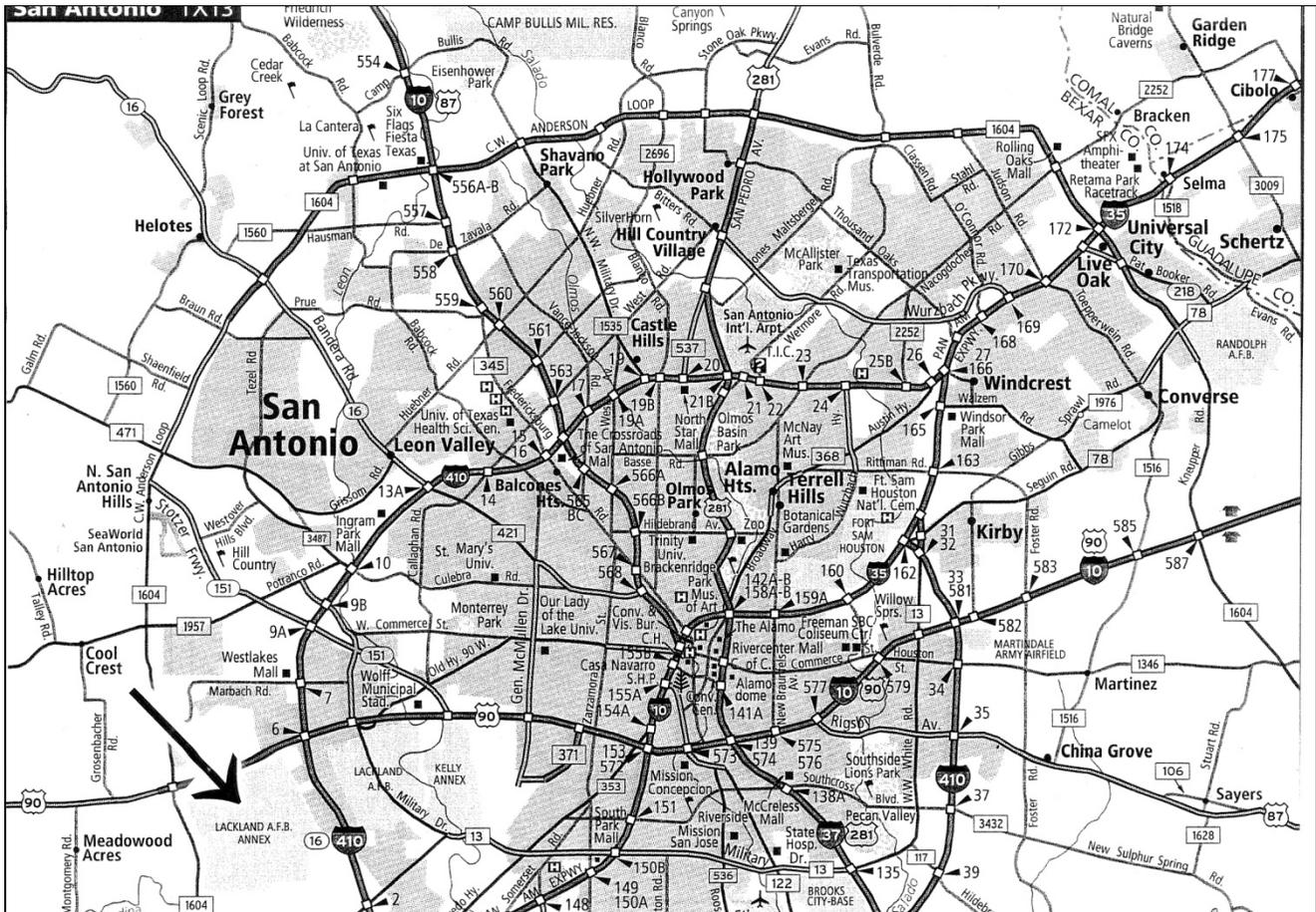


Figure A-1. San Antonio, Texas, area showing location of Lackland Training Annex (previously called Medina Base; Rand McNally 2005).

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GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

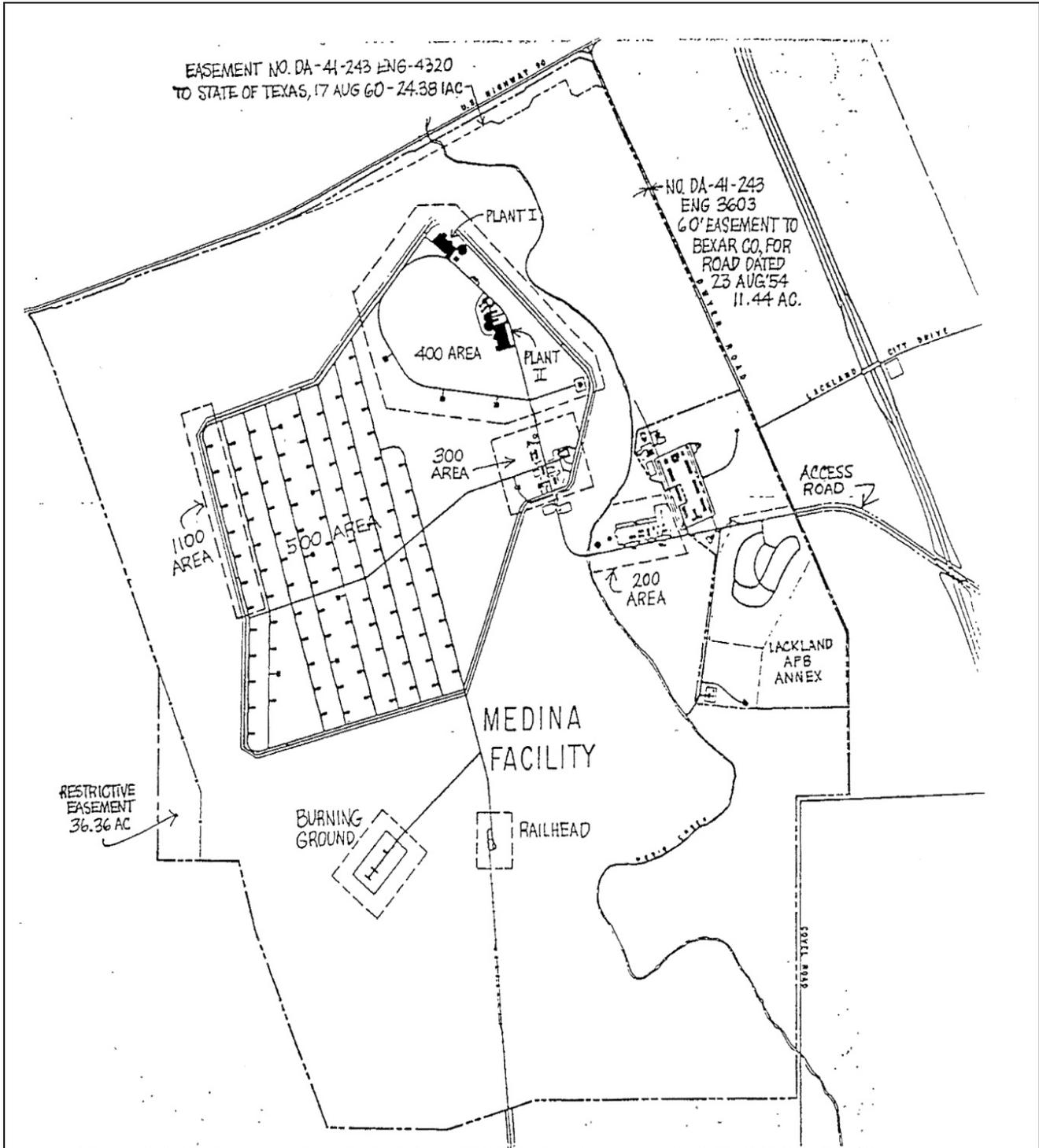


Figure A-2. Medina Base (Lamb and Halliburton 1995).

There were seven main types of structures at the Medina Base, including A Structures, C Structure, Base Spares Warehouse, assembly/maintenance buildings, S Structure, storage igloos, and the plants for modification disassembly (Lamb and Halliburton 1995). The site also included low-level

## **ATTACHMENT A**

### **GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

radioactive waste (LLRW) disposal areas and emergency underground storage tanks (USTs; also underground holding tanks). Each of these structures is described in the following paragraphs.

A Structures included Buildings 301, 402, 403, 404, 552, 556, 562, 571, and 585 in the 300, 400, and 500 Areas. A Structures were used to store nuclear capsules for weapon systems (Lamb and Halliburton 1995). The buildings, although massive concrete structures, had only four small storage rooms, each approximately 10 ft wide, 13 ft deep, and 9 ft high. Each room had a capacity for approximately 30 nuclear capsules that were stored in criticality-safe bird cage containers (Figure 2-5). Each room had a bank vault type door equipped with dual combination locks. The 10-ft-thick walls and massive berms around the rooms were designed to protect the nuclear capsules from external attacks, rather than as containment of possible accidental detonations in the buildings. Maintenance activities always took place in the C Structure, never in the vault where the capsules were stored. Therefore, no nuclear material was ever exposed in an A Structure and there was little or no potential for a release of radioactive material with these buildings. Activities in the A Structures ended in 1960 (Lamb and Halliburton 1995).

Building 307, a C Structure, was used as a nuclear materials inspection laboratory and maintenance building for the nuclear weapons at Medina Base. The C Structure provided bench space to perform required maintenance operations, storage space for neutron calibration and assay sources, and support facilities that included a change room and storage areas. Nuclear capsules destined for maintenance were transported in their bird cages to the C Structure; when maintenance was completed, the capsules were placed back in their bird cages, sealed, and returned to one of the A Structure buildings (Lamb and Halliburton 1995).

Workrooms in the C Structure were constructed with floor drains that were connected to an emergency UST in the building. If there had been an accident, the UST would have collected the decontamination wash water and any released plutonium. No accidental releases of plutonium are known to have occurred at Medina Base during 1955 through 1966 (Lamb and Halliburton 1995).

The C Structure had an extensive ventilation system that prevented the release of uranium oxides to the atmosphere. Based on review of environmental reports, there are no indications that spills or releases of radioactive material occurred in the C Structure during its operational lifetime (Lamb and Halliburton 1995).

The Base Spares Warehouse was used to store spare weapon components for maintenance purposes (Lamb and Halliburton 1995).

The Assembly/Maintenance Buildings were also called Plants 1 and 2; each plant consisted of two buildings used for maintaining nonnuclear components of weapons at Medina. The buildings contained several bays, and activities included inspection, testing, and assembly of nonnuclear mechanical and electrical systems. The buildings featured heavy blast doors and earthworks that would have deflected the effects of an accidental explosion upward. The design is typical for facilities in which large amounts of high explosive (HE) are handled (Lamb and Halliburton 1995).

An S, or Surveillance, Structure (Building 444) was used for inspections and testing of weapons in the stockpile. The S Structure separated quality assurance activities from the routine maintenance and assembly functions at Plants 1 and 2. Building 444 contained electrical and mechanical bays and a calibration room, but did not have a floor drain connected to a UST. The building was modified in 1959 for the modification and disassembly mission managed by MHSMC (Lamb and Halliburton 1995).

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### **GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

One hundred igloos were constructed in the 500 Area for the storage of weapon components, assembled weapons, and weapon casings. All nuclear materials in the igloos were sealed in the weapons. No maintenance activities took place in the igloos and, therefore, there was little or no potential for a release of radioactive or hazardous materials (Lamb and Halliburton 1995).

In 1959, three gravel gertie cells were built for modifying and disassembling weapons. HE shells were removed from nuclear assemblies in these structures. Several tons of gravel were above the ceiling of each structure for containment of fissile material in the event of an accidental detonation of the HE system. The gravel gerties were used between 1959 and 1965 (Lamb and Halliburton 1995).

Three sites at Medina (RW-15, RW-17, and RW-19) were designed for the collection of dry and liquid LLRW. RW-15 was a landfill for the disposal of LLRW, and might have received classified limited-life components disposed of during weapons modification and disassembly operations between 1959 and 1965. The LLRW was excavated in 1965 and transferred in container express (CONEX) containers to the Pantex Plant. The RW-15 site was cleared by the AEC as decontaminated when the site was closed in 1965 (Lamb and Halliburton 1995). Dry LLRW from operations in the C Structure was packed in cardboard boxes and disposed of in the RW-17 site. RW-17 was an unlined pit that was fenced and considered a classified waste landfill. RW-19 was a small gravel leaching area behind Building 444. The site reportedly received intermittent LLRW wastewater discharges from Building 444. Gravel and soil from the area were excavated in 1965 and transferred in CONEX containers to the Pantex Plant (Lamb and Halliburton 1995).

Three emergency USTs were designated RW-16, RW-18, and RW-20. The USTs were intended for the collection of liquid LLRW in the event of an accidental release; however, no evidence has been found that any of the USTs were ever used (Lamb and Halliburton 1995). RW-16 and RW-18 are 1,000-gal steel tanks; RW-20 is a 5,000-gal steel tank.

#### **A.2.2 Operational History as a Weapons Storage Area, 1954 to 1960**

The early nuclear weapons used Po-Be initiators to generate neutrons during the explosion sequence. Because  $^{210}\text{Po}$  has a half-life of only 138 days, the initiators had to be replaced periodically. According to former SNL personnel (ORAUT 2006e), these devices were maintained following precise quality control methods that required maintenance personnel to:

1. Release pressure from the bird cage container through a filter and check the filter for alpha activity. If no activity was found, remove the capsule from the container using a handling tool.
2. Place the capsule on a table top with an alpha probe at one end. (The table was covered with a large piece of butcher paper to contain any spalling of uranium oxides.)
3. Place a plexiglass glovebox over the capsule.
4. Disassemble the capsule parts and check the integrity of the coatings.
5. Remove the glovebox.
6. Remove uranium oxide deposits from the threads using a small cloth or paper swipe and trichloroethylene. Wipe the threads with ethyl alcohol to dry the components.

**ATTACHMENT A**  
**GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

7. Use acetone to remove previous markings made with blue machinist's dye and make new markings. (Later components had serial numbers etched on their surfaces.)
8. Check the activity of the fissile material using beta and gamma radiation measurements.
9. Assay the nuclear material by accurately weighing it and perform subcritical multiplication measurements using external neutron sources.
10. Replace the Po-Be initiators. (These were later replaced with nonradioactive initiators.)
11. Reassemble the capsule.
12. Place the capsule and a sack of desiccant in the bird cage container.
13. Screw on the bird cage container top. Repressurize and wire seal the bird cage container (positive pressure was maintained to ensure dryness and keep O-rings in place) (Lamb and Halliburton 1995). [Later designs used a vacuum rather than overpressure (ORAUT 2006f).]

Contaminants from the maintenance process were the chemicals mentioned above and uranium oxides. Polonium-210 waste was not generated (Lamb and Halliburton 1995). Used (decayed) initiators were sent to Los Alamos National Laboratory for storage, regeneration, or disposal. The spalled uranium oxides, swipes contaminated with solvents, lead-wire seals, and gloves were wrapped in butcher paper and placed in 18- by 18- by 24-in. cardboard boxes for disposal in the dry LLRW disposal area (currently designated RW-17) (Lamb and Halliburton 1995).

A source safe (a cylindrical apparatus below the floor surface with a polyethylene neutron absorber at the top) was in a corner of the laboratory room in the C Structure. Below the neutron absorber, the source safe had a tray for storing check sources for verifying the activity of the fissile material in the weapons (Lamb and Halliburton 1995).

Between 1954 and 1957, the Po-Be initiators and plated pits in the in-flight-insertable design were phased out and replaced with sealed pits and a newer type of sealed neutron generator that did not require routine replacement (Lamb and Halliburton 1995; Mitchell 2003). Therefore, while some SNL workers handled Po-Be initiators and plated pits before 1957, no MHSMC workers were exposed to the initiators or plated pits. After 1957, maintenance activities were reduced to annual disassembly of capsules to determine their condition and to verify the integrity of the fissile materials. Maintenance of the newer capsules generated the same types of waste, but in smaller quantities because of the less frequent maintenance schedule. By 1960, nuclear capsules had been phased out of the stockpile and maintenance activities no longer involved exposed nuclear material (Lamb and Halliburton 1995).

### **A.2.3 Operation as a Modification and Disassembly Center**

Between 1959 and 1966, the mission of MHSMC workers was to perform stockpile surveillance, modifications, retrofits, and weapon retirements (Carr ca. 1992). Typical modifications involved disassembly and reassembly with some modified components and replacement of tritium reservoirs. Weapon retirements involved complete disassembly and return of nuclear components to other DOE sites. Some damaged weapons were returned to Medina during these years. Their ultimate disposition has not been determined, but they were no longer at Medina after shutdown. During this period, the MHSMC workers at Medina were exposed to the same types of radiation and levels of

**ATTACHMENT A**  
**GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

contamination as Pantex workers because their work activities were nearly identical (except there were no hydroshot operations at Medina) (Mitchell 2003).

**A.3 OCCUPATIONAL MEDICAL DOSE**

Similar to the Clarksville Modification Center, the Pantex Plant has the X-ray histories of Medina workers during the MHSMC years. Only written histories, not film, are available. Because essentially the same work was done by the same contractor, it is assumed that the X-ray guidance for Clarksville Modification Center should be applied to Medina workers for the MHSMC years, 1958 to 1966. There is evidence in the claims files that MHSMC gave some pre-employment X-rays to Medina workers in October 1958 (see Section 3.0). However, several of the X-ray records in the claim files for workers at Medina suggest that the X-rays may have been performed at the Minter X-ray Clinic. If the dose reconstructor is certain that the X-rays were performed off the site at a non-covered facility, then the dose from the X-rays cannot be included in dose reconstruction per ORAUT-OTIB-0079.

**A.4 ENVIRONMENTAL DOSE**

**A.4.1 Routine Doses**

Insufficient information has been obtained about Medina Base to develop site-specific considerations for environmental releases. The only environmental doses to be assigned for the Pantex Plant are from radon and a large accidental release of tritium. Similarly, environmental doses at Clarksville Modification Center resulted from a tritium accident modeled after the Pantex accident and from direct radiation from use of radiography sources. Throughputs, in terms of number of disassemblies, for instance, of the four assembly and disassembly sites (Pantex, Iowa Army Ammunition Plant, Clarksville, and Medina) are classified, so comparison of effluents by relationships to throughput is not permissible in an unclassified document. Medina had three gravel gerties in comparison with one at Clarksville.

The average tritium release from the Pantex Plant from 1981 through 1988, when a large number of disassemblies was performed, was 70,000  $\mu\text{Ci/yr}$ . Assuming that Medina Base operations were similar to those of the Clarksville Modification Center and Pantex, the annual doses from tritium intakes are also less than 0.001 rem. Therefore, the annual dose to any organ from tritium intakes at the Medina Base are less than 0.001 rem and can be ignored.

There is no reason not to believe that Medina Base had the same radiography sources as Clarksville Modification Center. Dose reconstructors should assign Medina workers the same 4-mrem external dose from radiography as for Clarksville workers (Section 4.0 and Table 4-1.). The 4-mrem annual dose is applied as a lognormal distribution with a GSD of 2.0 with a photon energy range of 100% 30 to 250 keV.

**A.4.2 November 13, 1963, Explosion**

**A.4.2.1 Background**

On November 13, 1963, an explosion involving 50,500 kg (123,000 lb) of chemical HE components of nuclear weapons occurred at the Medina site. Workers were placing subassemblies from dismantled atomic bombs into storage Igloo 572. The subassemblies, which were being stored for further processing and disposal, contained chemical HE, natural uranium, and DU. They were handled by a

**ATTACHMENT A**  
**GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

three-man crew – two forklift operators who moved them from a straddle carrier into the igloo and one man on the carrier.

Most of the load was in the igloo when, at about 10:24 a.m., the explosive in one of the subassemblies ignited. Seeing the flash, the drivers sprinted for cover, alerting the workers outside. For about 45 seconds the explosive burned, then it detonated with a force of more than 60 tons of trinitrotoluene (TNT). The first explosion set off other subassemblies in the igloo and those still on the carrier. The igloo disappeared in a cloud of smoke and dust, leaving a crater some 20 ft deep. A large cloud of dust was seen near the ground moving downwind of the event.

In the 45 seconds between ignition and detonation, the three workers got away. Their injuries were minor. Adjacent igloos were not disturbed. The only known radioactive material involved was a mixture of DU and natural uranium. Fissile materials (enriched uranium or plutonium) were not involved in the accident.

**A.4.2.2 Direct Radiation**

Assuming an infinite plane source and the distribution of natural uranium (which has a higher compounded dose rate than DU) in equilibrium with its short-lived progeny, external doses can be calculated. Dose rates can be calculated for each organ using organ-specific, dose rate conversion factors such as those in FGR 12 (Eckerman and Ryman 1993) or the CD supporting FGR 13 (Eckerman et al. 1999).

Using the factors from FGR 13 CD (Eckerman et al. 1999), the rate of effective dose per  $\mu\text{Ci}/\text{m}^2$  would be:

$$\begin{aligned}
 {}^{238}\text{U} + {}^{234}\text{Th} + {}^{234\text{m}}\text{Pa} &= (0.489)(49.5 + 876 + 12,600) \times 10^{-6} \text{ rem/yr per } \mu\text{Ci}/\text{m}^2 \\
 + {}^{235}\text{U} + {}^{231}\text{Th} &= (0.0225)(16,400 + 1,720) \times 10^{-6} \text{ rem/yr per } \mu\text{Ci}/\text{m}^2 \\
 + {}^{231}\text{Th} &= (0.489)(68.4) \times 10^{-6} \text{ rem/yr per } \mu\text{Ci}/\text{m}^2 \qquad \qquad \qquad (\text{A-1}) \\
 &= 0.025 \text{ rem/yr} \\
 &= 25 \text{ mrem/yr per } \mu\text{Ci}/\text{m}^2 \text{ for full-time occupancy}
 \end{aligned}$$

However, this value is somewhat misleading because FGR 13 (Eckerman et al. 1999) factors include a tissue-weighting factor for skin dose. Using FGR 13 factors but omitting the contribution from the weighted skin dose, the gamma dose rate, which more closely approximates the average organ dose, is:

$$\begin{aligned}
 {}^{238}\text{U} + {}^{234}\text{Th} + {}^{234\text{m}}\text{Pa} &= (0.489)(40.7 + 856 + 1,600) \times 10^{-6} \text{ rem/yr per } \mu\text{Ci}/\text{m}^2 \\
 + {}^{235}\text{U} + {}^{231}\text{Th} &= (0.0225)(16,400 + 1,820) \times 10^{-6} \text{ rem/yr per } \mu\text{Ci}/\text{m}^2 \\
 + {}^{231}\text{Th} &= (0.489)(57.8) \times 10^{-6} \text{ rem/yr per } \mu\text{Ci}/\text{m}^2 \qquad \qquad \qquad (\text{A-2}) \\
 &= 0.0017 \text{ rem/yr} \\
 &= 1.7 \text{ mrem/yr per } \mu\text{Ci}/\text{m}^2 \text{ for full-time occupancy}
 \end{aligned}$$

For an occupational exposure of 2,000 hr/yr, this would be 0.39 mrem/yr per  $\mu\text{Ci}/\text{m}^2$ . The highest onsite location, 60  $\mu\text{Ci}/\text{m}^2$ , might have resulted in 23 mrem/yr. For regularly occupied areas

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### **GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

downwind, a value of one-tenth of that, or 2.3 mrem/yr, would be appropriate. Most of the site is upwind of the footprint left by the plume, so the external dose from uranium in the soil would be negligible. However, at present there is no way to discriminate between workers in offices upwind versus downwind of the plume footprint. Therefore, dose reconstructors should apply a 2.3-mrem/yr external dose from photons with energy from 30 to 250 keV.

#### **A.5 INTERNAL DOSE**

NIOSH has concluded that it is not possible to reconstruct internal doses completely during the operational period of the Medina Modification Center. Therefore, in the absence of monitoring data for an individual claim, no occupational internal doses should be assigned. For claims in which individual internal monitoring data are available, the internal dose should be reconstructed based on interpretation of the monitoring data using existing NIOSH dose reconstruction processes and procedures.

#### **A.6 EXTERNAL DOSIMETRY**

The MHSMC dosimetry records for Medina began on April 27, 1959, and extended through January 24, 1966 (Pantex Plant 1959–1966). It is possible that some earlier dosimetry records exist for SNL personnel, but none have been found to date. Exposures to the few (less than 10) SNL personnel between 1955 and 1959 did not involve exchange of Po-Be initiators, and a former employee estimated maximum exposures at 100 mrem/yr (ORAUT 2006e). However, the approved EEOICPA dates for this site are 1958 through 1966 only. MHSMC used weekly dosimetry services from Tracerlab from April 1959 until July 1964 (Tracerlab 1965) and from Nuclear Service Laboratories of Knoxville, Tennessee, from July 1964 until January 1966 (Pantex 1959–1966). Work at Medina was completed in January 1966, and dosimetry services were terminated on January 24, 1966. Most of the MHSMC workers left the site in January and February 1966. Many of the workers transferred to the Pantex Plant in Amarillo, Texas.

The clerical maintenance of the dosimetry records was not rigorous. For example, individual names were consistently assigned to only 11 film badge numbers, and some numbers were reused when an individual left the program. More than 100 other film badges were assigned to different people each week and the individual names, for nonzero results only, were recorded on the film badge dose report after it was received. In some weeks, the task of recording names associated with nonzero dose results was not completed, so it is impossible to reconstruct who received nonzero doses. Because more than one individual was assigned to a given film badge number, the quarterly and annual totals maintained by the film badge processor were not useful.

Therefore, the dose records from Pantex were carefully examined, corrected, and summarized in a letter to the Project file, "Medina Dose Records, 1959–1966" (ORAUT 2006g). Dose reconstructors should disregard any incomplete dose records provided with the claims and use ORAUT (2006g).

Because the doses received by Medina and Clarksville workers appear similar in magnitude within the uncertainties in how annual doses were calculated, the recommendations for Medina are the same as those for Clarksville. However, the exception is that the exchange frequency at Medina was weekly for all years of operation (Pantex Plant 1959–1966). Because the work at Medina was similar to that at Clarksville, it is reasonable to apply the same dose assignment recommendations as for Clarksville.

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**GUIDANCE FOR THE MEDINA MODIFICATION CENTER (continued)**

**Radiation Incident at Medina on September 7, 1959**

On September 7, 1959, there was a radiation exposure incident at Medina that involved a radiography source (Pantex Plant 1959–1966). The details were provided in claimant interviews. A vendor came to the site to demonstrate a new type of portable radiography source with shield that was air operated (apparently referred to as a “Puff” camera). The device could pneumatically transfer a source from the safe shielded position, through a 30-ft tube, to a radiography exposure location. The end of the tube was located such that it could take an X-ray of an electronic part. The vendor representative first performed the transfer of the capsule out to the end of the tube and back into the lead shield using a dummy (nonradioactive) capsule. The transfer was successfully demonstrated several times and the Medina radiography staff successfully used the equipment with the dummy capsule in a training exercise. While the vendor representative was leaving the site, he realized he did not have the dummy capsule with him and there could be a problem. An investigation revealed that the dummy capsule was still in the lead shield and when the air flow was reversed, the 30-Ci  $^{192}\text{Ir}$  source could not enter the shield because the dummy capsule was in it. When the air flow stopped, the  $^{192}\text{Ir}$  source fell back down the tube to an area where personnel were present. As a result of this incident, three individuals received unusually high radiation exposures, as follows: Individual A – 6,600 mrem gamma, Individual B – 3,000 mrem gamma, and Individual C – 2,370 mrem gamma. These exposures are included in the summarized records (ORAUT 2006g).

**ATTACHMENT B**  
**ASSIGNMENT OF UNMONITORED EXTERNAL DOSE FOR CLARKSVILLE AND MEDINA**

The following table was adapted from Tables A-1 through A-3 of ORAUT-TKBS-0013-6, *Pantex Plant – Occupational External Dose* (ORAUT 2016a).

Table B-1. Unmonitored external doses by year (rem), Clarksville and Medina Modification Centers.

<b>Year</b>	<b>Photon 50th%</b>	<b>Photon 95th%</b>	<b>Neutron 50th%</b>	<b>Neutron 95th%</b>	<b>Electron 50th%</b>	<b>Electron 95th%</b>
1946 - 1963	0.010	0.302	0.007	0.482	0.012	0.112
1964	0.101	1.007	0.043	0.645	0.056	0.148
1965	0.029	0.440	0.015	0.168	0.036	0.180
1966 <sup>a</sup>	0.042	0.442	0.022	1.147	0.051	0.160

- a. All nuclear materials were removed for the Clarksville site in 1965. Therefore, unmonitored external doses should not be applied for 1966 at the Clarksville Modification Center.