ORAU TEAM
Dose Reconstruction Project for NIOSH

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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.

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
06/09/2004	00	New technical basis document for the Nevada Test Site – Occupational Medical Dose. Incorporates internal review and NIOSH comments. First approved issue. Initiated by Eugene M. Rollins.
06/22/2007	01	Approved revision initiated to concur with ORAUT-OTIB-0006 (ORAUT 2005), current data in other TBDs, and to include new legal wording in Section 3.1. Constitutes a total rewrite of the document. Incorporates formal internal and NIOSH review comments. Adds Attributions and Annotations section. This revision results in no change to the assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Vernon E. Shockley.
11/26/2012	02	Revision initiated to incorporate consistency with ORAUT-OTIB-0006, ORAUT-OTIB-0079, and new information in the Site Research Database (SRDB). Skin doses were developed and added to the document for all periods. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Elyse M. Thomas.

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
cGy	centigray
cm	centimeter
DCF	dose conversion factor
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ESE	entrance skin exposure
FDA	U.S. Food and Drug Administration
Gy	gray
HVL	half-value layer
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
kVp	peak kilovoltage
LAT	lateral
mA	milliampere
mGy	milligray
mm	millimeter
mR	milliroentgen
mrem	millirem
NCRP	National Council on Radiation Protection and Measurement
NIOSH	National Institute for Occupational Safety and Health
NTS	Nevada Test Site
ORAU	Oak Ridge Associated Universities
PA	posterior–anterior
PFG	photofluorography
POC	probability of causation
SRDB Ref ID	Site Research Database Reference Identification (number)
SSD	source-to-skin distance
TBD	technical basis document
U.S.C.	United States Code
§	section or sections

3.1 INTRODUCTION

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

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

For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the POC [probability of causation[1]] guidelines established under subsection (c) …" [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation, 42 C.F.R. Pt. 82) restrict the "performance of duty" referred to in 41 U.S.C. § 7384n(b) to nuclear weapons work (NIOSH 2010).

The statute also includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program" [42 U.S.C. § 7384l(12)]. While this definition excludes Naval Nuclear Propulsion Facilities from being covered under the Act, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty"] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all occupationally-derived radiation exposures at covered facilities in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external occupational radiation exposures are considered valid for inclusion in a dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction. NIOSH, however, does not consider the following exposures to be occupationally derived (NIOSH 2010):

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

1 The U.S. Department of Labor (DOL) is ultimately responsible under the EEOICPA for determining the POC.

3.1.1 Purpose

This technical basis document (TBD) documents historical practices at the Nevada Test Site (NTS) and provides the basis for organ dose from medical X-ray procedures that were performed for occupational health screening at NTS.

3.1.1 Scope

NTS has maintained an occupational health and safety program for its workers over the time of its operation, beginning in 1951. Physical examinations of workers typically included chest X-rays to screen for disease and monitor the health of its workforce. The organ dose from these X-ray procedures depends on the characteristics of the X-ray machine and the techniques that were used. Site-specific information about the NTS X-ray screening program, to the extent it is known, was used in the development of this document.

Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 3.5.

3.2 EXAMINATION TYPES AND FREQUENCIES

Early in NTS operations, it was the responsibility of the employer organizations to ensure that personnel who were part of test operations were healthy. A specific frequency or protocol for physical examinations was not a requirement early on, but individuals who had not had a physical examination within a year of participating in a test were encouraged to have one (Reeves 1957, p. 176).

Starting in about 1960 when X-ray equipment was first installed on the site (Geiger 1960, p. 4), physical examinations of workers occurred on a more regular basis (Kathren and Shockley 2004, p. 12). Chest X-rays were the most commonly performed radiographic screening examination, but some workers in certain job classifications appear to have had lumbar spine X-rays to screen for back problems. A review of claim file records indicates that chest X-rays were performed annually on workers in the early years [1] and less frequently in the later years, perhaps once every 2 to 3 years (Kathren and Shockley 2004, p. 10; REECo 1986). Other radiographic examinations of NTS workers that might have occurred were necessitated by illness or injury and were not part of the employee occupational health screening process. Eventually, NTS subcontracted the X-ray examinations out to offsite, noncovered facilities in Las Vegas (DeMarre 2012a), and the X-ray machine at Mercury was used only for accidents.

In the 1960s, there was another medical X-ray machine at the Nuclear Rocket Development Station complex. However, because of its remote location, it was not likely to have been used for routine physicals but might have been used for accidents in the field (DeMarre 2012a,c).

Table 3-1 lists the nominal frequency of examinations over the years during which chest X-rays were required as part of occupational health screening. Some workers might have received these X-rays on a schedule different from that in Table 3-1. Dose reconstructors should assign dose according to the X-rays that were performed for screening as listed in the claim file records or, in the absence of records, according to the frequency in Table 3-1.

3.2.1 Photofluorography

No evidence that photofluorography (PFG) was used at NTS has been found either in the historical documentation or in the claim file records. If a dose reconstructor finds evidence of PFG in the claim file records, dose should be assigned using the values in ORAUT-OTIB-0006, *Dose Reconstruction* *from Occupational Medical X-Ray Procedures* (ORAUT 2011a). In the absence of evidence in the claim file records, or in the absence of records, no dose from PFG should be assigned.

Table 3-1. Frequency of chest X-ray screening at NTS.

Period[a]	Worker category	Frequency	Examination and projections
1951–1959	All workers (offsite)[b]	Preemployment, annual[c], and termination	PA chest
1960–1966	All workers	Preemployment, annual[d], and termination	PA chest
1967–1972	All workers	Preemployment and termination	PA chest
	Respirator wearers[e] All other workers	Annual Every 2 yr[b]	PA chest
1973–1985	All workers (offsite)[f]	Preemployment and termination	PA and LAT chest[f]
	Respirator wearers[e] All other workers	Annual Every 2 yr[b]	PA and LAT chest[f]
1986–1988[g]	All workers (offsite)[f]	Preemployment (no termination)	PA chest
	Culinary workers in Mercury: 18–39 yr old ≥40 yr old Smokers	 Annual Annual Annual	 PA chest PA, plus LAT chest every 5 yr PA, plus LAT chest every 2 yr
	Miners, shaker plant workers, asbestos workers	Annual	PA, plus LAT every 5 yr
	All other workers in Mercury: 19–20 yr old 21–39 yr old ≥40 yr old ≥40 yr old (smoker)	 None Every 5 yr Every 5 yr Every 2 yr	 PA chest PA and LAT chest PA and LAT chest
1989–present (offsite)[f]	Same as for 1986–1988 (offsite)[f]	Same as for 1986–1988 (offsite)[f]	Same as for 1986–1988 (offsite)[f]

a. Dates are approximate.
b. Kathren and Shockley (2004, p. 7).
c. Reeves (1957).
d. Based on a review of claim file records.
e. REECo (ca. 1975).
f. DeMarre (2012a).
g. REECo (1986).

3.2.2 Chest Radiography, 1951 to 1959

Chest X-rays before 1960 were taken off the site at noncovered contractor facilities, probably physicians' offices in Las Vegas (Kathren and Shockley 2004, p. 7). This statement is supported by the historical information in Reeves (1957). Reeves lists the facilities available at NTS, and only a first aid station is mentioned (Reeves 1957 p. 9). A medical service was to have been retained with a skeleton crew should an evacuation be necessary after a detonation (Reeves 1957 p. 72), and that future plans called for a physician and nurse to be on duty during test operations (Reeves 1957 p. 73). There was a military dispensary on site for military personnel, but others (i.e. civilians) were to be sent to Las Vegas hospitals for treatment (Reeves 1957 p. 185-186). There is no evidence of X-ray equipment on-site at NTS before 1960. A review of claim file records with employment start dates before 1960 reveals that none have X-ray records with the "Medical Department, Mercury, Nevada" stamp on them, while six have evidence of having been performed off-site in Las Vegas [2].

According to ORAUT-OTIB-0079, *Guidance on Assigning Occupational X-ray Dose Under EEOICPA for X-rays Administered Off-Site* (ORAUT 2011b), dose from X-rays taken off the site at noncovered facilities cannot be included in dose reconstruction.

3.2.3 Chest Radiography, 1960 to 1966

During this period, all workers received a preemployment, annual, and termination posterior-anterior (PA) chest examination [1].

In 1960, a Standard X-ray machine was installed on the site at NTS (Geiger 1960, p. 4). A log of X-rays that were taken with this machine lists the technique factors for a PA chest as 72 to 75 kVp, 200 mA, and 1/20 second. Geiger (1960, pp. 4, 7) mentions that the collimating cones for the machine had been ordered but had not yet arrived on the date he performed a survey of the machine.

In 1955, the National Council on Radiation Protection and Measurements (NCRP) recommendation for minimum filtration for diagnostic X-ray units called for 2-mm Al equivalent filtration for new machines (NBS 1955). Assuming the Standard X-ray machine met this recommendation, the half-value layer (HVL) for the chest X-rays taken at 75 kVp would be 2.0 mm Al (NCRP 1997, p. 98).

The incident air kerma value for this period is 2.28 cGy based on the average air kerma rates in NCRP Report 102 (1997, p. 99), the technique factors and HVL information specific to NTS that are mentioned above, and the methodology in ORAUT-OTIB-0006 (ORAUT 2011a) for calculating incident air kerma. An almost identical value was obtained using the pelvis measurement data contained in Geiger after correction for use for chest X-rays (1960, pp. 9), or the information in DHEW (1970, p. 160). Poor collimation is assumed for this period, meaning that additional organs were included in the primary beam than would otherwise be included when an X-ray beam is properly collimated. The additional organs that are included in the primary beam of a poorly collimated beam are described in ORAUT-OTIB-0006. Incident air kerma values and HVL information is summarized in Table 3-2.

Table 3-2. X-ray equipment used at NTS and incident air kerma values.

Period	X-ray machine	kVp (kV)	Assumed HVL (mm Al)	Incident air kerma (cGy)	
				PA chest	LAT chest
1951–1959	Offsite	(a)	(a)	(a)	(a)
1960–1966	Standard X-ray	75[b]	2.0[b]	0.0228[b]	(c)
1967–1972	GE	Unknown	3.0[d]	0.040[e]	(c)
1973–1985	Unknown	Unknown	3.0[d]	0.040[e]	0.100[d]
1986–1988	GE	110[f]	3.0[f]	0.007[f]	0.018[f]
1989–present	Offsite	(a)	(a)	(a)	(a)

a. Dose from X-rays that were taken at noncovered offsite facilities is not eligible for inclusion under EEOICPA.
b. Based on technique factors and measurement data in Geiger (1960).
c. Not performed for screening during this period.
d. Based on ORAUT-TKBS-0008-3, Rev. 01.
e. Based on ORAUT-TKBS-0008-3, Rev. 01, Goldman and Beech (1979), and ORAUT (2009).
f. Stevenson (1988).

Dose reconstructors should assign dose for the X-rays that are listed in the claim file records. In the absence of records, dose reconstructors should assign dose according to the frequency in Table 3-1.

3.2.4 Chest Radiography, 1967 to 1972

During this period, all workers received a preemployment and a termination PA chest examination. In addition, respirator wearers received an annual PA chest examination (REECo ca. 1975), while all other workers received a PA chest every 2 years (Kathren and Shockley 2004, p. 7).

Photographs from the NTS archive from 1967 and 1970 show a General Electric (GE) machine with an adjustable collimator (rectangular beam) (DeMarre 2012a). Other records that were provided by NTS show that a GE X-ray machine was inspected by the U.S. Food and Drug Administration (FDA) in 1988 (Stevenson 1988). It is not certain if this is the same GE machine that was in place in 1967 (DeMarre 2012b).

No documentation has been found to date of surveys that were performed at NTS during this period. Data from the National X-ray Exposure Studies of 1970 report an entrance skin exposure (ESE) of 44 mR for the PA chest in facilities nationwide representing all types of equipment (Goldman and Beech, 1979, pg. 44). A later national study reports the mean of measured ESEs from all types of facilities and equipment as 23 mR (Wochos, 1979, pg. 130). Technique factor data from GE equipment used at the Idaho National Laboratory (INL) for 1967-1985 results in an ESE of 52 mR for a PA chest (ORAUT 2009, pp. 8-9), while technique factor information from GE equipment at Pinellas results in an ESE of 32 mR for 1972-1987 (ORAUT 2011c). Since all of these values bracket the 40 mR ESE value used in Rev. 01 of the NTS Medical TBD, and several of them are lower, there does not seem to be solid evidence for a change at this time. Incident air kerma values and HVL information are summarized in Table 3-2.

Dose reconstructors should assign dose for the X-rays that are listed in the claim file records. In the absence of records, dose reconstructors should assign dose according to the frequency in Table 3-1.

3.2.5 Chest Radiography, 1973 to 1985

During this period, workers received preemployment physicals, including X-rays, at contracted, noncovered facilities in Las Vegas (DeMarre 2012a,c). Steinberg Radiographic Service was one such contractor. These contractors might also have provided the periodic and termination chest X-rays if the worker was in Las Vegas. The location where the X-rays were taken was sometimes, but not always recorded in the submitted claim file records [1]. Lateral chest X-ray projections appear in the claim file records for this period (see Table 3-1).

Dose reconstructors should review the location information that might be recorded on the X-ray records. Without records, or specific location information, dose reconstructors should assume that the preemployment chest X-ray was taken off the site at a noncovered facility and should assign dose for the remaining X-rays in the claim file records (because those might have been performed at NTS). In the absence of records, dose reconstructors should assign dose according to the frequency in Table 3-1.

No documentation has been found to date of surveys that were performed at NTS during this period. Data from the National X-ray Exposure Studies of 1970 report an ESE of 44 mR for the PA chest in facilities nationwide representing all types of equipment (Goldman and Beech, 1979, pg. 44). A later national study reports the mean of measured ESEs from all types of facilities and equipment as 23 mR (Wochos, 1979, pg. 130). Technique factor data from GE equipment used at INL for 1967-1985 results in an ESE of 52 mrad for a PA chest (ORAUT 2009, pp. 8-9), while technique factor information from GE equipment at Pinellas results in an ESE of 32 mR for 1972-1987 (ORAUT 2011c). Since all of these values bracket the 40 mR ESE value used in Rev. 01 of the NTS Medical TBD, and several of them are lower, there does not seem to be solid evidence for a change at this time. Incident air kerma values and HVL information is summarized in Table 3-2.

3.2.6 Chest Radiography, 1986 to 1995

There are two important pieces of evidence that were provided by NTS for this period. A 1986 document describes the X-ray screening protocols, including specific information about the PA and LAT chest projections to be taken and when (REECo 1986). It is clear from this document that the frequency of X-ray screening was decreasing for some groups of workers. However, the recommendations for other groups of workers, such as culinary workers, miners, shaker plant workers, and asbestos workers, remained on an annual chest X-ray screening schedule. The details of this document are summarized in Table 3-1.

The other important piece of evidence that was provided by NTS for this period is a letter from the FDA providing the results of a 1988 survey of the X-ray equipment at NTS. It mentions that such surveys were performed every 2 years (Stevenson 1988). The survey of a GE machine states that the measured entrance skin exposure (ESE) for a PA chest examination was 8 mR at 110 kVp. The letter does not mention that the machine's filtration was noncompliant, so the HVL can be assumed to be at least 3.1 mm Al at 110 kVp (NCRP 1997, p. 98). A rounded value of 3.0 mm Al is used for ease in selection of dose conversion factors for dose reconstruction.

During this period, workers continued to receive preemployment physicals at contracted, noncovered facilities in Las Vegas (DeMarre 2012a,c). Steinberg Radiographic Service was one such contractor (DeMarre 2012c). These contractors might also have provided the periodic and termination chest X-rays if the worker was in Las Vegas. The location where the X-rays were taken was sometimes, but not always recorded in the submitted claim file records [1]. Lateral chest X-ray projections appear in the claim file records for this period (see Table 3-1).

Dose reconstructors should review the location information that might be recorded on the X-ray records. Without records, or specific location information, dose reconstructors should assume that the preemployment chest X-ray was taken off the site at a noncovered facility and should assign dose for the remaining X-rays in the claim file records (because these might have been performed at NTS). In the absence of records, dose reconstructors should assign dose according to the frequency in Table 3-1.

The organ doses for this period were determined starting with the 8 mR ESE that was measured by FDA with correction of this value to incident air kerma as described in ORAUT-OTIB-0006 (ORAUT 2011a) and assuming an HVL of 3.0 mm Al. Incident air kerma values and HVL information is summarized in Table 3-2.

3.2.7 Chest Radiography, 1996 to Present

NTS sold and removed its X-ray equipment in 1996 (Moon, 2012). After this date, all radiographic services were contracted out to a variety of offsite, noncovered facilities in Las Vegas such as the previously mentioned Steinberg Radiographic Services (DeMarre 2012c). All X-rays of NTS workers after 2000 have been performed at Centennial Hospital (DeMarre 2012a). According to ORAUT-OTIB-0079 (ORAUT 2011b), dose from X-rays taken off the site at noncovered facilities cannot be included in dose reconstruction, so dose reconstructors should not include dose from X-ray procedures of NTS workers after 1995.

3.2.8 Lumbar Spine Radiography, 1960 to 1985

No evidence has been found in historical records that lumbar spine X-rays were taken for screening. A detailed screening protocol for 1986 and later makes no mention of lumbar spine X-rays for screening (REECo 1986). However, some of the claim file records show that lumbar spine X-rays were taken on some workers. Because the claim file records do not usually specify the reason for the X-ray, it cannot be determined from them if the lumbar spine X-rays were taken for screening or as a result of an injury, symptom, or complaint. Dose reconstructors should, therefore, include dose from lumbar spine X-rays if they were taken before 1986 and when it might make sense to do so from the information in the claim file records (e.g., the worker's job description implies heavy lifting). If any information in the claim file records implies that the lumbar spine X-rays were taken as a result of an injury, accident, or back pain, then dose from lumbar spine X-rays should not be assigned. In the absence of records, dose from lumbar spine X-rays should not be assigned.

Doses for lumbar spine X-rays [PA and lateral (LAT) projections] are from ORAUT-OTIB-0006 (ORAUT 2011a).

3.3 ORGAN DOSE CALCULATIONS

Organ dose equivalents for PA and LAT chest X-rays were based on the method that is described in ORAUT-OTIB-0006 (ORAUT 2011a) and dose conversion factors in International Commission on Radiological Protection (ICRP) Publication 34 (ICRP 1982). ICRP (1982) provides tables of average absorbed dose (in milligray) in selected organs for selected X-ray projections at 1-Gy entrance kerma (i.e., air kerma without backscatter) for selected projections and selected beam qualities (i.e., various HVLs). The tables list the basic dose conversion factors (DCFs) for converting air kerma to organ dose. Substitute DCFs for organs that are listed in the Interactive RadioEpidemiological Program (IREP) but without unique DCFs in ICRP Publication 34 (1982) were selected as described in ORAUT-OTIB-0006 or are footnoted in the organ dose tables.

Table 3-3 lists the organ dose equivalents for PA and LAT chest X-rays for 1960 through 1988. Table 3-4 lists the organ dose equivalents for AP and LAT lumbar spine X-rays for 1960 through 1985. Skin dose equivalents for all skin areas were determined according to the method that is described in ORAUT-OTIB-0006 (ORAUT 2011a) and listed in Tables 3-5 and 3-6.

Table 3-3. Organ dose equivalents (rem) from PA and LAT chest X-rays at NTS, 1960 through 1995.

Organ	Chest projection	1960–1966 Standard X-ray machine	1967–1972 GE machine[a]	1973–1985 Equipment unknown[a]	1986–1995 GE machine[b]
Thyroid	PA	3.44E-03[c]	1.84E-03	1.84E-03	3.22E-04
	LAT	(d)	(d)	1.33E-02	2.33E-03
Eye/brain	PA	4.79E-04[e]	1.84E-03	1.84E-03	3.22E-04
	LAT	(d)	(d)	1.33E-02	2.33E-03
Ovaries	PA	2.62E-03[f]	7.20E-05	7.20E-05	1.26E-05
	LAT	(d)	(d)	9.00E-05	1.58E-05
Liver/gall bladder/ spleen/pancreas	PA	8.09E-03	2.14E-02	2.14E-02	3.75E-03
	LAT	(d)	(d)	2.67E-02	4.67E-03
Urinary bladder/ prostate	PA	2.62E-03	7.20E-05	7.20E-05	1.26E-05
	LAT	(d)	(d)	9.00E-05	1.58E-05
Colon/rectum	PA	2.62E-03	7.20E-05	7.20E-05	1.26E-05
	LAT	(d)	(d)	9.00E-05	1.58E-05
Testes	PA	1.30E-04[f]	4.00E-07	4.00E-07	7.00E-08
	LAT	(d)	(d)	1.00E-05	1.75E-06
Lungs (male)	PA	7.64E-03	1.98E-02	1.98E-02	3.47E-03
	LAT	(d)	(d)	2.36E-02	4.13E-03
Lungs (female)	PA	8.09E-03	2.14E-02	2.14E-02	3.75E-03
	LAT	(d)	(d)	2.67E-02	4.67E-03
Thymus	PA	8.09E-03	2.14E-02	2.14E-02	3.75E-03
	LAT	(d)	(d)	2.67E-02	4.67E-03
Esophagus	PA	8.09E-03	2.14E-02	2.14E-02	3.75E-03
	LAT	(d)	(d)	2.67E-02	4.67E-03
Stomach	PA	8.09E-03	2.14E-02	2.14E-02	3.75E-03
	LAT	(d)	(d)	2.67E-02	4.67E-03
Bone surfaces	PA	8.09E-03	2.14E-02	2.14E-02	3.75E-03
	LAT	(d)	(d)	2.67E-02	4.67E-03
Remainder	PA	8.09E-03	2.14E-02	2.14E-02	3.75E-03
	LAT	(d)	(d)	2.67E-02	4.67E-03

Organ	Chest projection	1960–1966 Standard X-ray machine	1967–1972 GE machine[a]	1973–1985 Equipment unknown[a]	1986–1995 GE machine[b]
Breast	PA	7.30E-04	2.76E-03	2.76E-03	4.83E-04
	LAT	(d)	(d)	2.87E-02	5.02E-03
Uterus	PA	2.35E-03[f]	9.20E-05	9.20E-05	1.61E-05
	LAT	(d)	(d)	9.00E-05	1.58E-05
Bone marrow (male)	PA	1.57E-03	4.68E-03	4.68E-03	8.19E-04
	LAT	(d)	(d)	4.80E-03	8.40E-04
Bone marrow (female)	PA	1.44E-03	4.48E-03	4.48E-03	7.84E-04
	LAT	(d)	(d)	3.80E-03	6.65E-04
Entrance skin[g]	PA	3.01E-02[h]	5.60E-02[h]	5.60E-02[h]	9.80E-03[h]
	LAT	(d)	(d)	1.40E-01[h]	2.45E-02[h]

a. ORAUT-TKBS-0008-3, Rev. 01.
b. Stevenson 1988.
c. DCF for AP cervical spine, corrected with depth dose factor of 0.2 (ORAUT 2011a).
d. Not performed for screening in this period.
e. DCF for PA chest (ORAUT 2011a).
f. DCF for PA abdomen (ORAUT 2011a).
g. Skin dose equivalents for all areas of skin are provided in Table 3-5.
h. Calculated using backscatter factor of 1.32 for HVL of 2.0 mm Al, 1.35 for HVL of 2.5 mm, and 1.4 for HVL of 3.0 mm Al from NCRP Report 102 (NCRP 1997, Table B.8).

Table 3-4. Organ dose equivalents (rem) for lumbar spine projections, 1960 through 1985.[a]

Organ	Projection	1960–1970	1971–1985
Thyroid	AP	2.88E-04	2.73E-04
	LAT	3.79E-05	3.48E-05
Eye/brain	AP	2.88E-04	2.73E-04
	LAT	3.79E-05	3.48E-05
Ovaries	AP	5.60E-01	1.97E-01
	LAT	7.10E-01	1.64E-01
Urinary/bladder/prostate	AP	2.30E-01	1.97E-01
	LAT	1.17E-01	1.64E-01
Colon/rectum	AP	2.30E-01	1.97E-01
	LAT	1.17E-01	1.64E-01
Testes	AP	2.70E-02	3.82E-03
	LAT	5.60E-02	2.78E-03
Lungs (male)	AP	8.93E-02	7.19E-02
	LAT	3.79E-02	4.87E-02
Lungs (female)	AP	8.93E-02	7.19E-02
	LAT	3.79E-02	4.87E-02
Thymus	AP	8.93E-02	7.19E-02
	LAT	3.79E-02	4.87E-02
Esophagus	AP	8.93E-02	7.19E-02
	LAT	3.79E-02	4.87E-02
Stomach	AP	2.30E-01	1.97E-01
	LAT	1.17E-01	1.64E-01
Bone surface	AP	2.30E-01	1.97E-01
	LAT	1.17E-01	1.64E-01
Liver/gall bladder/spleen/pancreas	AP	2.30E-01	1.97E-01
	LAT	1.17E-01	1.64E-01
Remainder organs	AP	2.30E-01	1.97E-01
	LAT	1.17E-01	1.64E-01
Breast	AP	4.78E-03	9.56E-04
	LAT	7.58E-03	2.07E-03
Uterus	AP	3.12E-01	2.61E-01

Organ	Projection	1960–1970	1971–1985
	LAT	7.58E-02	1.08E-01
Bone marrow (male)	AP	3.46E-02	3.37E-02
	LAT	5.69E-02	7.66E-02
Bone marrow (female)	AP	3.46E-02	3.37E-02
	LAT	5.69E-02	7.66E-02
Entrance skin[b]	AP	1.90E+00	1.23E+00
	LAT	5.00E+00	4.70E+00

a. ORAUT-OTIB-0006 (ORAUT 2011a).
b. Skin dose equivalents for all areas of skin are provided in Table 3-6.

Table 3-5. Skin dose equivalents (rem) from chest projections, 1960 through 1995.[a]

Area of skin	PA chest 1960–1966	PA chest 1967–1972	PA chest 1973–1985	LAT chest 1973–1985	PA chest 1986–1988	LAT chest 1986–1995
Right front shoulder	7.E-04	1.4E-03	1.4E-03	1.40E-01	2.E-04	2.45E-02
Right back shoulder	3.01E-02	5.60E-02	5.60E-02	1.40E-01	9.8E-03	2.45E-02
Left front shoulder	7.E-04	1.4E-03	1.4E-03	7.E-04	2.E-04	1.E-04
Left back shoulder	3.01E-02	5.60E-02	5.60E-02	7.E-04	9.8E-03	1.E-04
Right upper arm to elbow	3.01E-02	5.6E-03	5.6E-03	1.40E-01	1.E-03	2.45E-02
Left upper arm to elbow	3.01E-02	5.6E-03	5.6E-03	7.E-04	1.E-03	1.E-04
Left hand	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Right hand	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Left elbow, forearm, wrist	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Right elbow, forearm, wrist	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Right side of head including temple and ear	3.0E-03	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Left side of head including temple and ear	3.0E-03	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Front left thigh	7.E-06	2.E-05	2.E-05	2.E-05	3.E-06	4.E-06
Back left thigh	7.E-06	2.E-05	2.E-05	2.E-05	3.E-06	4.E-06
Front right thigh	7.E-06	2.E-05	2.E-05	2.E-05	3.E-06	4.E-06
Back right thigh	7.E-06	2.E-05	2.E-05	2.E-05	3.E-06	4.E-06
Left knee and below	3.E-06	7.E-06	7.E-06	8.E-06	1.E-06	1.E-06
Right knee and below	3.E-06	7.E-06	7.E-06	8.E-06	1.E-06	1.E-06
Left side of face	5.E-04	1.8E-03	1.8E-03	1.40E-02	3.E-04	2.5E-03
Right side of face	5.E-04	1.8E-03	1.8E-03	1.40E-02	3.E-04	2.5E-03
Left side of neck	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Right side of neck	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Back of head	3.0E-03	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Front of neck	5.E-04	1.8E-03	1.8E-03	1.40E-02	3.E-04	2.5E-03
Back of neck	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Front torso: base of neck to end of sternum	7.E-04	1.4E-03	1.4E-03	2.67E-02	2.E-04	4.7E-03
Front torso: end of sternum to lowest rib	7.E-04	1.4E-03	1.4E-03	2.67E-02	2.E-04	4.7E-03
Front torso: lowest rib to iliac crest	7.E-04	1.E-04	1.E-04	2.7E-03	2.E-05	5.E-04
Front torso: iliac crest to pubis	7.E-05	1.E-04	1.E-04	2.7E-03	2.E-05	5.E-04
Back torso: base of neck to mid-back	3.01E-02	5.60E-02	5.60E-02	2.67E-02	9.8E-03	4.7E-03
Back torso: mid-back to lowest rib	3.01E-02	5.60E-02	5.60E-02	2.67E-02	9.8E-03	4.7E-03
Back torso: lowest rib to iliac crest	3.01E-02	5.6E-03	5.6E-03	2.7E-03	1.E-03	5.E-04

Area of skin	PA chest 1960–1966	PA chest 1967–1972	PA chest 1973–1985	LAT chest 1973–1985	PA chest 1986–1988	LAT chest 1986–1995
Back torso: buttocks (Iliac crest and below)	3.0E-03	5.6E-03	5.6E-03	2.7E-03	1.E-03	5.E-04
Right torso: base of neck to end of sternum	3.01E-02	5.60E-02	5.60E-02	1.40E-01	9.8E-03	2.45E-02
Right torso: end of sternum to lowest rib	3.01E-02	5.60E-02	5.60E-02	1.40E-01	9.8E-03	2.45E-02
Right torso: lowest rib to iliac crest	3.01E-02	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Right torso: iliac crest to pubis (right hip)	3.0E-03	5.6E-03	5.6E-03	1.40E-02	1.E-03	2.5E-03
Left torso: base of neck to end of sternum	3.01E-02	5.60E-02	5.60E-02	7.E-04	9.8E-03	1.E-04
Left torso: end of sternum to lowest rib	3.01E-02	5.60E-02	5.60E-02	7.E-04	9.8E-03	1.E-04
Left torso: lowest rib to iliac crest	3.01E-02	5.6E-03	5.6E-03	7.E-05	1.E-03	1.E-05
Left torso: iliac crest to pubis (left hip)	3.0E-03	5.6E-03	5.6E-03	7.E-05	1.E-03	1.E-05

a. Values less than 0.1 mrem shown to one significant digit.

Table 3-6. Skin dose equivalents (rem) from lumbar spine projections, 1960 through 1985.[a]

Area of skin	AP lumbar spine 1960–1970	LAT lumbar spine 1960–1970	AP lumbar spine 1971–1985	LAT lumbar spine 1971–1985
Right front shoulder	1.90E-01	5.00E-01	1.23E-01	4.70E-01
Right back shoulder	3.6E-03	5.00E-01	2.7E-03	4.70E-01
Left front shoulder	1.90E-01	1.9E-03	1.23E-01	2.1E-03
Left back shoulder	3.6E-03	1.9E-03	2.7E-03	2.1E-03
Right upper arm to elbow	1.90E-01	5.00E-01	1.23E-01	4.70E-01
Left upper arm to elbow	1.90E-01	1.9E-03	1.23E-01	2.1E-03
Left hand	1.90E+00	1.9E-03	1.23E-01	2.1E-03
Right hand	1.90E+00	5.00E-01	1.23E-01	4.70E-01
Left elbow, forearm, wrist	1.90E+00	1.9E-03	1.23E-01	2.1E-03
Right elbow, forearm, wrist	1.90E+00	5.00E-01	1.23E-01	4.70E-01
Right side of head including temple and ear	3.E-04	4.E-05	3.E-04	3.E-05
Left side of head including temple and ear	3.E-04	4.E-05	3.E-04	3.E-05
Front left thigh	1.90E-01	1.9E-03	1.23E-01	2.1E-03
Back left thigh	3.6E-03	1.9E-03	2.7E-03	2.1E-03
Front right thigh	1.90E-01	5.00E-01	1.23E-01	4.70E-01
Back right thigh	3.6E-03	5.00E-01	2.7E-03	4.70E-01
Left knee and below	4.E-04	4.E-04	3.E-04	5.E-04
Right knee and below	4.E-04	4.E-04	3.E-04	5.E-04
Left side of face	3.E-04	4.E-05	3.E-04	3.E-05
Right side of face	3.E-04	4.E-05	3.E-04	3.E-05
Left side of neck	3.E-04	4.E-05	3.E-04	3.E-05
Right side of neck	3.E-04	4.E-05	3.E-04	3.E-05
Back of head	3.E-04	4.E-05	3.E-04	3.E-05
Front of neck	3.E-04	4.E-05	3.E-04	3.E-05
Back of neck	3.E-04	4.E-05	3.E-04	3.E-05
Front torso: base of neck to end of sternum	1.90E-01	3.79E-02	1.23E-01	4.87E-02

Area of skin	AP lumbar spine 1960–1970	LAT lumbar spine 1960–1970	AP lumbar spine 1971–1985	LAT lumbar spine 1971–1985
Front torso: end of sternum to lowest rib	1.90E+00	3.79E-02	1.23E+00	4.87E-02
Front torso: lowest rib to iliac crest	1.90E+00	3.79E-02	1.23E+00	4.87E-02
Front torso: iliac crest to pubis	1.90E+00	3.79E-02	1.23E+00	4.87E-02
Back torso: base of neck to mid-back	3.6E-03	3.79E-02	2.7E-03	4.87E-02
Back torso: mid-back to lowest rib	3.64E-02	3.79E-02	2.68E-02	4.87E-02
Back torso: lowest rib to iliac crest	3.64E-02	3.79E-02	2.68E-02	4.87E-02
Back torso: buttocks (Iliac crest and below)	3.64E-02	3.79E-02	2.68E-02	4.87E-02
Right torso: base of neck to end of sternum	1.90E-01	5.00E-01	1.23E-01	4.70E-01
Right torso: end of sternum to lowest rib	1.90E+00	5.00E+00	1.23E+00	4.70E+00
Right torso: lowest rib to iliac crest	1.90E+00	5.00E+00	1.23E+00	4.70E+00
Right torso: iliac crest to pubis (right hip)	1.90E+00	5.00E+00	1.23E+00	4.70E+00
Left torso: base of neck to end of sternum	1.90E-01	1.9E-03	1.23E-01	2.1E-03
Left torso: end of sternum to lowest rib	1.90E+00	1.90E-02	1.23E+00	2.06E-02
Left torso: lowest rib to iliac crest	1.90E+00	1.90E-02	1.23E+00	2.06E-02
Left torso: iliac crest to pubis (left hip)	1.90E+00	1.90E-02	1.23E+00	2.06E-02

a. Values less than 0.1 mrem shown to one significant digit.

3.4 UNCERTAINTY

ORAUT-OTIB-0006 (ORAUT 2011a) lists the major sources of uncertainty in X-ray output intensity and subsequent effect on dose to the worker. The five sources of uncertainty are:

1. X-ray beam measurement error (±2%),
2. Variation in peak kilovoltage (±9%),
3. Variation in X-ray beam current (±5%),
4. Variation in exposure time (±25%), and
5. Variation in source-to-skin distance (SSD) as a result of worker size (±10%).

The 10% uncertainty in output intensity as a result of worker size was based on an inverse square correction of output intensity changes from differences from the standard chest thickness of ±7.5 cm.

These uncertainties are assumed to be random; therefore, the combined statistical uncertainty was calculated as the square root of the sum of the squares of all the uncertainties, which is ±28.9%. Rounding this up to ±30% provides an adequate and suitably conservative indication of uncertainty. Therefore, for a derived dose equivalent to an individual organ, a total combined standard uncertainty of ±30% can be assumed. Dose reconstructors should, therefore, input the organ dose equivalent as the mean of a normal distribution with a standard uncertainty of ±30%.

3.5 ATTRIBUTIONS AND ANNOTATIONS

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

[1] Thomas, E. Oak Ridge Associated Universities (ORAU) Team. Principal Medical Dosimetrist. March 2012.
A random sample of claim file records was reviewed to assess the types and frequency of screening X-rays that were performed at NTS.

[2] Thomas, E. Oak Ridge Associated Universities (ORAU) Team. Principal Medical Dosimetrist. June 2012. A complete review of X-ray records (N=119) in claims with start dates before 1960 (N= 474) show that only 8 had X-rays before 1960, 6 of these showed that the X-rays were taken off-site, 2 were uncertain as to where they were taken because NTS extracted the information, but none appear to have been taken at Mercury; none had the “Medical Department, Mercury, Nevada” stamp on them.

REFERENCES

DeMarre, M., 2012a, "RE: Nevada Test Site Request (NTS FY12-001)," e-mail to D. G. Morris (Oak Ridge Associated Universities Team), National Security Technologies, Las Vegas, Nevada, March 13. [SRDB Ref ID: 112131, p. 1]

DeMarre, M., 2012b, "RE: Additional Questions (X-Ray Issue at NTS)," e-mail to D. G. Morris (Oak Ridge Associated Universities Team), National Security Technologies, Las Vegas, Nevada, March 15. [SRDB Ref ID: 112140]

DeMarre, M., 2012c, "RE: Additional X-Ray Related Questions (NTS) Related to Request NTS-FY12-001," e-mail to D. G. Morris (Oak Ridge Associated Universities Team), National Security Technologies, Las Vegas, Nevada, March 14. [SRDB Ref ID: 112248]

DHEW (U.S. Department of Health, Education, and Welfare), 1970, *Radiological Health Handbook, Revised Edition*, Public Health Service, Rockville, Maryland, January. [SRDB Ref ID: 75017]

Kathren, R. L., and V. E. Shockley, 2004, "Personal Communications with ME DeMarre re Medical X-Rays at NTS," memorandum to file, Oak Ridge Associated Universities, Oak Ridge, Tennessee, August 30. [SRDB Ref ID: 13367]

Geiger, E. L., A. N. Tschaeche, and F. W. Wilcox, 1960, *Nevada Test Site Medical X-Ray Equipment, A Preliminary Hazards Evaluation*, RRS-60-10, Reynolds Electrical & Engineering Company, Las Vegas, Nevada, May. [SRDB Ref ID: 13365]

Goldman, L.W., and Beech, S., 1979, *Analysis of Retakes: Understanding, Managing, and Using an Analysis of Retakes Program for Quality Assurance*, DHEW (U.S. Department of Health, Education, and Welfare) Publication (FDA) 79-8097, Public Health Service, Rockville, Maryland, August. [SRDB Ref ID: 38739]

ICRP (International Commission on Radiological Protection), 1982, *Protection of the Patient in Diagnostic Radiology*, Publication 34, Pergamon Press, Oxford, England. [SRDB Ref ID: 76680]

Moon, J. C., 2012, "Request X-ray Surveillance/Testing Information" email to M. DeMarre (National Testing Archive), National Security Technologies, Las Vegas, Nevada, March 15. [SRDB Ref ID: 112245]

NBS (National Bureau of Standards), 1955, *X-Ray Protection, Recommendations of the National Committee on Radiation Protection*, Handbook 60, U.S. Department of Commerce, Washington, D.C., December 1. [SRDB Ref ID: 73173]

NCRP (National Council on Radiation Protection and Measurements), 1997, *Medical X-Ray, Electron Beam and Gamma-Ray Protection for Energies up to 50 MeV (Equipment Design, Performance and Use)*, Report 102, Bethesda, Maryland. [SRDB Ref ID: 32467]

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

ORAUT (Oak Ridge Associated Universities Team), 2009, *INL-ANL-W Occupational Medical Dose*, ORAUT-TKBS-0007-3, Rev. 02, Oak Ridge Associated Universities, Oak Ridge, Tennessee, December 21.

ORAUT (Oak Ridge Associated Universities Team), 2011a, *Dose Reconstruction from Occupational Medical X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 04, Oak Ridge Associated Universities, Oak Ridge, Tennessee, June 20.

ORAUT (Oak Ridge Associated Universities Team), 2011b, *Guidance on Assigning Occupational X-ray Dose Under EEOICPA for X-rays Administered Off-Site*, ORAUT-OTIB-0079, Rev. 00, Oak Ridge, Tennessee, January 3.

ORAUT (Oak Ridge Associated Universities Team), 2011c, *Pinellas Plan – Occupational Medical Dose*, ORAUT-TKBS-0029, Rev. 01, Oak Ridge Associated Universities, Oak Ridge, Tennessee, October 13.

REECo (Reynolds Electrical & Engineering Company), ca. 1975, *Respirator Users Medical Examination Requirements*, Las Vegas, Nevada. [SRDB Ref ID: 16744]

REECo (Reynolds Electrical & Engineering Company), 1986, *Description of the REECo Integrated Medical Program*, Las Vegas, Nevada. [SRDB Ref ID: 112131, pp. 7–9]

Reeves, J. E., 1957, "Test Manager's Standard Operating Procedure for the Nevada Test Organization," memorandum to Distribution, U.S. Atomic Energy Commission, Albuquerque Operations Office, Albuquerque, New Mexico, March 15. [SRDB Ref ID: 7972]

Stevenson, D. A., 1988, untitled letter to S. Anson (Reynolds Electrical & Engineering Company), U.S. Department of Health and Human Services, Food and Drug Administration, San Francisco, California, August 31. [SRDB Ref ID: 112131, p. 5]

Wochos, J.F., Detorie, N.A., and Cameron, J.R., 1979, *Patient Exposure from Diagnostic X-rays: An Analysis of 1972-1975 NEXT Data*, Health Physics 36:127-134. [SRDB Ref ID: 91506]

GLOSSARY

entrance skin exposure (ESE)

Exposure in air, measured in roentgens, at the point where an X-ray beam enters the skin surface (without backscatter).

filtration

The process of filtering an X-ray beam, usually with millimeter thicknesses of aluminum material between the X-ray source and the film that preferentially absorbs photons from the beam. Usually measured in equivalent millimeters of aluminum.

gray (Gy)

The special name for the SI unit of absorbed dose, kerma, and specific energy imparted equal to one (1) joule per kilogram (J/kg) (1 Gy = 1 J/kg = 100 rad).

half-value layer (HVL)

Thickness of a specified substance usually specified in millimeters of aluminum, which, when introduced into the path of a given beam of radiation, reduces the kerma rate by one-half.

Interactive RadioEpidemiological Program (IREP)

Computer program that uses a person's calculated annual organ doses and other information (e.g., gender, age at diagnosis, and age at exposure) to calculate the probability of causation of a specific cancer for a given pattern and level of radiation exposure.

International Commission on Radiological Protection (ICRP)

An independent international scientific body, established to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation.

kerma

Measure in units of absorbed dose (usually grays but sometimes rads) of the energy released by radiation from a given amount of a substance. Kerma is the sum of the initial kinetic energies of all the charged ionizing particles liberated by uncharged ionizing particles (neutrons and photons) per unit mass of a specified material. Free-in-air kerma refers to the amount of radiation at a location before adjustment for any external shielding form structures or terrain. The word derives from <u>k</u>inetic <u>e</u>nergy <u>r</u>eleased per unit <u>ma</u>ss.

National Council on Radiation Protection and Measurements (NCRP)

Private U. S. public service organization chartered by the U.S. Congress to formulate and disseminate information, guidance, and recommendations on radiation protection and measurements.

organ dose

Dose to a given organ from an X-ray procedure.

photofluorography (PFG)

Historical radiographic technique used for chest images for screening a large number of people in a short period. The X-ray image produced on a fluorescent screen was photographed on 4- by 5-inch film. PFG was the primary method of screening large populations for tuberculosis before the advent of nonradiographic screening methods. Also called fluorography or mass miniature radiography. Not to be confused with fluoroscopy.

photon

Basic unit of electromagnetic radiation. Photons are massless “packages” of light energy that range from low-energy microwave photons to high-energy gamma rays. Photons have energies between 10 and 100 kiloelectron-volts. 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.

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.

preemployment X-ray

An X-ray, usually of the chest, taken before hire or assignment to a specific job. The purpose of preplacement X-rays was to screen for active disease, such as tuberculosis.

probability of causation (POC)

For purposes of dose reconstruction for the Energy Employees Occupational Illness Compensation Program Act, the percent likelihood, at the 99th percentile, that a worker incurred a particular cancer from occupational exposure to radiation.

radiograph

Static images produced on radiographic film by gamma rays or X-rays after passing through matter. Some of the rays (photons) can pass through parts of an item, while more opaque parts partially or completely absorb them and thus cast a shadow on the film. In the context of EEOICPA, radiographs are X-ray images of the various parts of the body used to screen for disease.

source-to-skin distance (SSD)

Distance from the X-ray machine target (anode) to the skin of the person being X-rayed. This distance varies with the size of the person being radiographed.

technique factors

Combination of X-ray machine settings (technique factors) used to produce radiographs, which consists of the kilovoltage, tube current (milliamperes), and exposure time (seconds). The last two parameters are often multiplied to yield the electric charge that has crossed the X-ray tube during the exposure in units of milliampere-seconds. Any combination of time and tube current that produces a given product in milliampere-seconds produces the same exposure for a fixed peak kilovoltage.

termination X-ray

X-ray, usually of the chest, taken when an employee separates from the company.

tube current

Average electrical current measured in milliamperes flowing from the cathode to the anode of an X-ray tube during operation of the tube.

X-ray

(1) Ionizing electromagnetic radiation of external nuclear origin, or (2) a radiograph.

X-ray tube

Evacuated electronic tube in which electrons accelerated by an applied voltage to strike an anode or target and produce X-rays.