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Rocky Flats Plant – Occupational Medical Dose

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
02/09/2004	00	New Technical Basis Document for the Rocky Flats Plant – Occupational Medical Dose. First approved issue. Initiated by Robert Meyer.
04/23/2007	01	Approved Revision 01 initiated to revise Table 3.4.2-2 (now Table 3-6), text, and dose estimate tables to be consistent with ORAUT-OTIB-0006 Rev 03 PC-1. Revised Table 3.2-1 (now Table 3-1) and text to specify the inclusion of termination X-rays for the period of 1952-1986. Revised Table 3.4.1-2 (now Table 3-5) per commitment tracking form dated 02/06/2006. Revised to include attribution information per ORAU direction. The Worker Outreach comment from CT-0203 was addressed. Worker outreach comment from the June 23, 2004, meeting of the United Steelworkers of America Local 8031 and Rocky Flats Security Officers Local Union 1 was addressed in Section 3.1. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of document. This revision results in an increase in assigned dose and a PER is required. Training required: As determined by the Task Manager. Initiated by Robert Meyer.
06/27/2017	02	Revision initiated to update occupational medical X-ray doses for PFG, AP and LAT lumbar spine, and AP chest examinations. The AP chest examination dose update is specific to those performed starting June 11, 2001. Skin dose guidance and doses are also included in Attachment 1 of this revision based on information presented in ORAUT-OTIB-0006 Rev 04. Additional information regarding the availability of X-ray inventory sheets starting around February 2009 is included. CLL uncertainty parameters have been included as well. Updated Table A-2 to separate skin dose values for PA chest examinations between 1971 and 2001 into two time periods (1971-1984 and 1985-2001). Corrected transcription errors in Table A-1 of 8 skin doses for LAT exams performed prior through 1970 to correctly reflect values listed in ORAUT-OTIB-0006 Rev 04. Incorporates formal internal review comments. No changes occurred as a result of formal NIOSH review. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Brian P. Martin.
08/19/2019	03	Revision initiated to update occupational medical X-ray doses for AP and LAT lumbar spine in Table 3-7; for PFG, AP, and LAT chest in Table A-1; and AP and LAT lumbar and PA chest in Table A-2 based on information presented in ORAUT-OTIB-0006, Revision 05. Table 3-7 column header dates corrected to read “1951–1970” and “1971–1974”. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Brian P. Martin.

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ACRONYMS AND ABBREVIATIONS

AP	anterior-posterior
AWE	atomic weapons employer
cGy	centigray
CLL	chronic lymphocytic leukemia
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
ENSD	entrance skin dose
EXSD	exit skin dose
Gy	gray
HVL	half-value layer
ICRP	International Commission on Radiological Protection
in.	inch
IREP	Interactive RadioEpidemiological Program
keV	kilo-electron volt
kV	kilovolt
kVp	kilovolts-peak
LAT	lateral
m	meter
mA	milliampere
mAs	milliampere-second
mGy	milligray
mm	millimeter
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
PA	posterior-anterior
PER	program evaluation report
PFG	photofluorography
R	roentgen
RFP	Rocky Flats Plant
RSD	remote skin dose
s	second
SEC	Special Exposure Cohort
SID	source-to-image distance

SRDB Ref ID	Site Research Database Reference Identification (number)
SSD	source-to-skin distance
Sv	sievert
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 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 7384l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), respectively. An AWE facility means "a facility, owned by an atomic weapons employer, that is or was used to process or produce, for use by the United States, material that emitted radiation and was used in the production of an atomic weapon, excluding uranium mining or milling." 42 U.S.C. § 7384l(5). On the other hand, a DOE facility is defined as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the [DOE] (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program);" and with regard to which DOE has or had a proprietary interest, or "entered into a contract with an entity to provide management and operation, management and integration, environmental remediation services, construction, or maintenance services." 42 U.S.C. § 7384l(12). The Department of Energy (DOE) determines whether a site meets the statutory definition of an AWE facility and the Department of Labor (DOL) determines if a site is a DOE facility and, if it is, designates it as such.

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

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

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

3.1.1 Purpose

This technical basis document (TBD) describes the methods for estimating absorbed dose from medical X-ray exposures to Rocky Flats Plant (RFP) workers. All information regarding X-ray examination types/frequencies, machine specific parameters, and relevant doses presented in this document are particular to RFP. Dose calculations are based on information presented in ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures* (ORAUT 2018). Where data are unavailable, assumptions have been made that are favorable to claimants and in line with current guidance (ORAUT 2018).

3.1.2 Scope

Section 3.2 provides background. Section 3.3 provides information on equipment and techniques used at RFP including assumptions necessitated by lack of protocol, measurement, or records data. Section 3.4 provides organ dose estimates for RFP beginning on June 11, 2001. Section 3.5 documents uncertainties. Section 3.6 describes X-ray examination frequency at RFP. Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 3.7.

3.1.3 Special Exposure Cohort

The Secretary of the U.S. Department of Health and Human Services has designated the following class of RFP workers as an addition to the SEC (Sebelius 2013):

> *All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Rocky Flats Plant in Golden, Colorado, from April 1, 1952 through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.*

NIOSH has determined that doses to unmonitored RFP workers from neptunium, thorium, and ^{233}U (and its associated ^{232}U and ^{228}Th progeny) cannot be reconstructed from April 1, 1952, through December 31, 1983, inclusive (NIOSH 2013). The class includes all workers during the SEC period.

Based on the inability to reconstruct unmonitored doses from 1952 through 1983, as described above, all dose reconstructions for monitored workers during the SEC period are considered partial dose reconstructions. If monitoring data are available for workers in the SEC, dose is to be assigned as appropriate based on that data. Unmonitored neutron doses before 1967 have been identified as infeasible and therefore cannot be bounded. It is not feasible to reconstruct unmonitored neutron doses, in a bounding manner, before 1967; therefore, this TBD does not provide dose reconstruction guidance for unmonitored neutron doses before 1967. For all other years, external dose records and/or an unmonitored external dose reconstruction approach are provided. However, such dose reconstructions are still considered partial dose reconstructions because of the determination that exposure to neptunium, thorium, and ^{233}U (and its associated ^{232}U and ^{228}Th progeny) during the SEC period cannot be bounded (NIOSH 2013).

The principal sources of external radiation doses, including medical X-ray dose, for members of the proposed class were evaluated in the NIOSH RFP SEC-00030 Evaluation Report (ER). In SEC-00030, NIOSH concluded that all external dose, except neutrons, could be estimated with sufficient accuracy.

3.2 BACKGROUND

As part of the requirements for employment at RFP, entrance, exit, and periodic physical examinations were performed on all employees. These physical examinations included radiographic examinations of the lungs and, for some employees, the lumbar spine as shown in reviews of claimant records. Diagnostic medical X-rays administered in conjunction with routine or special physical examinations and required for employment are occupational exposures (NIOSH 2007). Only medical exposures that were required as a condition of employment are included; diagnostic and therapeutic procedures that were not required for employment are excluded (e.g., exposures that were received in the treatment of work-related injuries).

Additional information on the assessment and calculation of dose from occupational medical X-rays is given in ORAUT (2018).

3.3 EQUIPMENT AND TECHNIQUES

It was determined after a review of information about specific machines and machine settings used at RFP that it is not possible to calculate machine specific doses for equipment in use before June 11, 2001. Therefore, the information needed to fully develop site-specific organ doses from occupational medical X-rays (i.e., the type of equipment, technique factors, and machine calibrations) is not fully known for years before 2001. Some information has been found regarding equipment types and ratings. Tables 3-1 and 3-2 summarize known information about equipment and techniques. The available data has been used in conjunction with default data (ORAUT 2018), where necessary, to provide estimates of potential exposure

Efforts will continue to find related information for RFP. However, until more accurate records are found, these assumptions provide estimates for medical X-ray exposure that are favorable to claimants.

Table 3-1. Description of X-ray equipment at RFP.

Period	Classification	Equipment	Source
07/1953–08/30/1976	Type IV	Keleket	ORAUT 2003a
09/01/1976–05/28/1987	Type III	Generator unknown; Victoreen R Meter; Bureau of Radiological Health test stand; X-ray timer; aluminum filter set; light meter	ORAUT 2003a
05/29/1987–03/06/2001	Type II	Eureka XMA tube; generator unknown	ORAUT 2003a
06/11/2001–03/31/2005	Type I	Hologic/BXT202W	ORAUT 2003a

Table 3-2. Equipment settings and ratings (ORAUT 2003a).

Period	Machine	View	Current (mA)	Voltage (kVp)	Exposure time (s)
1952–1974	Type IV[b]	Lumbar AP[a]	200	140	Unknown
1952–1974	Type IV[b]	Lumbar LAT[a]	200	140	Unknown
07/1953–08/30/1976	Type IV[b]	Chest PA	200	140	Unknown
09/01/1976–05/28/1987	Type III[b]	Chest PA	Unknown	80	Unknown
05/29/1987–03/06/2001	Type II[b]	Chest PA	360	130	Unknown
06/11/2001–03/31/2005	Type I[c]	Chest PA	300	125	0.013

a. Assume performed from 1952 to 1974.
b. Maximum machine ratings (ORAUT 2003a); data not used to calculate doses, but are presented for informational purposes.
c. The maximum kVp, mA, and exposure time are listed as provided by Senior X-ray Technician (Various 2003–2005). This results in a maximum mAs of 3.9.

The onsite medical office ceased operation in mid-March of 2005 and the X-ray unit was sold the following month (Various 2003–2005). As such, it is assumed all occupational medical doses for RFP

employees ended that same month, and therefore, no occupational medical doses should be assigned for employment starting April 1, 2005. Historical review of claimant records indicate lumbar spine examinations were discontinued in 1975, and therefore, are only assumed for 1952 through 1974.

Based on X-ray inventory records provided after February 2009, photofluorography (PFG) examinations were performed at RFP. A note in the available documentation indicates that the fluoroscope was removed from the plant in 1968 (ORAUT 2003a). There is not enough information about the machine and settings to derive site-specific doses; therefore, default PFG doses from ORAUT (2018) are assigned.

As no information was available regarding examination film/projection sizes, default assumptions (ORAUT 2018) are used for all RFP medical X-ray examinations.

3.4 ORGAN DOSE ESTIMATES

This section provides organ dose estimates. Section 3.4.1 describes the method used to estimate the doses post-June 11, 2001, when there is enough information to calculate site-specific organ doses. As discussed in Section 3.3, not all equipment or settings information about what was in use at RFP before 2001 has been located. Therefore, site-specific organ doses cannot be calculated for the time period prior to June 11, 2001, and default dose values are assigned from ORAUT (2018).

Section 3.4.2 will discuss the assignment of organ dose for both periods: prior to June 11, 2001 when default OTIB-0006 doses are assigned and post-June 11, 2001 when site-specific organ doses are assigned.

3.4.1 Parameters and Estimation Method

The ICRP (1982) guidance uses the following parameters to estimate air kerma and absorbed dose:

1. Source-to-image distance (SID) in centimeters,
2. Total filtration (millimeters of aluminum),
3. Estimate of person thickness for AP and LAT projections, and
4. Machine settings (mAs, kVp, film size, and single- or three-phase).

Because measured air kerma data are unavailable for the RFP, air kerma rates are estimated from Figure A.1 in ICRP Publication 34, *Protection of the Patient in Diagnostic Radiology* (ICRP 1982), using average voltage from Table 3-2 and total filtration. SID, filtration, and chest thickness parameters are based on information presented in ORAUT (2018) while machine settings are specific to Hologic X-ray unit on site with a 125 kVp and 300 mA technique (Various 2003–2005). The calculated HVL of 3.57 mm Al at 80 kVp was rounded to 4.0 mm Al as a claimant favorable assumption (Various 2003–2005). These values differ from previously assumed machine parameters as recently obtained site specific information (Various 2003–2005) indicates these are the maximum settings that were used for the Hologic X-ray unit.

Since Figure A.1 is for single-phase machines, the estimate from this graph is multiplied by 1.8 to account for the fact that the RFP machine is three-phase. Therefore, the air kerma in air rate in units of mGy per mAs estimated from Figure A.1 is 0.090 mGy per mAs. This rate is then used to estimate the air kerma at 1m by multiplying the air kerma in air rate by the current and exposure time for the RFP machine. Next, the air kerma at the source-to-skin distance (SSD) is calculated. The SSD

assumed for the PA chest projection that was performed at RFP is 154 cm and is the default SSD for this projection from ORAUT (2018). This yields an air kerma of 0.266 mGy at the SSD.

Tables A.2 through A.9 of ICRP (1982) are then used to estimate organ dose directly. The tables list organ doses in milligray normalized to an air kerma of 1 Gy in air at the skin, as a function of half-value layers (HVLs) in millimeters of aluminum. Entrance skin dose (ENSD) was calculated by multiplying the air kerma at SSD by the appropriate backscatter factor from Table B-8 of National Council on Radiation Protection and Measurements Report 102 (NCRP 1989). The backscatter factor used for these RFP-specific calculations is 1.42 and was chosen based on the HVL and field size assumptions for Rocky Flats Plant.

The ICRP tables that were used to estimate absorbed dose do not include all organs in the Interactive RadioEpidemiological Program (IREP). For those organs in IREP but not specifically identified in the ICRP tables, the dose conversion coefficient that is anatomically closest to the IREP-specified organs can be used to estimate dose. ORAUT (2018) provides the analogues for IREP organs and specific organ analogues according to International Classification of Diseases code in Table 5-1 and Attachment A of the document. Dose conversion factors used for RFP are consistent with those found in Table B-3 of ORAUT (2018).

3.4.2 Organ Dose Estimates

At this time, there is insufficient information to calculate site-specific organ doses for chest X-rays before 2001, all lumbar spine X-rays, and all PFG examinations at RFP. The organ doses that are presented in this document will be revised if additional site-specific information is found that allows for a more refined calculation of organ doses.

The use of proxy data for the earlier periods is based on the idea that RFP, like other DOE sites, used the standard radiological procedure of the time [1]. Organ dose estimates for occupational X-rays from June 11, 2001, to March 31, 2005 are provided in Table 3-4.

All doses and dose views for RFP X-ray examinations before June 11, 2001, should be assigned based on those presented in ORAUT (2018). PFG was used at RFP, but no information about protocol has been found. Lacking information about PFG at RFP, default dose estimates from ORAUT (2018) are assigned.

Doses starting June 11, 2001, to March 31, 2005 are based on known machine settings and information such as HVL supplied by former medical workers and quality assurance documents (Various 2003–2005). Skin doses for RFP X-ray examinations from June 11, 2001 and later were determined based on the guidance in ORAUT-PROC-0061, *Occupational Medical X-Ray Dose Reconstruction for DOE Sites* (ORAUT 2017), and Table B-8 of ORAUT (2018). Skin dose guidance for this time period is provided in Attachment A.

Entrance skin dose (ENSD), exit skin dose (EXSD), and remote skin dose (RSD) are all described in Section 6.0 through 6.4 of ORAUT (2018). This information regarding calculation of dose was used to calculate the doses in Attachment A for post June 11, 2001 examinations. In calculating EXSD, an Absorption Factor of 32.66 was assumed based on information presented Table B-7 of NCRP (1989) while an average depth dose of 0.193 was used in calculating RSD based on Table B-8 of NCRP (1989). Both factors are based on assumed patient thickness of 24 cm. The average depth dose is calculated at the midpoint of the body, at a depth of 12 cm.

Where information is unavailable or not known regarding the energy spectra of examinations, values should be conservatively assumed to be in the 30- to 250-keV photon range in accordance with ORAUT (2018).

The tissue at risk for chronic lymphocytic leukemia is the B-lymphocytes. The dose to the B-lymphocytes was determined using the method in ORAUT-RPRT-0064, *Medical Dose to the B-Lymphocytes* (ORAUT 2014), site-specific information, and ICRP Publication 34 DCFs (ICRP 1982). Table 3-4 provides dose distributions and statistical parameters for input into IREP for determining dose to the B-lymphocytes as provided in Attachment B of ORAUT (2014).

Table 3-3. Organ dose estimates for PA chest beginning June 11, 2001, to March 31, 2005 (Various 2003–2005).

HVL = 4.0 mm Al, air kerma at skin = 0.266 mGy[a]

Organ	mGy	rem
Thyroid	2.08E–02	2.08E–03
Eye/brain	2.08E–02	2.08E–03
Ovaries	1.39E–03	1.39E–04
Liver/gall bladder/spleen	1.80E–01	1.80E–02
Urinary bladder	1.39E–03	1.39E–04
Colon/rectum	1.39E–03	1.39E–04
Testes	2.66E–06	2.66E–07
Lung (male)	1.67E–01	1.67E–02
Lung (female)	1.80E–01	1.80E–02
Thymus	1.80E–01	1.80E–02
Esophagus	1.80E–01	1.80E–02
Stomach	1.80E–01	1.80E–02
Bone surfaces	1.80E–01	1.80E–02
Remainder	1.80E–01	1.80E–02
Female breast	3.09E–02	3.09E–03
Uterus	1.39E–03	1.39E–04
Bone marrow (male)	4.74E–02	4.74E–03
Bone marrow (female)	4.58E–02	4.58E–03
Entrance skin	3.78E–01	3.78E–02

a. HVL determined rounded up based on calculation of total filtration 3.57 mm Al (Various 2003-2005).

Table 3-4. IREP dose distributions and statistical parameters for the dose to the B-lymphocytes.

Projection	Year	Distribution	Parameters 1, 2, and 3
PFG	1952–1968	Use OTIB-0006 PFG	Use OTIB-0006 PFG
PA chest	1952–1970	Use OTIB-0006 through 1970	Use OTIB-0006 through 1970
AP LS	1952–1970	Use OTIB-0006 through 1970	Use OTIB-0006 through 1970
LAT LS	1952–1970	Use OTIB-0006 through 1970	Use OTIB-0006 through 1970
AP LS	1971–1974	Use OTIB-0006 after 1970	Use OTIB-0006 after 1970
LAT LS	1971–1974	Use OTIB-0006 after 1970	Use OTIB-0006 after 1970
PA chest	1971–1985	Use OTIB-0006 1971–1985	Use OTIB-0006 1971–1985
PA chest	1986–June 10, 2001	Use OTIB-0006 1986–present	Use OTIB-0006 1986–present
PA chest	June 11, 2001–March 31, 2005	Weibull3	2.124902, 0.003815, and –7.1779E–07

3.5 UNCERTAINTIES

Although many factors can introduce uncertainty and error into X-ray dose estimates, five factors contribute the most: measurement error, variation in peak kilovoltage, variation in beam current, variation in exposure time, and SSD. Film speed, use of screens, or use of grids do not affect the beam output intensity. The lack of records for these measurements for most years at RFP introduces a large uncertainty into the dose estimates that cannot be readily quantified, although there is no apparent reason to believe that practices at RFP were different from those at other facilities or from

recommended standards of the medical community at the time. Therefore, use of default estimates and reliance on information from other DOE sites when site-specific information was unavailable is likely to closely approximate X-ray performance at RFP. For the pre-June 11, 2001, time period, when default doses are assigned, default uncertainty assumptions will be used (normal distribution, standard deviation of 30%), as discussed in ORAUT (2018). Because the approach used for calculating the RFP-specific doses for the time period post-June 11, 2001, relied on the approaches and defaults from OTIB-0006, the default uncertainty from ORAUT (2018) is also assumed (normal distribution, standard deviations of 30%).

3.6 EXAMINATION FREQUENCY

Site-specific information indicates the first X-ray unit was not on site until July of 1953. Since construction was started in 1952 and employees were present, assume X-ray examinations started in 1952 (claimant-favorable assumption). The onsite medical office ceased operation in mid-March of 2005 and the X-ray unit was sold the following month (Various 2003–2005). As such, no occupational medical doses should be assigned for employment after March 30, 2005.

The frequency of X-ray examinations varied significantly for RFP workers. Before approximately 1986, many production workers received single-view chest X-rays on a nearly annual basis. A protocol for frequency of a single posterior-anterior (PA) view chest X-ray as a function of job category was not fully established until approximately 1986. Therefore, beginning in 1986, the frequency of routine chest X-rays varied widely depending on job description (EG&G 1991). The RFP default frequency assumption is an annual chest projection, with PFG being used prior to 1969 and PA chest after 1969.

Between 1952 and 1974, it is assumed all workers received spinal X-rays during their initial employment (prehire) medical examination, as this was typical across the complex. Termination chest X-rays are assumed for the period from 1952 to 2005 because they were common at other DOE sites.

Beginning with DR claims received in February of 2009, the RFP records group committed to providing an X-ray "inventory" with new EEOICPA claim responses. X-ray records provided to NIOSH before February 2009 might be incomplete. For claims initially received prior to February 2009, dose reconstructors should request an X-ray inventory spreadsheet when a best estimate is required. The RFP records group reviews documented films and provides a list (i.e., inventory) of all X-ray examinations. Film records are provided in a spreadsheet, which contains the claimant's name, NIOSH ID number, examination type, date of examination, and number of X-rays taken. The dose reconstructor should review all relevant claim information in order to determine if X-ray examinations provided in the film inventory are those required for employment and not related to work related injuries. If no X-ray records are located in this review, RFP does not provide an inventory, but completes the records request form with this information. Justification for including, or not including, assumed annual X-ray examinations should be provided by the dose reconstructor.

In the absence of an RFP-provided X-ray film inventory or claim-specific information, assume the RFP default examination frequencies given in Table 3-5.

Table 3-5. Default X-ray examination frequencies for all workers.[a]

Period	Frequency	View
1952–1968	Annual and termination	Chest (PFG)
1952–1974	Once	Lumbar (AP and LAT)
1969–2005	Annual and termination	Chest (PA)

a. Default frequencies provide overestimating assumptions for the assignment of RFP occupational medical dose in the absence of an RFP X-ray inventory collected after January 2009.

3.7 ATTRIBUTIONS AND ANNOTATIONS

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

[1] Lopez, Theresa. Oak Ridge Associated Universities (ORAU) Team. Senior Toxicologist. July 2006.
In the absence of data or protocols, assumptions that needed to be made were favorable to claimants.

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GLOSSARY

exposure
In this document, measure of the ionization produced by X- and gamma-ray photons in air in units of roentgens.

gray (Gy)
International System unit of absorbed radiation dose, which is the amount of energy from any type of ionizing radiation deposited in any medium; 1 gray equals 1 joule per kilogram or 100 rads.

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 from structures or terrain. The word derives from kinetic energy released per unit mass.

lumbosacral spine
Region of the spine including the five lumbar vertebrae (lower back) and the five fused sacral vertebrae (posterior wall of the pelvis).

radiation
Subatomic particles and electromagnetic rays (photons) with kinetic energy that interact with matter through various mechanisms that involve energy transfer.

rem
Traditional unit of radiation dose equivalent that indicates the biological damage caused by radiation equivalent to that caused by 1 rad of high-penetration X-rays multiplied by a quality factor. The sievert is the International System unit; 1 rem equals 0.01 sievert. The word derives from roentgen equivalent in man; rem is also the plural.

roentgen (R)
Unit of photon (gamma or X-ray) exposure for which the resultant ionization liberates a positive or negative charge equal to 2.58×10^{-4} coulombs per kilogram (or 1 electrostatic unit of electricity per cubic centimeter) of dry air at 0 degrees Celsius and standard atmospheric pressure. An exposure of 1 roentgen is approximately equivalent to an absorbed dose of 1 rad in soft tissue for higher energy photons (generally greater than 100 kiloelectron-volts).

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

skin dose
See *shallow dose equivalent*.

sievert (Sv)
International System unit for dose equivalent, which indicates the biological damage caused by radiation. The unit is the radiation value in gray (equal to 1 joule per kilogram) multiplied by a weighting factor for the type of radiation and a weighting factor for the tissue; 1 sievert equals 100 rem.

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
SKIN VIEW GUIDANCE AND DOSE TABLES

Table A-1. Skin dose guidance and doses PA chest (rem), June 11, 2001, to March 31, 2005.[a]

Area of skin	Basis for PA chest	PA chest dose
R front shoulder	EXSD	1.29E–03
R back shoulder	ENSD	3.78E–02
L front shoulder	EXSD	1.29E–03
L back shoulder	ENSD	3.78E–02
R upper arm to elbow	10% ENSD	3.78E–03
L upper arm to elbow	10% ENSD	3.78E–03
L hand	10% ENSD	3.78E–03
R hand	10% ENSD	3.78E–03
L elbow, forearm, wrist	10% ENSD	3.78E–03
R elbow, forearm, wrist	10% ENSD	3.78E–03
R side of head (including temple and ear)	10% ENSD	3.78E–03
L side of head (including temple and ear)	10% ENSD	3.78E–03
Front left thigh	RSD (0.52m)	1.49E–05
Back left thigh	RSD (0.52m)	1.49E–05
Front right thigh	RSD (0.52m)	1.49E–05
Back right thigh	RSD (0.52m)	1.49E–05
L knee and below	RSD (0.86m)	5.43E–06
R knee and below	RSD (0.86m)	5.43E–06
L side of face	Eye/brain	2.08E–03
R side of face	Eye/brain	2.08E–03
L side of neck	10% ENSD	3.78E–03
R side of neck	10% ENSD	3.78E–03
Back of head	10% ENSD	3.78E–03
Front of neck	Thyroid	2.08E–03
Back of neck	10% ENSD	3.78E–03
Front torso: base of neck to end of sternum	EXSD	1.29E–03
Front torso: end of sternum to lowest rib	EXSD	1.29E–03
Front torso: lowest rib to iliac crest	10% EXSD	1.29E–04
Front torso: iliac crest to pubis	10% EXSD	1.29E–04
Back torso: base of neck to mid-back	ENSD	3.78E–02
Back torso: mid-back to lowest rib	ENSD	3.78E–02
Back torso: lowest rib to iliac crest	10% ENSD	3.78E–03
Back torso: buttocks (Iliac crest and below)	10% ENSD	3.78E–03
Right torso: base of neck to end of sternum	ENSD	3.78E–02
Right torso: end of sternum to lowest rib	ENSD	3.78E–02
Right torso: lowest rib to iliac crest	10% ENSD	3.78E–03
Right torso: iliac crest to pubis (R hip)	10% ENSD	3.78E–03
Left torso: base of neck to end of sternum	ENSD	3.78E–02
Left torso: end of sternum to lowest rib	ENSD	3.78E–02
Left torso: lowest rib to iliac crest	10% ENSD	3.78E–03
Left torso: iliac crest to pubis (L hip)	10% ENSD	3.78E–03

a. ENSD = entrance skin dose; EXSD = exit skin dose; RSD = remote skin dose.