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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
02/05/2004	00	New technical basis document for the Paducah Gaseous Diffusion Plant – Occupational Medical Dose. First approved issue. Initiated by Jay J. Maisler.
09/26/2006	01	Revised as a result of biennial review. Approved Revision 01. Constitutes a total rewrite of the document. Incorporates internal formal review comments. Incorporates NIOSH formal review comments. This revision results in a reduction in assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Daniel S. Mantooth.
06/18/2007	02	Approved revision initiated to add Attribution and Annotations Section. Constitutes a total rewrite of the document. Incorporates formal internal and NIOSH review comments. This revision results in no change to the assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Daniel S. Mantooth.
08/23/2012	03	Revision initiated to add assignment of dose from lumbar spine X-rays. Incorporated all site specific information found into dose assessments. Added skin doses from all procedures and periods. Added ORAUT-OTIB-0079 Rev 00 reference. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Jodie L. Phillips.

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AP	anterior-posterior
cGy	centigray
cm	centimeter
DCF	dose conversion factor
DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ENSD	entrance skin dose
EXSD	exit skin dose
GE	General Electric Corporation
Gy	gray
HVL	half-value layer
ICRP	International Commission on Radiological Protection
in.	inch
IREP	Interactive RadioEpidemiological Program
kVp	peak kilovoltage
LAT	lateral (X-ray projection)
mAs	milliampere second
mm	millimeter
mR	milliroentgen
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
OBL	oblique
PA	posterior-anterior
PGDP	Paducah Gaseous Diffusion Plant
POC	probability of causation
RAO	right anterior oblique
RSD	remote skin dose
s	second
SRDB	Site Research Database
SSD	source-to-skin distance
TBD	technical basis document
U.S.C.	United States Code
yr	year
§	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 historic 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 42 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

The purpose of this technical basis document is to describe the occupational medical X-ray screening program and practices at the Paducah Gaseous Diffusion Plant (PGDP). This document discusses historical and current practices in relation to the evaluation of dose from medical X-ray procedures for PGDP workers. Dose reconstructors will use this information as needed to assign medical X-ray doses to workers' EEOICPA claims at PGDP.

3.1.2 Scope

The NIOSH Dose Reconstruction Project requires assessment of doses from medical X-rays that were performed for screening and required as a condition of employment. This TBD contains tables of organ dose equivalents (including skin) that result from chest and lumbar spine procedures performed for screening at PGDP. The tables are the result of an assessment of the incident air kerma at the source-to-skin distance (SSD), based on specific operating parameters for the facility insofar as these are known.

3.2 EXAMINATION FREQUENCIES

The PGDP occupational medicine program required preemployment, periodic, and termination screening chest X-ray examinations (Union Carbide 1958, p. 50; Ely et al. 1957, p.11). The chest examinations usually consisted of one posterior-anterior (PA) in the early years, and both a PA and a lateral (LAT) starting in the mid-1970s and continuing into the 1980s and 1990s (Turner 2003). While there are some LAT chest projections in the claim file records before the mid-1970s, they were much more commonly performed after that time. Dose reconstructors should include the dose from LAT chest projections if they appear in the claim file records. If the records state "PA chest", only dose from the PA chest should be assigned. If the records state "Chest", the dose reconstructor should assign dose from the PA only from 1951 through 1973, and dose from both the PA and LAT chest from 1974 to the present.

A few oblique (OBL) chest X-rays appear in the claim file records for asbestos workers. Because the OBL chest projection can be useful in the diagnosis of asbestosis (ORAUT 2011a), an occupational disease, dose from this projection should be included if it appears in the claim file records.

About half the claim file records include lumbar spine X-rays that can be reasonably assumed to have been performed for screening; in other words, they do not appear to have been performed for job-related injuries. However, no historical information has been found about lumbar spine X-rays at Paducah. Because they appear quite frequently in the claim file records, it will be assumed that lumbar spine examinations were performed for screening on some workers. It will also be assumed that the lumbar spine examination consisted of two projections, AP and LAT. Dose reconstructors should include dose from lumbar spine X-rays only if they appear in the claim file records, and only through 1979.

Table 3-1 lists default chest examination frequencies for PGDP employees for dose reconstructors to use in the absence of claim file records.

Table 3-1. Frequency of chest X-ray examinations.

Period	Employees	Frequency	Projections
1951–1973	All	Every 2 yr[a]	PA only
1974–present[b]	Nonsmokers	Every 5 yr[c]	PA and LAT
	Smokers under age 40	Every 5 yr[c]	PA and LAT
	Smokers age 40 and older	Every 3 yr[c]	PA and LAT
1986–present	Asbestos workers	Every 2 yr[c]	PA and LAT
1974–present	All workers if smoking history or asbestos exposure is unknown.	Every 2 yr[a]	PA and LAT

a. Based on average interval between chest X-rays in claim file records.
b. Ex-smokers are considered smokers for 10 years after quitting.
c. From Turner (2003).

3.3 EQUIPMENT AND TECHNIQUES

3.3.1 Photofluorography

A review of a sample of claim file records does not indicate PFG was prevalent, although a "photoroentgen" chest X-ray (PFG) taken in 1954 was found during the review. No historical information has been located to indicate use of PFG at Paducah. Ely et al. (1957, p. 11) specifically mentions the taking of "chest X-rays on 14 in. × 17 in. film," and that "this is the best practice for reducing exposure." Dose reconstructors should include dose from PFG procedures if they are indicated in the claim file records, using the organ doses from ORAUT-OTIB-0006 (ORAUT 2011a). Because PFG does not appear to be prevalent at PGDP, it should not be assumed in the absence of records.

3.3.2 Chest Radiography – 1951–1974

A General Electric (GE) machine was used from the start of PGDP operations in 1951 through 1974 (Turner 2003). However, no historical information has been found about this machine, or the technique factors that might have been used during this period. Therefore, the organ doses for this period come from ORAUT-OTIB-0006 (ORAUT 2011a), and are reproduced in the organ dose tables for convenience.

3.3.3 Chest Radiography – 1975–1995

In 1975, the GE machine was replaced by a Picker unit (Collins 1988), which was used through 1995. The same X-ray technician has operated the X-ray unit at PGDP from November 1974 to 2003. He was interviewed in 2003, and provided technique factors for chest X-rays for males and females of various builds such as small, medium, and large (Turner 2003). The technique factors for the medium-sized male of 95 kVp, 16 mAs (for the PA chest) and 95 kVp and 64 mAs (for the LAT chest) were used in the determination of the incident air kerma for this period in this TBD.

Food and Drug Administration personnel surveyed the Picker machine in 1988, and measured the half-value layer (HVL), which was 3.0 mm Al at 80 kVp (Collins 1988). According to NCRP Report 102, the HVL would be approximately 3.2 mm Al at the 95 kVp used for chest X-rays, which implies a total filtration in the machine of 3.5 mm Al eq. (NCRP 1997, Table B-2). An HVL of 3.5 mm Al is assumed for the dose calculations in this TBD.

The tabulated values of average air kerma rates in NCRP Report 102 assume a total filtration of 2.5 mm Al eq. (NCRP 1997, Table B-3). From the HVL measurement, it appears the Picker machine probably had 3.5 mm Al eq. total filtration; the average air kerma rate of 0.2 cGy/100 mAs at 95 kVp was corrected to reflect an additional millimeter of aluminum total filtration using the equation in ORAUT-OTIB-0006 (ORAUT 2011a, p. 9). The incident air kerma rate used to calculate organ doses

for the PA chest, after correcting for additional filtration, the actual mAs used for chest X-rays at Paducah, and the SSD, is 2.99×10^{-2} cGy. The incident air kerma rate for the LAT chest of 1.39×10^{-1} cGy was calculated in the same way, but using the 64 mAs reportedly used for the LAT chest, and using the SSD for the LAT chest.

3.3.4 Chest Radiography – 1996–Present

The present PGDP X-ray equipment has been in operation since January 1996 and consists of a single-phase XMA machine (Turner 2003). Gregory (2003) surveyed this equipment and measured an HVL of 3.85 mm of Al at 100 kVp. Gregory reported the technique factors for PA chest of 90 kVp and 15 mAs, with a measured exposure of 19 mR at 183 cm.

The tabulated values of average air kerma rates in NCRP Report 102 assume a total filtration of 2.5 mm Al eq. (NCRP 1997, Table B-3). From the HVL measurement, it appears the XMA machine probably has 3.5 mm Al eq. total filtration; the average air kerma rate of 0.18 cGy/100 mAs at 90 kVp was corrected to reflect an additional millimeter of aluminum total filtration using the equation in ORAUT-OTIB-0006 (ORAUT 2011a, p. 9). The incident air kerma rate used to calculate organ doses for the PA chest, after correcting for additional filtration, the actual mAs used for the PA chest, and the SSD, is 2.52×10^{-2} cGy. A calculation of the incident air kerma using the 19-mR measured exposure at 183 cm and converting from exposure in air to air kerma and SSD yields a comparable but slightly lower result.

The incident air kerma for the LAT chest of 6.31×10^{-2} cGy was calculated by multiplying the incident air kerma for the PA chest by 2.5 (ORAUT 2011a), because Gregory (2003) did not report technique factors for the LAT chest projection.

3.3.5 Lumbar Spine Radiography – 1951–1974

While no historical evidence exists that lumbar spine X-rays were performed for screening at PGDP, about half the claim file records in the 1950s, 1960s, and 1970s contain lumbar spine X-rays. They appear frequently enough to consider them as a screening examination for some workers.

There is no evidence of technique factors or machine measurements for the 1952–1974 period, so organ doses from the lumbar spine examinations come from ORAUT-OTIB-0006 (ORAUT 2011a). The lumbar spine examination is assumed to consist of an anterior-posterior (AP) and LAT lumbar spine projection. Poor collimation will be assumed through 1974 to coincide with the change of equipment at PGDP in 1975, even though ORAUT-OTIB-0006 assumes good collimation starting in 1970.

Dose reconstructors should assign dose from lumbar spine examinations only if they appear in the claim file records. Lumbar spine examinations should not be assumed to have been performed for screening if the records are not available, because they clearly were not performed on all workers.

3.3.6 Lumbar Spine Radiography – 1975–1979

There is no evidence of technique factors or machine measurements for the 1975–1979 period, so organ doses from the lumbar spine examination come from ORAUT-OTIB-0006 (ORAUT 2011a). The lumbar spine examination is assumed to consist of an AP and LAT lumbar spine projection.

While there are some lumbar spine measurements and technique factors reported in Collins (1988) and Gregory (2003), these are later than the period of frequent lumbar spine examinations in the claim file records. Dose reconstructors should assign dose from lumbar spine examinations only if

they appear in the claim file records, and only through 1979. In 1980 and later, the lumbar spine examinations that appear in the records were probably not performed for screening.

Table 3-2 summarizes the technical parameters pertinent to dose reconstruction for Paducah.

Table 3-2. Technical parameters pertinent to dose reconstruction.

Period	Projection	kVp	HVL(mm Al)	Incident air kerma (cGy)
1951 – 1974	PA chest	--	2.5[a]	0.20[a]
	LAT chest[b]	--	2.5[a]	0.50[a]
	AP lumbar spine	--	2.0[a]	1.44[a]
	LAT lumbar spine	--	2.0[a]	3.79[a]
1975 – 1995	PA chest	95[c]	3.5[d]	2.99E-02[e]
	LAT chest	95[c]	3.5[d]	1.39E-01[e]
	AP lumbar spine	--	2.5[a]	0.91[a]
	LAT lumbar spine	--	2.5[a]	3.48[a]
1996–present	PA chest	90[f]	3.5[f]	2.52E-02[e]
	LAT chest	90[f]	3.5[f]	6.31E-02[e]

a. From ORAUT-OTIB-0006 (ORAU 2011a).
b. Assign dose only if recorded in claim file records for this period.
c. From Turner (2003).
d. From Collins (1988).
e. Calculated as described in the text.
f. From Gregory (2003).

Regular repeat/retake analyses for the X-ray department have been performed for a number of years. The actual repeat rate is not known. There is no indication that the repeat rate has been of any significance (Turner 2003).

3.4 ORGAN DOSE CALCULATIONS

Organ doses for PFG, PA and LAT chest X-rays, and AP and LAT lumbar spine X-rays were determined based on the method described in ORAUT-OTIB-0006 (ORAUT 2011a) and dose conversion factors in International Commission on Radiological Protection (ICRP) Publication 34 (ICRP 1982), which provides tables of average absorbed dose (in milligrays) 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). These 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 RadioEpidemiology Program (IREP) but without unique DCFs in ICRP Publication 34 (ICRP 1982) were selected as described in ORAUT-OTIB-0006 or are footnoted in the organ dose tables. Air kerma was obtained from Table 3-2.

Table 3-3 lists the organ doses from chest X-rays for all periods. Table 3-4 lists the organ doses from lumbar spine X-rays for all periods. Skin doses for all skin areas were determined according to the method described in ORAUT-OTIB-0006 (ORAUT 2011a) and are listed in Tables 3-5 through 3-8.

3.5 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 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 of 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%.

Table 3-3. Organ dose equivalents (rem) for chest projections for all periods.

Organ	Projection	PFG, 1951–1957[a]	14- × 17-in., 1951–1974[b]	14- × 17-in., 1975–1995	14- × 17-in., 1996–present
Thyroid	PA	3.94E–01	3.48E–02	1.85E–03	1.56E-03
	LAT/OBL	--[c]	6.85E–02	2.09E–02	9.52E-03
Eye/brain	PA	7.25E–02	6.40E–03	1.85E–03	1.56E-03
	LAT/OBL	--	6.85E–02	2.09E–02	9.52E-03
Ovaries	PA	2.50E–02	2.50E–02	9.57E–05	8.07E-05
	LAT/OBL	--	1.30E–02	2.22E–04	1.01E-04
Urinary/bladder/prostate	PA	2.50E–02	2.50E–02	9.57E–05	8.07E-05
	LAT/OBL	--	1.30E–02	2.22E–04	1.01E-04
Colon/rectum	PA	2.50E–02	2.50E–02	9.57E–05	8.07E-05
	LAT/OBL	--	1.30E–02	2.22E–04	1.01E-04
Testes	PA	5.00E–03	5.00E–03	2.99E–07	2.52E-07
	LAT/OBL	--	2.50E–03	1.39E–05	6.31E-06
Lungs (male)	PA	9.50E–01	8.38E–02	1.69E–02	1.43E-02
	LAT/OBL	--	9.65E–02	3.82E–02	1.74E-02
Lungs (female)	PA	1.02E+00	9.02E–02	1.82E–02	1.54E-02
	LAT/OBL	--	1.10E–01	4.30E–02	1.96E-02
Thymus	PA	1.02E+00	9.02E–02	1.82E–02	1.54E-02
	LAT/OBL	--	1.10E–01	4.30E–02	1.96E-02
Esophagus	PA	1.02E+00	9.02E–02	1.82E–02	1.54E-02
	LAT/OBL	--	1.10E–01	4.30E–02	1.96E-02
Stomach	PA	1.02E+00	9.02E–02	1.82E–02	1.54E-02
	LAT/OBL	--	1.10E–01	4.30E–02	1.96E-02
Bone surface	PA	1.02E+00	9.02E–02	1.82E–02	1.54E-02
	LAT/OBL	--	1.10E–01	4.30E–02	1.96E-02
Liver/gall bladder/ spleen/pancreas	PA	1.02E+00	9.02E–02	1.82E–02	1.54E-02
	LAT/OBL	--	1.10E–01	4.30E–02	1.96E-02
Remainder organs	PA	1.02E+00	9.02E–02	1.82E–02	1.54E-02
	LAT/OBL	--	1.10E–01	4.30E–02	1.96E-02
Breast	PA	1.11E–01	9.80E–03	2.72E–03	2.30E-03
	LAT/OBL	--	1.28E–01	4.38E–02	1.99E-02
Uterus	PA	2.50E–02	2.50E–02	8.79E–05	7.57E-05
	LAT/OBL	--	1.30E–02	1.94E–04	8.83E-05
Bone marrow (male)	PA	2.09E–01	1.84E–02	4.37E–03	3.68E-03
	LAT/OBL	--	1.85E–02	8.45E–03	3.85E-03
Bone marrow (female)	PA	1.95E–01	1.72E–02	4.22E–03	3.56E-03
	LAT/OBL	--	1.45E–02	6.65E–03	3.03E-03
Entrance skin[d]	PA	3.06E+00	2.70E–01	4.19E–02	3.53E-02
	LAT/OBL	--	6.75E–01	1.94E–01	8.83E-02

a. Doses for PFG are from ORAUT-OTIB-0006 (ORAUT 2011a) and assumed to be stereo views.

b. Doses before 1975 are based on values in ORAUT-OTIB-0006 (ORAUT 2011a).
c. -- = not applicable.
d. Entrance skin dose (ENSD) is determined by multiplying the incident air kerma by the backscatter factors of 1.35 and 1.4 for HVL of 2.5 and 3.5 mm Al, respectively, from NCRP Report 102 (NCRP 1997, Table B-8). Skin doses for all areas of skin are provided in Tables 3-5 to 3-8 below.

Table 3-4. Organ dose equivalents (rem) for lumbar spine projections for all periods.

Organ	AP lumbar spine projection, 1951–1974[a]	LAT lumbar spine projection, 1951–1974[a]	AP lumbar spine projection, 1975–1980[a]	LAT lumbar spine projection, 1975–1980[a]
Thyroid	2.88E–04	3.79E–05	2.73E–04	3.48E–05
Eye/brain	2.88E–04	3.79E–05	2.73E–04	3.48E–05
Ovaries	5.60E–01	7.10E–01	1.97E–01	1.64E–01
Urinary/bladder/prostate	2.30E–01	1.17E–01	1.97E–01	1.64E–01
Colon/rectum	2.30E–01	1.17E–01	1.97E–01	1.64E–01
Testes	2.70E–02	5.60E–02	3.82E–03	2.78E–03
Lungs male	8.93E–02	3.79E–02	7.19E–02	4.87E–02
Lungs female	8.93E–02	3.79E–02	7.19E–02	4.87E–02
Thymus	8.93E–02	3.79E–02	7.19E–02	4.87E–02
Esophagus	8.93E–02	3.79E–02	7.19E–02	4.87E–02
Stomach	2.30E–01	1.17E–01	1.97E–01	1.64E–01
Bone surfaces	2.30E–01	1.17E–01	1.97E–01	1.64E–01
Liver/gall bladder/spleen/pancreas	2.30E–01	1.17E–01	1.97E–01	1.64E–01
Remainder	2.30E–01	1.17E–01	1.97E–01	1.64E–01
Breast	4.78E–03[b]	7.58E–03[b]	9.56E–04[b]	2.07E–03[b]
Uterus	3.12E–01	7.58E–02	2.61E–01	1.08E–01
Bone marrow male	3.46E–02	5.69E–02	3.37E–02	7.66E–02
Bone marrow female	3.46E–02	5.69E–02	3.37E–02	7.66E–02
Entrance skin	1.90E+00	5.00E+00	1.20E+00	4.59E+00

a. From ORAUT-OTIB-0006 (ORAUT 2011a).
b. Using method described in ORAUT-OTIB-0006 (ORAUT 2011a).

Table 3-5. Skin dose guidance and skin dose equivalents (rem) for chest projections, 1951 – 1974.

Area of skin	PFG 1951–1957		PA chest 1951–1974		LAT chest 1951–1974		RAO chest 1951–1974	
	Guidance	Dose	Guidance	Dose	Guidance	Dose	Guidance	Dose
Right front shoulder	EXSD	6.67E–02	EXSD	5.9E–03	ENSD	6.75E–01	EXSD	3.0E–03
Right back shoulder	ENSD	3.06E+00	ENSD	2.70E–01	ENSD	6.75E–01	ENSD	6.75E–01
Left front shoulder	EXSD	6.67E–02	EXSD	5.9E–03	EXSD	3.0E–03	EXSD	3.0E–03
Left back shoulder	ENSD	3.06E+00	ENSD	2.70E–01	EXSD	3.0E–03	ENSD	6.75E–01
Right upper arm to elbow	10% ENSD	3.06E–01	ENSD	2.70E–01	ENSD	6.75E–01	ENSD	6.75E–01
Left upper arm to elbow	10% ENSD	3.06E–01	ENSD	2.70E–01	EXSD	3.0E–03	ENSD	6.75E–01
Left hand	ENSD	3.06E+00	ENSD	2.70E–01	10% ENSD	6.75E–02	10% ENSD	6.75E–02
Right hand	ENSD	3.06E+00	ENSD	2.70E–01	10% ENSD	6.75E–02	10% ENSD	6.75E–02
Left elbow, forearm, wrist	10% ENSD	3.06E–01	ENSD	2.70E–01	10% ENSD	6.75E–02	10% ENSD	6.75E–02
Right elbow, forearm, wrist	10% ENSD	3.06E–01	ENSD	2.70E–01	10% ENSD	6.75E–02	10% ENSD	6.75E–02
Right side of head (including ear and temple)	10% ENSD	3.06E–01	10% ENSD	2.70E–02	Eye/brain	6.85E–02	10% EXSD	3.E–04
Left side of head (including ear and temple)	10% ENSD	3.06E–01	10% ENSD	2.70E–02	Eye/brain	6.85E–02	10% ENSD	6.75E–02
Front left thigh	RSD (0.52 m)	9.E–04	RSD (0.52 m)	8.E–05	RSD (0.52 m)	9.E–05	RSD (0.52 m)	9.E–05
Back left thigh	RSD (0.52 m)	9.E–04	RSD (0.52 m)	8.E–05	RSD (0.52 m)	9.E–05	RSD (0.52 m)	9.E–05
Front right thigh	RSD (0.52 m)	9.E–04	RSD (0.52 m)	8.E–05	RSD (0.52 m)	9.E–05	RSD (0.52 m)	9.E–05
Back right thigh	RSD (0.52 m)	9.E–04	RSD (0.52 m)	8.E–05	RSD (0.52 m)	9.E–05	RSD (0.52 m)	9.E–05
Left knee and below	RSD (0.86 m)	3.E–04	RSD (0.86 m)	3.E–05	RSD (0.86 m)	3.E–05	RSD (0.86 m)	3.E–05
Right knee and below	RSD (0.86 m)	3.E–04	RSD (0.86 m)	3.E–05	RSD (0.86 m)	3.E–05	RSD (0.86 m)	3.E–05
Left side of face	Eye/brain	7.25E–02	Eye/brain	6.4E–03	Eye/brain	6.85E–02	ENSD	6.75E–01
Right side of face	Eye/brain	7.25E–02	Eye/brain	6.4E–03	Eye/brain	6.85E–02	EXSD	3.0E–03
Left side of neck	10% ENSD	3.06E–01	ENSD	2.70E–01	Eye/brain	6.85E–02	ENSD	6.75E–01
Right side of neck	10% ENSD	3.06E–01	ENSD	2.70E–01	Eye/brain	6.85E–02	EXSD	3.0E–03
Back of head	10% ENSD	3.06E–01	10% ENSD	2.70E–02	Eye/brain	6.85E–02	10% ENSD	6.75E–02
Front of neck	Eye/brain	7.25E–02	Eye/brain	6.4E–03	Eye/brain	6.85E–02	Eye/Brain	6.85E–02
Back of neck	10% ENSD	3.06E–01	ENSD	2.70E–01	Eye/brain	6.85E–02	ENSD	6.75E–01
Front torso: base of neck to end of sternum	EXSD	6.67E–02	EXSD	5.9E–03	Lung	1.10E–01	EXSD	3.0E–03
Front torso: end of sternum to lowest rib	EXSD	6.67E–02	EXSD	5.9E–03	Lung	1.10E–01	EXSD	3.0E–03
Front torso: lowest rib to iliac crest	EXSD	6.67E–02	EXSD	5.9E–03	Lung	1.10E–01	EXSD	3.0E–03
Front torso: iliac crest to pubis	10% EXSD	6.7E–03	10% EXSD	6.E–04	10% lung	1.10E–02	10% EXSD	3.E–04
Back torso: base of neck to mid–back	ENSD	3.06E+00	ENSD	2.70E–01	Lung	1.10E–01	ENSD	6.75E–01
Back torso: mid–back to lowest rib	ENSD	3.06E+00	ENSD	2.70E–01	Lung	1.10E–01	ENSD	6.75E–01

Area of skin	PFG 1951–1957		PA chest 1951–1974		LAT chest 1951–1974		RAO chest 1951–1974	
	Guidance	Dose	Guidance	Dose	Guidance	Dose	Guidance	Dose
Back torso: lowest rib to iliac crest	ENSD	3.06E+00	ENSD	2.70E–01	Lung	1.10E–01	ENSD	6.75E–01
Back torso: buttocks (Iliac crest and below)	10% ENSD	3.06E–01	10% ENSD	2.70E–02	10% Lung	1.10E–02	10% ENSD	6.75E–02
Right torso: base of neck to end of sternum	ENSD	3.06E+00	ENSD	2.70E–01	ENSD	6.75E–01	EXSD	3.0E–03
Right torso: end of sternum to lowest rib	ENSD	3.06E+00	ENSD	2.70E–01	ENSD	6.75E–01	EXSD	3.0E–03
Right torso: lowest rib to iliac crest	ENSD	3.06E+00	ENSD	2.70E–01	ENSD	6.75E–01	EXSD	3.0E–03
Right torso: iliac crest to pubis (right hip)	10% ENSD	3.06E–01	10% ENSD	2.70E–02	10% ENSD	6.75E–02	10% EXSD	3.E–04
Left torso: base of neck to end of sternum	ENSD	3.06E+00	ENSD	2.70E–01	EXSD	3.0E–03	ENSD	6.75E–01
Left torso: end of sternum to lowest rib	ENSD	3.06E+00	ENSD	2.70E–01	EXSD	3.0E–03	ENSD	6.75E–01
Left torso: lowest rib to iliac crest	ENSD	3.06E+00	ENSD	2.70E–01	EXSD	3.0E–03	ENSD	6.75E–01
Left torso: iliac crest to pubis (left hip)	10% ENSD	3.06E–01	10% ENSD	2.70E–02	10% EXSD	3.E–04	10% ENSD	6.75E–02

Table 3-6. Skin dose guidance and skin dose equivalents (rem) for chest projections, 1975 – 1995.

Area of skin	PA chest, 1975–1995		LAT chest, 1975–1995		RAO chest, 1975–1995	
	Guidance	Dose	Guidance	Dose	Guidance	Dose
Right front shoulder	EXSD	1.2E-03	ENSD	1.94E-01	EXSD	1.2E-03
Right back shoulder	ENSD	4.19E-02	ENSD	1.94E-01	ENSD	1.94E-01
Left front shoulder	EXSD	1.2E-03	EXSD	1.2E-03	EXSD	1.2E-03
Left back shoulder	ENSD	4.19E-02	EXSD	1.2E-03	ENSD	1.94E-01
Right upper arm to elbow	10% ENSD	4.2E-03	ENSD	1.94E-01	10% ENSD	1.94E-02
Left upper arm to elbow	10% ENSD	4.2E-03	EXSD	1.2E-03	10% ENSD	1.94E-02
Left hand	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Right hand	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Left elbow, forearm, wrist	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Right elbow, forearm, wrist	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Right side of head (including ear and temple)	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% EXSD	1.E-04
Left side of head (including ear and temple)	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Front left thigh	RSD (0.52 m)	2.E-05	RSD (0.52 m)	4.E-05	RSD (0.52 m)	4.E-05
Back left thigh	RSD (0.52 m)	2.E-05	RSD (0.52 m)	4.E-05	RSD (0.52 m)	4.E-05
Front right thigh	RSD (0.52 m)	2.E-05	RSD (0.52 m)	4.E-05	RSD (0.52 m)	4.E-05
Back right thigh	RSD (0.52 m)	2.E-05	RSD (0.52 m)	4.E-05	RSD (0.52 m)	4.E-05

Area of skin	PA chest, 1975–1995		LAT chest, 1975–1995		RAO chest, 1975–1995	
	Guidance	Dose	Guidance	Dose	Guidance	Dose
Left knee and below	RSD (0.86 m)	6.E-06	RSD (0.86 m)	1.E-05	RSD (0.86 m)	1.E-05
Right knee and below	RSD (0.86 m)	6.E-06	RSD (0.86 m)	1.E-05	RSD (0.86 m)	1.E-05
Left side of face	Eye/brain	1.9E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Right side of face	Eye/brain	1.9E-03	10% ENSD	1.94E-02	10% EXSD	1.E-04
Left side of neck	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Right side of neck	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% EXSD	1.E-04
Back of head	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Front of neck	Thyroid	1.9E-03	10% ENSD	1.94E-02	Thyroid	2.09E-02
Back of neck	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% ENSD	1.94E-02
Front torso: base of neck to end of sternum	EXSD	1.2E-03	Lung	4.30E-02	EXSD	1.2E-03
Front torso: end of sternum to lowest rib	EXSD	1.2E-03	Lung	4.30E-02	EXSD	1.2E-03
Front torso: lowest rib to iliac crest	10% EXSD	1.E-04	10% Lung	4.3E-03	10% EXSD	1.E-04
Front torso: iliac crest to pubis	10% EXSD	1.E-04	10% Lung	4.3E-03	10% EXSD	1.E-04
Back torso: base of neck to mid–back	ENSD	4.19E-02	Lung	4.30E-02	ENSD	1.94E-01
Back torso: mid–back to lowest rib	ENSD	4.19E-02	Lung	4.30E-02	ENSD	1.94E-01
Back torso: lowest rib to iliac crest	10% ENSD	4.2E-03	10% lung	4.3E-03	10% ENSD	1.94E-02
Back torso: buttocks (Iliac crest and below)	10% ENSD	4.2E-03	10% lung	4.3E-03	10% ENSD	1.94E-02
Right torso: base of neck to end of sternum	ENSD	4.19E-02	ENSD	1.94E-01	EXSD	1.2E-03
Right torso: end of sternum to lowest rib	ENSD	4.19E-02	ENSD	1.94E-01	EXSD	1.2E-03
Right torso: lowest rib to iliac crest	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% EXSD	1.E-04
Right torso: iliac crest to pubis (right hip)	10% ENSD	4.2E-03	10% ENSD	1.94E-02	10% EXSD	1.E-04
Left torso: base of neck to end of sternum	ENSD	4.19E-02	EXSD	1.2E-03	ENSD	1.94E-01
Left torso: end of sternum to lowest rib	ENSD	4.19E-02	EXSD	1.2E-03	ENSD	1.94E-01
Left torso: lowest rib to iliac crest	10% ENSD	4.2E-03	10% EXSD	1.E-04	10% ENSD	1.94E-02
Left torso: iliac crest to pubis (left hip)	10% ENSD	4.2E-03	10% EXSD	1.E-04	10% ENSD	1.94E-02

Table 3-7. Skin dose guidance and skin dose equivalents (rem) for chest projections, 1996 – present.

Area of skin	PA chest, 1996–present		LAT chest, 1996–present		RAO chest, 1996–present	
	Guidance	Dose	Guidance	Dose	Guidance	Dose
Right front shoulder	EXSD	1.0E-03	ENSD	8.83E-02	EXSD	5.E-04
Right back shoulder	ENSD	3.53E-02	ENSD	8.83E-02	ENSD	8.83E-02
Left front shoulder	EXSD	1.0E-03	EXSD	5.E-04	EXSD	5.E-04
Left back shoulder	ENSD	3.53E-02	EXSD	5.E-04	ENSD	8.83E-02
Right upper arm to elbow	10% ENSD	3.5E-03	ENSD	8.83E-02	10% ENSD	8.8E-03
Left upper arm to elbow	10% ENSD	3.5E-03	EXSD	5.E-04	10% ENSD	8.8E-03
Left hand	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Right hand	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Left elbow, forearm, wrist	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Right elbow, forearm, wrist	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03

Area of skin	PA chest, 1996–present		LAT chest, 1996–present		RAO chest, 1996–present	
	Guidance	Dose	Guidance	Dose	Guidance	Dose
Right side of head (including ear and temple)	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% EXSD	5.E-05
Left side of head (including ear and temple)	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Front left thigh	RSD (0.52 m)	1.E-05	RSD (0.52 m)	2.E-05	RSD (0.52 m)	2.E-05
Back left thigh	RSD (0.52 m)	1.E-05	RSD (0.52 m)	2.E-05	RSD (0.52 m)	2.E-05
Front right thigh	RSD (0.52 m)	1.E-05	RSD (0.52 m)	2.E-05	RSD (0.52 m)	2.E-05
Back right thigh	RSD (0.52 m)	1.E-05	RSD (0.52 m)	2.E-05	RSD (0.52 m)	2.E-05
Left knee and below	RSD (0.86 m)	5.E-06	RSD (0.86 m)	6.E-06	RSD (0.86 m)	6.E-06
Right knee and below	RSD (0.86 m)	5.E-06	RSD (0.86 m)	6.E-06	RSD (0.86 m)	6.E-06
Left side of face	Eye/brain	1.56E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Right side of face	Eye/brain	1.56E-03	10% ENSD	8.8E-03	10% EXSD	5.E-05
Left side of neck	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Right side of neck	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% EXSD	5.E-05
Back of head	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Front of neck	Thyroid	1.56E-03	10% ENSD	8.8E-03	Thyroid	9.5E-03
Back of neck	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% ENSD	8.8E-03
Front torso: base of neck to end of sternum	EXSD	1.0E-03	Lung	1.96E-02	EXSD	5.E-04
Front torso: end of sternum to lowest rib	EXSD	1.0E-03	Lung	1.96E-02	EXSD	5.E-04
Front torso: lowest rib to iliac crest	10% EXSD	1.E-04	10% Lung	2.0E-03	10% EXSD	5.E-05
Front torso: iliac crest to pubis	10% EXSD	1.E-04	10% Lung	2.0E-03	10% EXSD	5.E-05
Back torso: base of neck to mid–back	ENSD	3.53E-02	Lung	1.96E-02	ENSD	8.83E-02
Back torso: mid–back to lowest rib	ENSD	3.53E-02	Lung	1.96E-02	ENSD	8.83E-02
Back torso: lowest rib to iliac crest	10% ENSD	3.5E-03	10% lung	2.0E-03	10% ENSD	8.8E-03
Back torso: buttocks (Iliac crest and below)	10% ENSD	3.5E-03	10% lung	2.0E-03	10% ENSD	8.8E-03
Right torso: base of neck to end of sternum	ENSD	3.53E-02	ENSD	8.83E-02	EXSD	5.E-04
Right torso: end of sternum to lowest rib	ENSD	3.53E-02	ENSD	8.83E-02	EXSD	5.E-04
Right torso: lowest rib to iliac crest	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% EXSD	5.E-05
Right torso: iliac crest to pubis (right hip)	10% ENSD	3.5E-03	10% ENSD	8.8E-03	10% EXSD	5.E-05
Left torso: base of neck to end of sternum	ENSD	3.53E-02	EXSD	5.E-04	ENSD	8.83E-02
Left torso: end of sternum to lowest rib	ENSD	3.53E-02	EXSD	5.E-04	ENSD	8.83E-02
Left torso: lowest rib to iliac crest	10% ENSD	3.5E-03	10% EXSD	5.E-05	10% ENSD	8.8E-03
Left torso: iliac crest to pubis (left hip)	10% ENSD	3.5E-03	10% EXSD	5.E-05	10% ENSD	8.8E-03

Table 3-8. Skin dose guidance and skin dose equivalents (rem) for lumbar spine projections, 1951 – 1979.

Area of skin	AP lumbar spine, 1951–1974		LAT lumbar spine, 1951–1974		AP lumbar spine, 1975–1979		LAT lumbar spine, 1975–1979	
	Guidance	Dose	Guidance	Dose	Guidance	Dose	Guidance	Dose
Right front shoulder	10% ENSD	1.90E-01	10% ENSD	5.00E-01	10% ENSD	1.20E-01	10% ENSD	4.59E-01
Right back shoulder	10% EXSD	3.6E-03	10% ENSD	5.00E-01	10% EXSD	2.6E-03	10% ENSD	4.59E-01
Left front shoulder	10% ENSD	1.90E-01	10% EXSD	1.90E-03	10% ENSD	1.20E-01	10% EXSD	2.0E-03

Area of skin	AP lumbar spine, 1951–1974		LAT lumbar spine, 1951–1974		AP lumbar spine, 1975–1979		LAT lumbar spine, 1975–1979	
	Guidance	Dose	Guidance	Dose	Guidance	Dose	Guidance	Dose
Left back shoulder	10% EXSD	3.6E-03	10% EXSD	1.90E-03	10% EXSD	2.6E-03	10% EXSD	2.0E-03
Right upper arm to elbow	10% ENSD	1.90E-01	10% ENSD	5.00E-01	10% ENSD	1.20E-01	10% ENSD	4.59E-01
Left upper arm to elbow	10% ENSD	1.90E-01	10% EXSD	1.90E-03	10% ENSD	1.20E-01	10% EXSD	2.0E-03
Left hand	ENSD	1.90E+00	10% EXSD	1.90E-03	10% ENSD	1.20E-01	10% EXSD	2.0E-03
Right hand	ENSD	1.90E+00	10% ENSD	5.00E-01	10% ENSD	1.20E-01	10% ENSD	4.59E-01
Left elbow, forearm, wrist	ENSD	1.90E+00	10% EXSD	1.90E-03	10% ENSD	1.20E-01	10% EXSD	2.0E-03
Right elbow, forearm, wrist	ENSD	1.90E+00	10% ENSD	5.00E-01	10% ENSD	1.20E-01	10% ENSD	4.59E-01
Right side of head (including ear and temple)	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Left side of head (including ear and temple)	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Front left thigh	10% ENSD	1.90E-01	10% EXSD	1.90E-03	10% ENSD	1.20E-01	10% EXSD	2.0E-03
Back left thigh	10% EXSD	3.6E-03	10% EXSD	1.90E-03	10% EXSD	2.6E-03	10% EXSD	2.0E-03
Front right thigh	10% ENSD	1.90E-01	10% ENSD	5.00E-01	10% ENSD	1.20E-01	10% ENSD	4.59E-01
Back right thigh	10% EXSD	3.6E-03	10% ENSD	5.00E-01	10% EXSD	2.6E-03	10% ENSD	4.59E-01
Left knee and below	RSD (0.60 m)	4.E-04	RSD (0.60 m)	4.E-04	RSD (0.60 m)	3.E-04	RSD (0.60 m)	5.E-04
Right knee and below	RSD (0.60 m)	4.E-04	RSD (0.60 m)	4.E-04	RSD (0.60 m)	3.E-04	RSD (0.60 m)	5.E-04
Left side of face	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Right side of face	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Left side of neck	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Right side of neck	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Back of head	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Front of neck	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Back of neck	Eye/brain	3.E-04	Eye/brain	3.E-05	Eye/brain	3.E-04	Eye/brain	3.E-05
Front torso: base of neck to end of sternum	10% ENSD	1.90E-01	Lung	3.79E-02	10% ENSD	1.20E-01	Lung	4.87E-02
Front torso: end of sternum to lowest rib	ENSD	1.90E+00	Lung	3.79E-02	ENSD	1.20E+00	Lung	4.87E-02
Front torso: lowest rib to iliac crest	ENSD	1.90E+00	Lung	3.79E-02	ENSD	1.20E+00	Lung	4.87E-02
Front torso: iliac crest to pubis	ENSD	1.90E+00	Lung	3.79E-02	ENSD	1.20E+00	Lung	4.87E-02
Back torso: base of neck to mid–back	10% EXSD	3.6E-03	Lung	3.79E-02	10% EXSD	2.6E-03	Lung	4.87E-02
Back torso: mid–back to lowest rib	EXSD	3.64E-02	Lung	3.79E-02	EXSD	2.61E-02	Lung	4.87E-02
Back torso: lowest rib to iliac crest	EXSD	3.64E-02	Lung	3.79E-02	EXSD	2.61E-02	Lung	4.87E-02
Back torso: buttocks (Iliac crest and below)	EXSD	3.64E-02	Lung	3.79E-02	EXSD	2.61E-02	Lung	4.87E-02
Right torso: base of neck to end of sternum	10% ENSD	1.90E-01	10% ENSD	5.00E-01	10% ENSD	1.20E-01	10% ENSD	4.59E-01

Area of skin	AP lumbar spine, 1951–1974		LAT lumbar spine, 1951–1974		AP lumbar spine, 1975–1979		LAT lumbar spine, 1975–1979	
	Guidance	Dose	Guidance	Dose	Guidance	Dose	Guidance	Dose
Right torso: end of sternum to lowest rib	ENSD	1.90E+00	ENSD	5.00E+00	ENSD	1.20E+00	ENSD	4.59E+00
Right torso: lowest rib to iliac crest	ENSD	1.90E+00	ENSD	5.00E+00	ENSD	1.20E+00	ENSD	4.59E+00
Right torso: iliac crest to pubis (right hip)	ENSD	1.90E+00	ENSD	5.00E+00	ENSD	1.20E+00	ENSD	4.59E+00
Left torso: base of neck to end of sternum	10% ENSD	1.90E-01	10% EXSD	1.90E-03	10% ENSD	1.20E-01	10% EXSD	2.0E-03
Left torso: end of sternum to lowest rib	ENSD	1.90E+00	EXSD	1.90E-02	ENSD	1.20E+00	EXSD	2.02E-02
Left torso: lowest rib to iliac crest	ENSD	1.90E+00	EXSD	1.90E-02	ENSD	1.20E+00	EXSD	2.02E-02
Left torso: iliac crest to pubis (left hip)	ENSD	1.90E+00	EXSD	1.90E-02	ENSD	1.20E+00	EXSD	2.02E-02

3.6 ATTRIBUTIONS AND ANNOTATIONS

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

REFERENCES

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GLOSSARY

absorbed dose
Amount of energy (ergs or joules) deposited in a substance by ionizing radiation per unit mass (grams or kilograms) of the substance and measured in units of rads or grays. See *dose*.

kilovoltage (kVp)
Electrical potential difference in units of kilovolts between the cathode and the anode in the X-ray generating tube. See *technique*.

backscatter (radiation)
Reflection or refraction of radiation at angles over 90 degrees from its original direction.

beam quality
Empirical measure of the ability of a polyenergetic X-ray beam to penetrate matter affected by the kilovoltage, anode material, voltage waveform, and filtration of an X-ray tube. The half-value layer in millimeters of aluminum is a typical measure of X-ray beam quality for the energy range used in radiography. See *kilovoltage* and *filtration*.

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 roentgens, rads, reps, or grays

dose conversion factor (DCF)
Multiplier for conversion of potential dose to the personal dose equivalent to the organ of interest (e.g., liver or colon). In relation to radiography, ratio of dose equivalent in tissue or organ to incident air kerma at the surface of the skin of the X-rayed person.

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*.

filtration
The process of filtering an X-ray beam, usually with millimeter thicknesses of aluminum material between the X-ray source and the image receptor that preferentially absorbs photons from the beam. Usually measured in equivalent millimeters of aluminum. See *beam quality* and *half-value layer*.

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 Gy equals 1 joule per kilogram or 100 rads.

half-value layer (HVL)
Thickness of a specified substance, usually specified in millimeters of aluminum, that attenuates an X-ray beam to one half the original kerma rate. See *filtration*.

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.

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.

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 Sv equals 100 rem.

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

Combination of X-ray machine settings 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.

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.