Document Title:	Document Number: ORAUT-TKBS-0038-3
Atomics International – Occupational Medical Dose	Revision: 01
	Effective Date: 09/08/2006
	Type of Document: TBD
	Supersedes: Revision 00

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☐ New ☐ Total Rewrite ☒ Revision ☐ Page Change

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
02/03/2006	00	New technical basis document for the Energy Technical Center - Occupational Medical Dose. First approved issue. Initiated by Melton H. Chew.
09/08/2006	01	Revision to change the site name to Atomics International throughout the document in keeping with DOE site naming conventions. Updated required language in Section 3.1. Purpose section (Section 3.2) and Scope section (Section 3.3) were added. Approved Revision 01. No further changes occurred as a result of formal internal review. Incorporates NIOSH formal review comments. Training required: As determined by the Task Manager. Initiated by Melton H. Chew.

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ACRONYMS AND ABBREVIATIONS

AP	anterior-posterior
AI	Atomics International
cGy	centigray
cm	centimeter
DCF	dose conversion factor
DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ESE	entrance skin exposure
ETEC	Energy Technology Center
FDA	Food and Drug Administration
Gy	gray
ICRP	International Commission on Radiological Protection
in.	inch
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron-volt (1,000 electron-volts)
kVp	kilovolts-peak
LAT	lateral
mA	milliampere
mGy	milligray
mm	millimeter
mR	milliroentgen
NIOSH	National Institute for Occupational Safety and Health
PA	posterior-anterior
R	roentgen
sec	second
SID	source-to-image distance
SSD	source-to-skin distance
U.S.C.	United States Code
yr	year

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 the 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) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work.

As noted above, the statute 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 contains an exclusion with respect to the Naval Nuclear Propulsion Program, 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 dosimetry monitoring results are considered valid for use in 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:

[1] The U.S. Department of Labor is ultimately responsible under the EEOICPA for determining the POC.

- Radiation from naturally occurring radon present in conventional structures
- Radiation from diagnostic X-rays received in the treatment of work-related injuries

3.2 PURPOSE

The purpose of this document is to provide a technical basis for evaluation of the occupational medical dose for EEOICPA claimants who were employed at the Atomics International (AI) facility described below.

3.3 SCOPE

The scope of this document is technical data regarding medical X-rays provided to workers as a condition of employment.

The facility, which includes four locations, has been identified in various ways over time. The name Atomics International (AI) is used to represent all of them unless more specific location information is warranted. In that context, AI includes Area IV of the Santa Susana Field Laboratory which has also been known as Nuclear Development Field Laboratory, Liquid Metal Engineering Center, and Energy Technology Engineering Center (ETEC), portions of the Downey facility, the Vanowen Building at the Canoga facility and the De Soto facility.

U.S. Atomic Energy Commission-funded work at the AI facility began in 1948. North American Aviation (NAA) entered into a contract with AEC to conduct nuclear research operations at Area IV and the Downey, Canoga and De Soto sites. At that time, Atomics International, an internal division of NAA, was the company's designated nuclear research and development division. In addition to the employees of the AI division, other employees of NAA who worked at any of the above sites during the AEC contract period are potentially eligible for EEOICPA benefits. AI clinicians prescribed chest X-ray examinations, and in some cases lumbar-spine X-ray examinations. These examinations caused exposure of the lungs and other tissues of the body. Exposure came from the primary X-ray beam and from scattered and leakage radiation.

A review of randomly selected X-ray films dating back to 1956 provided insight into the occupational medical program (Morris 2005a). Individual AI medical charts do not contain X-ray films. If an old film is to be reviewed, the separate X-ray record must be retrieved. Three boxes of archived radiographs representing approximately 300 individuals were reviewed. The boxes contained an envelope for each individual; each envelope contained films spanning many years for that person. The outside of each file storage envelope describes the contents, so it is possible to determine easily the number and kind of radiograph and if the radiograph represents a preemployment examination, periodic reexamination, or a workup following an industrial injury. Radiographs associated with an industrial injury are often identified as "IND"; they are not pertinent to dose reconstruction. Due to corporate reorganizations, the medical records of employees of the AI division of NAA are intermingled with records of another of NAA's internal divisions, Rocketdyne. Employees of Rocketdyne (or any other employee of NAA) are potentially within the scope of EEOICPA if they worked at Area IV or the Downey, Canoga, or De Soto locations during the period when the AEC contract work was performed. In a few cases, a file was annotated "AI" indicating that the person was an Atomics International employee, but in the majority of cases the employment status is not clear. The review of records suggests that:

- About half of the pre-employment examinations included both posterior-anterior (PA) and lateral (LAT) chest views and one or two views (PA and LAT) of the lumbar spine. The remainder included only one PA chest view.

- It was rare for an employee to have annual chest radiographs. Most individuals were never subjected to periodic radiographic reexamination.
- Of those who were reexamined, the typical periodic examination frequency was every 3 to 5 years. About half of those reexamined had one PA chest view. Others had a PA chest and some form of lumbar-spine examination.
- There was no evidence of collimation on the radiographs.
- There was no evidence suggesting the use of photofluorography.
- There was no evidence suggesting the use of fluoroscopy.
- There was no evidence suggesting the use of stereo chest films (same view on two films, slightly displaced).
- All typical views – PA chest, LAT chest, AP lumbar spine, and LAT lumbar spine – commonly found in the records were of the same size: 14 in. by 17 in.
- In a few cases, AP spot and LAT spot lumbar-spine views were observed, and in these cases a smaller film size, 10 in. by 12 in., was common.
- There was no evidence of the use of gonadal shielding in the lumbar-spine views.

Interviews with medical clinic personnel provided information on the equipment and techniques used between 1971 and 1997. By 1998, all radiographic examinations were subcontracted to West Hills Hospital in West Hills, California.

Neutron exposures were not used in occupational medical evaluations and are not part of the occupational medical dose. Similarly, there is no electron dose in the occupational medical dose.

3.4 EXAMINATION FREQUENCY

Existing programmatic documents do not furnish a complete record of the criteria used since 1948 to determine which workers were required to have X-ray examinations or the frequencies of the examinations; nevertheless, some information is available. More importantly, the claimant records provided by DOE are likely to provide information on the radiographs administered to the claimant. This is discussed in section 3.5. Consequently the assumptions provided in this section should be used only for screening or when the claimant record proves to be inadequate.

This summary is based on inspection of records and discussions with current and former staff members of the AI clinic and health physics department.

3.4.1 Pre-employment Examination

3.4.1.1 Prior to 1971

Radiation safety standards dating back to 1966 (Garcia and Alexander 1970) required “pre-exposure examinations” for radiation workers. This examination was to include a chest X-ray. It is reasonable and favorable to the claimant to assume that this practice has been in effect for radiation workers

since the origination of AI. For dose reconstruction this should be interpreted as a pre-employment physical requirement.

Some AI employees who were not radiation workers would not have been covered by this standard. Therefore, some employees might not have received routine preemployment radiographic examinations. A review of AI X-ray film historical records (Morris 2005b) indicated that some employees had preemployment chest and lumbar-spine radiographic examinations. Criteria for the selection of these employees have not been found.

Lacking specific information in a claimant record, a reasonable science-based assumption that gives the benefit of the doubt to claimants is that all employees had a pre-employment examination consisting of:

- PA chest film,
- LAT chest film,
- AP lumbar spine film
- AP lumbar spine spot film.

3.4.1.2 1972 Through 1997

In an interview, the nurse who took many of the radiographs beginning in 1971 stated that preemployment physicals were routinely required of all AI personnel (Chew 2005). Such physicals included a PA chest radiograph. Lumbar-spine radiographs were sometimes required, depending on the job description. No photofluorography was performed. This or a similar examination policy was probably in place prior to 1966 and continued well into the 1990s. Lacking specific information in a claimant record, a reasonable science-based assumption that gives the benefit of the doubt to claimants is that all employees had a pre-employment examination consisting of:

- PA chest film,
- LAT chest film,
- AP lumbar spine film
- AP lumbar spine spot film.

3.4.1.3 After 1997

An interview with the current medical director found that the policy on chest X-rays was in place when he assumed his position in 1995 (Morris 2005a). By 1997, he was actively discouraging chest X-rays. Preemployment lumbar-spine and chest radiography has not occurred as a condition of employment since 1997.

3.4.2 Routine Examination

3.4.2.1 Prior to 1971

Radiation safety standards dating back to 1966 (Garcia and Alexander 1970) required periodic examinations at a minimum frequency of 1 yr for radiation workers. The standards also required termination examinations. The periodic examination included a chest X-ray. The standard does not require lumber spine examination. This or a similar examination policy was probably in place prior to 1966 and continued well into the 1990s. Lacking specific claimant information, assume each radiation worker had a PA and LAT radiographic chest examination every year and one AP lumbar spine with an AP lumbar spine spot film examination every four years.

For personnel who were not radiation workers, no information is available regarding the periodic radiographic examination schedule. A review of AI X-ray film historical records (Morris 2005b) suggests that some workers did undergo periodic surveillance. No clear frequency pattern was discernable, but annual examinations were rare. Among those receiving routine surveillance, three to five years (and often more) elapsed between radiographic examinations. Lacking specific claimant information assume each person who was not a radiation worker had one PA and LAT radiographic chest examination every three years and one AP lumbar spine with an AP lumbar spine spot film examination every three years.

3.4.2.2 1971 Through 1997

The examination frequency and assumptions described for years prior to 1971 applies for the period 1971 through 1997.

3.4.2.3 After 1997

An interview with the current medical director found that the policy on chest X-rays was in place when he assumed his position in 1995 (Morris 2005a). By 1997, he was actively discouraging routine chest X-rays. Routine lumbar-spine and chest radiography has not occurred as a condition of employment since 1997.

Tables 3-2 through 3-5 include information on the routine frequency of chest radiography for periods throughout the AI operating history.

3.5 EQUIPMENT AND TECHNIQUES

3.5.1 Prior to 1971

No specific information is available on diagnostic X-ray equipment and techniques used at AI prior to 1971. An interview with the current AI physician (Morris 2005a), who is familiar with the content of the historical medical files, and an inspection of randomly selected radiographs from this period (Morris 2005b) revealed no evidence that photofluorography, fluoroscopy, or stereo radiography was used at AI.

3.5.1.1 Chest Views

The pre-1971 parameters for PA and LAT chest techniques are assumed values based on data for the "Pre-1970 Period" in Table 3-4 of ORAU (2005). The TBD analysis assumed that the entrance kerma for the PA view is 0.20 cGy. For the LAT view, it assumed the entrance kerma is 0.50 cGy.

3.5.1.2 Lumbar-Spine Views

The pre-1971 default values for AP and LAT lumbar-spine views are assumed based on data for the technique described in Tables 7-7 through 7-10 of ORAU (2005). Table 7-7 lists the anterior-posterior (AP) and AP spot view techniques as 80 kVp, 2.0 mm of Al filtration, 40 mA, for 4 sec at a source-to-image distance (SID) of 99 cm with a 20-cm cone. Two AP views are assumed, the AP and the AP spot. Table 7-7 lists LAT and LAT spot view techniques as 86 kVp, 2.0 mm of Al filtration, 40 mA, for 8 sec at SID of 99 cm with a 20-cm cone. Two LAT views are assumed, the LAT and the LAT spot. Table 7-8 from ORAU (2005) defines the entrance skin exposure (ESE) for both AP lumbar-spine views combined as 4.0 rem. The unit *rem* is typically assumed for dosimetry purposes to be numerically the same as the unit *cGy*, so the ESE is interpreted to be 4 cGy. The ESE for both LAT

lumbar-spine views combined is 10 rem (10 cGy). If it can be shown that only one AP or LAT lumbar-spine view was made, it is reasonable to assume the values can be divided by 2. Table 7-10 in ORAU (2005) lists measured or calculated organ doses that are acceptable default values for pairs of early lumbar-spine exposures.

3.5.2 1971 Through 1997

An interview with the nurse/technician who operated the X-ray machine revealed that prior to or during 1971 a Picker X-ray system, Model 754971, was installed in the AI clinic (Chew 2005). The reported maximum settings on the unit were 125 kVp and 600 mA. The machine filtration is not known so, consistent with the recommendation of ORAU (2005) for machines prior to 1980, this TBD analysis assumed it to be 2.5 mm Al. The equipment was used for PA chest and lumbar-spine projections. The normal technique for chest X-rays was to use 80- to 90-kVp tube potential and 1/60 second exposure time, resulting in a collimated exposure of 200 mAs at a standard SID of 72 in. The routine practice of the clinic was to use lead aprons on patients as practicable and to provide gonadal shielding, in the form of a lead cup, to male patients.

This TBD analysis assumed that the reported value of 200 mAs, is unreasonably high, and is wrong. If the Picker X-ray machine delivered a 200 mAs exposure to a contemporary X-ray film and cassette assembly, the resulting film would be overexposed and of marginal value (perhaps no value) as a diagnostic tool. The reviewing physician would have required the technique be changed to a lower exposure. For chest exams PA views, a value closer to 10 mAs is more likely (CRCPD 1994) and 20 mAs is a high estimate. Therefore the value of 20 mAs is assumed. ORAU (2005) suggests a conservative estimate for the ESE for the LAT view of 2.5 times the PA ESE. Using this estimate, the analysis assumed the exposure for the LAT view is 50 mAs. This TBD assumes these values for calculation of ESE and organ dose for chest X-rays.

Photofluorography was not performed in the AI clinic during this period because the Picker system was not capable of that technique.

3.5.2.1 Chest Views

For simplicity, this TBD assumes the performance of all chest radiographs at 90 kVp because this produces a higher average air kerma rate than 80 kVp and is, therefore, favorable to claimants. Based on Table B.3 in NCRP (1989), a single-phase machine with an SID of 183 cm (72 in.) operating at 90 kVp produces an average air kerma rate of 0.18 cGy/100 mAs. For a 20-mAs exposure in the AP view, this equates to average air kerma of 0.036 cGy. For 50 mAs in the LAT view, this equates to an average air kerma of 0.09 cGy. Correcting for a source to skin distance (SSD) of 154 cm, the entrance kerma (numerically the same as the ESE) is 0.050 cGy for the PA view and 0.130 cGy for the LAT view. These ESE values are used to calculate organ doses, as discussed in Section 3.1 of ORAU (2005).

3.5.2.2 Lumbar-spine Views

No specific information is available on the lumbar-spine technique used at AI in this period; the default data in ORAU (2005) for lumbar-spine views is derived from 1953 data and unlikely to reflect the practice two decades later. The lumbar-spine technique was probably a modern one, similar to that described in 1995 by the Conference of Radiation Control Program Directors (CRCPD 2001). As a consequence, this analysis assumes the technique to be 78 kVp, 294 mAs, HVL of 3.1 mm Al, with an average ESE of 0.370 cGy.

3.5.3 After 1997

In 1997, the Picker system was retired and radiographic examinations were performed on a subcontract basis at West Hills Hospital. That arrangement continues today. Considering the wide assortment of X-ray equipment at a modern medical center such as West Hills, it is not possible to identify the specific equipment and techniques that were used. However, it is reasonable to assume the use of modern well-maintained equipment for exposures. This TBD assumes that the ESE is comparable to the default values for modern equipment specified in Table 3-4 of ORAU (2005). It also assumes that filtration is equivalent to 4.0 mm Al, which is the default value for beam quality after 1980.

3.5.3.1 Chest Views

This TBD bases its assumption of the post-1997 default values for PA and LAT chest on data for the "Post-1985 Period" in Table 3-4 of ORAU (2005). It assumed that the entrance kerma for the PA view is 0.05 cGy. For the LAT view, it assumed the entrance kerma is 0.13 cGy.

3.5.3.2 Lumbar-Spine Views

No specific information is available on the lumbar-spine technique used at AI during this period; the default data in ORAU (2005) for lumbar-spine views is derived from 1953 data and unlikely to reflect the practice two decades later. The lumbar-spine technique was probably a modern one, similar to that described in 1995 by the Conference of Radiation Control Program Directors (CRCPD 2001). As a consequence, the TBD analysis assumed that the technique is 78 kVp, 294 mAs, with an average ESE of 0.370 cGy.

3.6 ORGAN DOSE CALCULATIONS

3.6.1 Basis and Methodology

With the exception of measured values taken from tables, and dose to the skin, estimates of the mean dose equivalents to individual organs from a given X-ray exposure are the product of the ESE and a dose conversion factor (DCF) from ICRP (1982). Skin doses are calculated as the product of ESE and a backscatter factor from Table B.8 in NCRP (1989). The backscatter factor varies by field size and filtration. ORAU (2005) recommends a backscatter factor of 1.35 for chest films made using a machine with 2.5 mm of Al filtration. For chest films made using a machine with 4.0 mm of Al filtration, ORAU (2005) recommends a backscatter factor of 1.40. The skin dose calculated in ORAU (2005) for the default evaluation of early lumbar-spine techniques uses a backscatter factor of 1.32. More recent equipment used in lumbar spine examinations is likely to be more highly filtered and a backscatter factor of 1.35 is more appropriate.

For chest views and lumbar-spine views of differing beam quality, ICRP (1982) contains tables of DCFs for as many as seven organs and the total (whole) body based on an adult anthropomorphic phantom. For an organ not listed in these tables, but needed for the Interactive RadioEpidemiological Program (IREP), the DCF is that for the anatomically closest organ in the ICRP tables. Table 3-1 lists ICRP reference organs for IREP analogs (ORAU 2005). ICRP (1982) lists different DCFs for males and females for the lung, bone marrow, and total (whole) body. The larger of the two values is assigned for the dose equivalent to the IREP organ analogs.

The ICRP tables were developed under the assumption that the primary X-ray beam is collimated to the image receptor size, which is reasonable subsequent to 1971. Earlier techniques were probably

not well collimated. Because no information regarding the collimation practices prior to 1971 was discovered, the application of these DCF tables to the early X-ray machines must occur in a way that compensates for the possible lack of collimation. ORAU (2005) assessed allowance for this circumstance during different periods in the past based on ICRP (1982).

The ICRP DCFs give the average dose equivalent in a given organ in milligray for different beam qualities when the entrance kerma (air kerma in air without backscatter) is 1 Gy. ORAU (2005) approximated that an ESE of 1 R produces a skin entrance kerma of 1 rad. In addition to simplifying

Table 3-1. Analogs for IREP organs not included in ICRP (1982).

Anatomical location	ICRP (1982) reference organ	IREP organ analog
Thorax	Lung	Thymus Esophagus Stomach Bone surface Liver/gall bladder/spleen Remainder organs
Abdomen	Ovaries	Urinary/bladder Colon/rectum
Head and neck	Thyroid	Eye/brain

the computations, this assumption is well within relatively large uncertainties from other sources and is favorable to claimants.

This TBD analysis used the following guidelines to develop Tables 3-2 through 3-9.

When an organ-dose equivalent difference between male and female organs exists, both are listed in Tables 3-2 through 3-5. The larger of the two is listed in Tables 3-6 through 3-9.

ICRP (1982) does not tabulate dose conversion factors for lumbar-spine views for the female breast, but the table includes the comment “Not computed but small compared to the projections listed above.” The smallest DCF in those tabulated projections is 9 mGy/Gy for beams filtered with 2.5 mm Al and 21 mGy/Gy for beams filtered with 4.0 mm Al. A DCF approximately 50% of the smallest tabulated value for each beam quality is assumed. A DCF of 5 mGy/Gy is used for beams filtered with 2.5 mm Al and a DCF of 10 mGy/Gy is used for beams filtered with 4.0 mm Al. This assumption can be validated by comparing the assumed DCFs to those tabulated in ICRP (1982) for the approximately inverse exposure condition: dose to the ovary delivered by a chest X-ray. For both filtrations the value is 5.2 mGy/Gy or less. For years prior to 1971 the selection of an appropriate DCF is not at issue as the breast dose is taken from measured values in Table 7-10 of ORAU (2005).

Default assumptions in ORAU (2005) are used unless specific data or documented assumptions to the contrary are cited. If specific claimant files indicate the use of photofluorography, dose reconstructors should apply the default parameters and organ dose factors values in ORAU (2005).

Table 3-2 is a summary of parameters and organ doses for 14-in. by 17-in. PA chest radiography for periods during which each X-ray system was in use. Table 3-3 is a summary of parameters and organ doses for LAT chest radiography. For the period prior to 1971 organ doses are taken from ORAU (2005) Table 6-5, with the exception of Whole Body, which is calculated as the product of ESE and an appropriate DCF from ICRP (1982). For periods subsequent to 1971 the doses are calculated as the product of ESE and a DCF from ICRP (1982). Lung dose is used as a surrogate for remainder organ dose.

Tables 3-4 and 3-5 summarize parameters and organ doses for AP and LAT lumbar-spine radiography, respectively. Lumbar-spine films are sometimes done in pairs: a large 14-in. by 17-in. radiograph and a smaller spot film of the same view. If the claimant medical records indicate the use of both a large format and spot film of the same view, dose reconstructors should double the doses in Tables 3-4 and 3-5 to represent the dose for that pair of exposures. For the period prior to 1971 organ doses are taken from ORAU (2005) Table 7-10, with the exception of Whole Body dose, which is calculated as the product of ESE and an appropriate DCF from ICRP (1982). For periods subsequent to 1971 the doses are calculated as the product of ESE and a DCF from ICRP (1982). Lung dose is used as a surrogate for remainder organ dose.

Tables 3-6 through 3-9 list doses for the thyroid, ovaries, maximum other organ (excluding skin), and maximum remainder organ for each year, beginning in 1948 and ending in 2003.

Tables 3-6 and 3-7 list PA and LAT chest radiography doses, respectively. In Table 3-6 and 3-7 the "maximum additional organ" represents the highest organ dose, excluding skin, not otherwise shown in that table. This may be the breast dose or lung dose depending on the view and technique. The "maximum remainder" organ dose is referenced to the lung dose as specified in Table 3-1.

Tables 3-8 and 3-9 list AP and LAT lumbar-spine radiography doses, respectively. In Table 3-8 and 3-9 the "maximum additional organ" represents the highest organ dose, excluding skin, not otherwise shown in that table. The uterus is the highest dose organ in the AP view. In the LAT view, the abdominal IREP organs (urinary tract, bladder, colon and rectum) share this designation. The "maximum remainder" organ dose is referenced to the lung dose as specified in Table 3-1.

3.7 DOSE RECONSTRUCTION

The records provided by DOE are likely to include adequate information to define the date, type, and count of X-ray examinations that were administered to the claimant as a condition of employment. Use the assumptions regarding radiographic exposure frequency only for screening or when specific claimant records are not available.

If confusion about the radiographic exposure record exists, consider requesting that the notes on the exterior of the envelope(s) containing the claimant's X-ray films be transcribed and provided. These notes should give insight to the reason that the exposures were made, for example pre-employment examination, routine surveillance, or diagnosis of injury. Assume that any radiograph that was not a PA chest, LAT chest, AP lumbar spine, or LAT lumbar spine view was diagnostic, not to be included in dose reconstruction. If the X-ray envelop notes associate the annotation "IND" or "industrial" with a particular exposure, that means the radiograph was a diagnostic exposure (i.e., associated with a workplace injury). "IND" radiographs are not included in dose reconstruction.

Depending on equipment and technique, the photon energy associated with occupational medical X-ray dose is in either the less-than-30-keV energy group or the 30-to-250-keV energy group. Assignment of all AI occupational medical doses to the 30-to-250-keV energy group is favorable to claimants and recommended.

3.8 UNCERTAINTY

ORAU (2005) analyzed uncertainties in the required occupational medical X-ray organ doses. The document considered several major sources of uncertainty: measurement errors; variations in applied voltage (peak voltage), beam current and exposure time; and uncertainties due to patient size and placement. ORAU (2005) assesses the relative error in an individual ESE or organ dose to be ±30%

at 1 standard deviation. The actual doses could have been as much as 30% larger than those listed in Tables 3-2 through 3-9.

Table 3-2. Parameters and organ doses for 14-in. by 17-in. PA chest radiography.

Period	Frequency	Applicability	PA chest ESE (mR)	Organ dose (rem)									
				Thyroid[a]	Ovaries[a]	Testes[a]	Lungs[a]	Breast[a]	Uterus (embryo)[a]	Bone marrow[a]	Skin[b,c]	WB[a]	Remainder[e]
Pre-1971	Entrance: likely Routine annual: likely Exit: likely	All radiation workers	200	3.48E-02 (d)	2.5E-02 (d)	5.0E-03 (d)	Male: 8.38E-02 Female: 9.02E-02 (d)	9.80E-03 (d)	2.5E-02 (d)	Male: 1.84E-02 Female: 1.72E-02 (d)	2.70E-01 (d)	Male: 2.62E-02 Female: 2.36E-02	9.02E-02 (d)
Pre-1971	Entrance: likely Routine assumed to be at 3-yr intervals Exit: not likely	Non-radiation workers	200	3.48E-02 (d)	2.5E-02 (d)	5.0E-03 (d)	Male: 8.38E-02 Female: 9.02E-02 (d)	9.80E-03 (d)	2.5E-02 (d)	Male: 1.84E-02 Female: 1.72E-02 (d)	2.70E-01 (d)	Male: 2.62E-02 Female: 2.36E-02	9.02E-02 (d)
1971 to 1997	Entrance: likely Routine annual: likely Exit: likely	All radiation workers	50	1.60E-03	5.00E-05	5.00E-07	Male: 2.10E-02 Female: 2.26E-02	2.45E-03	6.50E-05	Male: 4.60E-03 Female: 4.30E-03	6.75E-02	Male: 6.55E-03 Female: 5.90E-03	2.26E-02
1971 to 1997	Entrance: likely Routine: assumed to be at 3-yr intervals Exit: not likely	Non-radiation workers	50	1.60E-03	5.00E-05	5.00E-07	Male: 2.10E-02 Female: 2.26E-02	2.45E-03	6.50E-05	Male: 4.60E-03 Female: 4.30E-03	6.75E-02	Male: 6.55E-03 Female: 5.90E-03	2.26E-02
1998 to present	Highly unlikely	All workers	50	3.90E-03	2.60E-04	5.00E-07	Male: 3.14E-02 Female: 3.37E-02	5.80E-03	2.60E-04	Male: 8.90E-03 Female: 8.60E-03	7.00E-02	Male: 9.60E-03 Female: 8.90E-03	3.37E-02

a. Organs identified in ICRP (1982) for dose determination from ESE associated with chest radiography.
b. Skin dose for X-ray machines with filtration equivalent to 2.5 mm Al are calculated using a backscatter factor of 1.35 as recommended in ORAU (2005). This is the assumed filtration for machines used prior to 1998.
c. Skin dose for X-ray machines with filtration equivalent to 4.0 mm Al are calculated using a backscatter factor of 1.40 as recommended in ORAU (2005). This is the assumed filtration for machines used after 1997.
d. From ORAU (2005) Table 6-5 column labeled “Organ dose pre-1970 (rem) minimal collimation”.
e. Lung is the reference organ for “Remainder”, see Table 3-1.

Table 3-3. Parameters and organ doses for 14-in. by 17-in. LAT chest radiography.

Period	Frequency	Applicability	LAT chest ESE (mR)	Organ doses (rem)									
				Thyroid[a]	Ovaries[a]	Testes[a]	Lungs[a]	Breast[a]	Uterus (embryo)[a]	Bone marrow[a]	Skin[b,c]	WB[a]	Remainder[e]
Pre-1971	Entrance: likely Routine annual: likely Exit: likely	All radiation workers	500	6.85E-02 (d)	1.3E-02 (d)	2.5E-03 (d)	Male: 9.65E-02 Female: 1.10E-01 (d)	1.28E-01 (d)	1.3E-02 (d)	Male: 1.85E-02 Female: 1.45E-02 (d)	6.75E-01 (d)	Male: 3.00E-02 Female: 3.20E-02	1.10E-01 (d)
Pre-1971	Entrance: likely Routine assumed to be at 3-yr intervals Exit: not likely	Non-radiation workers	500	6.85E-02 (d)	1.3E-02 (d)	2.5E-03 (d)	Male: 9.65E-02 Female: 1.10E-01 (d)	1.28E-01 (d)	1.3E-02 (d)	Male: 1.85E-02 Female: 1.45E-02 (d)	6.75E-01 (d)	Male: 3.00E-02 Female: 3.20E-02	1.10E-01 (d)
1971 to 1997	Entrance: likely Routine annual: likely Exit: likely	All radiation workers	130	1.50E-02	7.80E-05	1.30E-05	Male: 2.51E-02 Female: 2.86E-02	3.32E-02	7.80E-05	Male: 4.81E-03 Female: 3.77E-03	1.76E-01	Male: 7.80E-03 Female: 8.32E-03	2.86E-02
1971 to 1997	Entrance: likely Routine: assumed to be at 3-yr intervals Exit: not likely	Non-radiation workers	130	1.50E-02	7.80E-05	1.30E-05	Male: 2.51E-02 Female: 2.86E-02	3.32E-02	7.80E-05	Male: 4.81E-03 Female: 3.77E-03	1.76E-01	Male: 7.80E-03 Female: 8.32E-03	2.86E-02
1998 to present	Highly unlikely	All workers	130	2.13E-02	3.25E-04	1.30E-05	Male: 4.07E-02 Female: 4.56E-02	4.46E-02	2.73E-04	Male: 9.88E-03 Female: 7.67E-03	1.82E-01	Male: 1.38E-02 Female: 1.29E-02	4.56E-02

a. Organs identified in ICRP (1982) for dose determination from ESE associated with chest radiography.
b. Skin dose for X-ray machines with filtration equivalent to 2.5 mm Al are calculated using a backscatter factor of 1.35 as recommended in ORAU (2005). This is the assumed filtration for machines used prior to 1998.
c. Skin dose for X-ray machines with filtration equivalent to 4.0 mm Al are calculated using a backscatter factor of 1.40 as recommended in ORAU (2005). This is the assumed filtration for machines used after 1997.
d. From ORAU (2005) Table 6-5 column labeled "Organ dose pre-1970 (rem) minimal collimation."
e. Lung is the reference organ for "Remainder", see Table 3-1.

Table 3-4. Parameters and organ doses for a single-exposure AP lumbar-spine radiograph.

Period	Frequency	Applicability	AP lumbar-spine ESE (mR)	Organ doses (rem) from 14-in. by 17-in. AP lumbar-spine or spot AP lumbar-spine radiography									
				Thyroid[a]	Ovaries[a]	Testes[a]	Lungs[a]	Breast[a]	Uterus (embryo)[a]	Bone marrow[a]	Skin[b,c]	WB[a]	Remainder[f]
Pre-1971[d]	Entrance: likely Routine annual: assumed to be at 3-yr intervals Exit: not likely	All workers	2,000[e]	4.00E-04	5.60E-01	2.70E-02	1.24E-01	3.60E-02	4.34E+00	4.80E-02	2.64E+00	1.66E-01	1.24E-01
1971 to 1997	Entrance: likely Routine annual: assumed to be at 3-yr intervals Exit: not likely	All workers	370	1.11E-04	7.99E-02	1.55E-03	2.92E-02	1.85E-03	1.06E-01	1.37E-02	5.00E-01	3.77E-02	2.92E-02
1998 to present[e]	Highly unlikely	All workers	370	4.81E-04	1.43E-01	4.07E-03	4.55E-02	3.7E-03	1.78E-01	3.44E-02	5.18E-01	5.62E-02	4.55E-02

a. Organs identified in ICRP (1982) for dose determination from ESE associated with lumbar-spine radiography.
b. Skin dose for X-ray machines with filtration equivalent to 2.5 mm Al are calculated using a backscatter factor of 1.35 as recommended in ORAU (2005). This is the assumed filtration for machines used prior to 1998.
c. Skin dose for X-ray machines with filtration equivalent to 4.0 mm Al are calculated using a backscatter factor of 1.40 as recommended in ORAU (2005). This is the assumed filtration for machines used after 1997.
d. Organ doses for Pre-1971 period are derived from ORAU (2005, Table 3-2).
e. ESE and organ doses are presented for a single AP or spot SP lumbar-spine view. If both AP and spot AP lumbar-spine views were imaged, double the ESE and organ doses in this row.
f. Lung is the reference organ for "Remainder", see Table 3-1.

Table 3-5. Parameters and organ doses for a single-exposure LAT lumbar-spine radiograph.

Period	Frequency	Applicability	LAT lumbar-spine ESE (mR)	Organ doses (rem) from 14- by 17-in. LAT lumbar-spine or Spot LAT lumbar-spine radiography									
				Thyroid[a]	Ovaries[a]	Testes[a]	Lungs[a]	Breast[a]	Uterus (Embryo)[a]	Bone marrow[a]	Skin[b,c]	WB[a]	Remainder[f]
Pre-1971[d]	Entrance: likely Routine annual: assumed to be at 3-yr intervals Exit: not likely	All workers	5,000[e]	5.00E-05	7.60E-01	5.6E-02	5.00E-02	4.75E-02	1.00E-01	7.50E-02	6.60E+00	1.90E-01	5.00E-02
1971 to 1997	Entrance: likely Routine annual: assumed to be at 3-yr intervals Exit: not likely	All workers	370	3.70E-06	1.74E-02	2.96E-04	5.18E-03	1.85E-03	1.15E-02	8.14E-03	5.00E-01	1.59E-02	5.18E-03
1998 to present[e]	Highly unlikely	All workers	370	3.70E-06	4.07E-02	9.62E-04	9.62E-03	3.70E-03	2.89E-02	2.04E-02	5.18E-01	2.44E-02	9.62E-03

a. Organs identified in ICRP (1982) for dose determination from ESE associated with lumbar-spine radiography.
b. Skin dose for X-ray machines with filtration equivalent to 2.5 mm Al are calculated using a backscatter factor of 1.35 as recommended in ORAU (2005). This is the assumed filtration for machines used prior to 1998.
c. Skin dose for X-ray machines with filtration equivalent to 4.0 mm Al are calculated using a backscatter factor of 1.40 as recommended in ORAU (2005). This is the assumed filtration for machines used after 1997.
d. Organ doses for Pre-1971 period are derived from ORAU (2005, Table 3-2).
e. ESE and organ doses are listed for a single LAT or Spot LAT lumbar-spine view. If both LAT and Spot LAT lumbar-spine views were imaged, double the ESE and organ doses in this row.
f. Lung is the reference organ for "Remainder", see Table 3-1.

Table 3-6. Maximum organ doses (rem) for 14-in. by 17-in. PA chest radiography.

Year	Maximum thyroid	Maximum ovaries	Maximum additional organs[a]	Maximum remainder[b]
1948	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1949	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1950	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1951	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1952	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1953	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1954	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1955	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1956	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1957	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1958	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1959	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1960	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1961	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1962	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1963	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1964	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1965	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1966	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1967	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1968	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1969	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1970	3.48E-02	2.5 E-02	9.02E-02	9.02E-02
1971	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1972	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1973	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1974	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1975	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1976	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1977	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1978	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1979	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1980	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1981	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1982	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1983	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1984	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1985	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1986	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1987	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1988	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1989	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1990	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1991	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1992	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1993	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1994	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1995	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1996	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1997	1.60E-03	5.00E-05	2.26E-02	2.26E-02
1998	3.90E-03	2.60E-04	3.37E-02	3.37E-02
1999	3.90E-03	2.60E-04	3.37E-02	3.37E-02
2000	3.90E-03	2.60E-04	3.37E-02	3.37E-02
2001	3.90E-03	2.60E-04	3.37E-02	3.37E-02
2002	3.90E-03	2.60E-04	3.37E-02	3.37E-02
2003	3.90E-03	2.60E-04	3.37E-02	3.37E-02

a. Not including skin.
b. Lung is the reference organ for “Remainder”, see Table 3-1.

Table 3-7. Maximum organ doses (rem) for LAT chest radiography.

Year	Maximum thyroid	Maximum ovaries	Maximum additional organs[a]	Maximum remainder[a,b]
1948	6.85E-02	1.3 E-02	1.10E-01	1.10E-01
1949	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1950	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1951	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1952	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1953	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1954	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1955	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1956	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1957	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1958	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1959	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1960	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1961	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1962	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1963	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1964	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1965	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1966	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1967	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1968	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1969	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1970	6.85E-02	1.3 E-02	1.28E-01	1.10E-01
1971	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1972	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1973	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1974	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1975	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1976	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1977	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1978	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1979	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1980	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1981	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1982	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1983	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1984	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1985	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1986	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1987	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1988	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1989	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1990	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1991	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1992	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1993	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1994	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1995	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1996	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1997	1.50E-02	7.80E-05	3.32E-02	2.86E-02
1998	2.13E-02	3.25E-04	4.56E-02	4.56E-02
1999	2.13E-02	3.25E-04	4.56E-02	4.56E-02
2000	2.13E-02	3.25E-04	4.56E-02	4.56E-02
2001	2.13E-02	3.25E-04	4.56E-02	4.56E-02
2002	2.13E-02	3.25E-04	4.56E-02	4.56E-02
2003	2.13E-02	3.25E-04	4.56E-02	4.56E-02

a. Not including skin.
b. Lung is the reference organ for “Remainder”, see Table 3-1.

Table 3-8. Maximum organ doses (rem) for single-exposure AP lumbar-spine radiography.

Year	Maximum thyroid[a]	Maximum ovaries[a]	Maximum additional organs[a,b,c]	Maximum remainder[a,b,d]
1948	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1949	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1950	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1951	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1952	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1953	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1954	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1955	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1956	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1957	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1958	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1959	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1960	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1961	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1962	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1963	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1964	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1965	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1966	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1967	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1968	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1969	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1970	4.00E-04	5.60E-01	4.34E+01	1.24E-01
1971	1.11E-04	7.99E-02	1.06E01	2.92E-02
1972	1.11E-04	7.99E-02	1.06E01	2.92E-02
1973	1.11E-04	7.99E-02	1.06E01	2.92E-02
1974	1.11E-04	7.99E-02	1.06E01	2.92E-02
1975	1.11E-04	7.99E-02	1.06E01	2.92E-02
1976	1.11E-04	7.99E-02	1.06E01	2.92E-02
1977	1.11E-04	7.99E-02	1.06E01	2.92E-02
1978	1.11E-04	7.99E-02	1.06E01	2.92E-02
1979	1.11E-04	7.99E-02	1.06E01	2.92E-02
1980	1.11E-04	7.99E-02	1.06E01	2.92E-02
1981	1.11E-04	7.99E-02	1.06E01	2.92E-02
1982	1.11E-04	7.99E-02	1.06E01	2.92E-02
1983	1.11E-04	7.99E-02	1.06E01	2.92E-02
1984	1.11E-04	7.99E-02	1.06E01	2.92E-02
1985	1.11E-04	7.99E-02	1.06E01	2.92E-02
1986	1.11E-04	7.99E-02	1.06E01	2.92E-02
1987	1.11E-04	7.99E-02	1.06E01	2.92E-02
1988	1.11E-04	7.99E-02	1.06E01	2.92E-02
1989	1.11E-04	7.99E-02	1.06E01	2.92E-02
1990	1.11E-04	7.99E-02	1.06E01	2.92E-02
1991	1.11E-04	7.99E-02	1.06E01	2.92E-02
1992	1.11E-04	7.99E-02	1.06E01	2.92E-02
1993	1.11E-04	7.99E-02	1.06E01	2.92E-02
1994	1.11E-04	7.99E-02	1.06E01	2.92E-02
1995	1.11E-04	7.99E-02	1.06E01	2.92E-02
1996	1.11E-04	7.99E-02	1.06E01	2.92E-02
1997	1.11E-04	7.99E-02	1.06E01	2.92E-02
1998	4.81E-04	1.43E-01	1.78E-01	4.55E-02
1999	4.81E-04	1.43E-01	1.78E-01	4.55E-02
2000	4.81E-04	1.43E-01	1.78E-01	4.55E-02
2001	4.81E-04	1.43E-01	1.78E-01	4.55E-02
2002	4.81E-04	1.43E-01	1.78E-01	4.55E-02
2003	4.81E-04	1.43E-01	1.78E-01	4.55E-02

a. Double this value if both an AP lumbar-spine and Spot AP lumbar-spine exposure were made.
b. Not including skin.
c. Representing the dose to the uterus.
d. Lung is the reference organ for "Remainder", see Table 3-1.

Table 3-9. Maximum organ doses (rem) for single-exposure LAT lumbar-spine radiography.

Year	Maximum thyroid[a]	Maximum ovaries[a]	Maximum additional organs[a,b,c]	Maximum remainder[a,b,d]
1948	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1949	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1950	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1951	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1952	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1953	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1954	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1955	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1956	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1957	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1958	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1959	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1960	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1961	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1962	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1963	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1964	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1965	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1966	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1967	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1968	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1969	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1970	5.00E-05	7.60E-01	7.60E-01	5.00E-02
1971	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1972	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1973	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1974	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1975	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1976	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1977	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1978	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1979	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1980	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1981	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1982	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1983	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1984	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1985	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1986	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1987	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1988	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1989	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1990	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1991	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1992	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1993	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1994	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1995	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1996	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1997	3.70E-06	1.74E-02	1.74E-02	5.18E-03
1998	3.70E-06	4.07E-02	4.07E-02	9.62E-03
1999	3.70E-06	4.07E-02	4.07E-02	9.62E-03
2000	3.70E-06	4.07E-02	4.07E-02	9.62E-03
2001	3.70E-06	4.07E-02	4.07E-02	9.62E-03
2002	3.70E-06	4.07E-02	4.07E-02	9.62E-03
2003	3.70E-06	4.07E-02	4.07E-02	9.62E-03

a. Double this value if both an LAT lumbar-spine and Spot LAT lumbar-spine exposure were made.
b. Not including skin.
c. Calculated from product of ESE times DCF for ovary to represent colon, rectum, urinary tract, or bladder.
d. Lung is the reference organ for “Remainder”, see Table 3-1.

REFERENCES

Chew, M. H., 2005, Documented Communication, "ETEC X-ray Equipment and Technique," November 1.

CRCPD (Conference of Radiation Control Program Directors), 1994, "Nationwide Evaluation of X-ray Trends (NEXT), 1994, P/A Chest X-Ray Data," www.crcpd.org/Pubs/NextTrifolds/NEXT94C_T.pdf.

CRCPD (Conference of Radiation Control Program Directors), 2001, "Nationwide Evaluation of X-ray Trends (NEXT), 1995, Abdomen and LS Spine X-Ray Data," revised May 16, www.crcpd.org/pubs/NextTrifolds/NEXT95Ab&LSspine.pdf.

Garcia, R.R. and R. E. Alexander, 1970, *Radiation Safety Standard Analysis – Medical Examinations for Radiation Workers*, REA-RSSA-12, prepared December 8, 1966, revised by F. M Staszeski December 8, 1970.

ICRP (International Commission on Radiological Protection), 1982, *Protection of the Patient in Diagnostic Radiology*, Publication 34, Pergamon Press, Oxford, England.

Morris, R. L., 2005a, Documented Communication, "ETEC Occupational Medical Exposures: Interview with Dr. Craig Conlon, ETEC Medical Director," December 1.

Morris, R. L., 2005b, Summary of review of a sample of ETEC archive X-ray films, December 1.

NCRP (National Council on Radiation Protection and Measurements), 1989, *Medical X-Ray, Electron Beam and Gamma-Ray Protection for Energies up to 50 MeV*, Report No. 102, Bethesda, Maryland.

ORAU (Oak Ridge Associated Universities), 2005, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 03, Oak Ridge, Tennessee, August 2.

GLOSSARY

absorbed dose
Energy absorbed per unit mass; units are rad and gray.

backscatter
Radiation scattered backwards, enhancing skin dose in areas where an X-ray beam enters the body.

dose equivalent
Product of absorbed dose and a quality factor or radiation weighting factor. With absorbed dose in rad, unit is rem.

exposure
Amount of electric charge produced per unit mass of air by electromagnetic radiation.

gray (Gy)
Unit of absorbed dose, defined as 1 joule per kilogram. It is equal to 100 rad.

kerma
Sum of initial kinetic energies of all charged particles (including Auger electrons) liberated by uncharged radiation per unit mass. Units are rad and gray. The word derives from the phrase Kinetic Energy Released in Matter.

lumbar spine
The vertebrae of the lower back.

rad
Unit of absorbed dose, defined as 100 ergs per gram. It is equal to 0.01 Gy.

rem
Unit of dose equivalent.

roentgen
Unit of exposure, abbreviated as R.

X-ray
(1) Electromagnetic radiation emitted by fast electrons slowing down in matter or in certain electronic transitions in atoms. (2) A radiograph produced by X-rays.