ORAU Team NIOSH Dose Reconstruction Project Technical Basis Document for Pantex Plant – Occupational Medical Dose	Document Number: ORAUT-TKBS-0013-3 Effective Date: 08/24/2004 Revision No.: 00 Controlled Copy No.: ______ Page 1 of 15
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ACRONYMS AND ABBREVIATIONS

AP	anterior-posterior
cm	centimeter
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ESE	entrance skin exposure
Gy	gray
HVL	half-value layer
ICRP	International Commission on Radiological Protection
in.	inch
kVp	kilovolt-peak
LAT	lateral
mA	milliampere
mAs	milliampere-second
mGy	milligray
mm	millimeter
mR	milliroentgen
NIOSH	National Institute for Occupational Safety and Health
PA	posterior-anterior
R	roentgen
s	second
SID	source-to-image distance
TBD	technical basis document
U.S.C.	United States Code
yr	year

3.1 INTRODUCTION

Technical Basis Documents (TBDs) and Site Profile Documents are general working documents that provide guidance concerning 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 National Institute for Occupational Safety and Health (NIOSH) 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 facility” as defined in the *Energy Employees Occupational Illness Compensation Program Act of 2000* [EEOICPA; 42 U.S.C. Sections 7384l(5) and (12)].

Diagnostic X-ray procedures contributed to the radiation exposure received by workers due to their employment at the Pantex Plant. In general, doses from these medical procedures were not included as part of the occupational recorded dose, although they were clearly related to occupation. NIOSH, in its role to reconstruct occupational dose under the EEOICPA, has classified diagnostic medical X-rays administered in conjunction with routine or special physical examinations required for employment as occupational exposures (NIOSH 2002). This TBD describes recommended options to conduct dose reconstruction for Pantex workers from medical X-rays administered before, during, and at termination of employment as a condition of employment. Background information on X-ray doses can be found in *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures* (ORAU 2003). This Pantex Plant TBD does not provide default values for lumbar spine examinations. The *Technical Basis Document – Occupational Medical Dose for the Rocky Flats Plant* (ORAU 2004) provides the method for calculating organ doses from lumbar spine examinations that was used in the analysis for this TBD.

3.2 EXAMINATION FREQUENCIES

Pantex required preemployment and routine physical examinations as part of its occupational health and safety program. Historical files examined for selected Pantex workers contained all the historical radiographs and a log of the respective examinations. Based on this examination, practices have varied among workers, probably based on occupation, and have generally been described according to periods from 1952 to 1982 and from 1982 to the present.

3.2.1 Frequencies from 1952 to 1982

From the start of U.S. Atomic Energy Commission operations at Pantex in 1952, X-ray examinations typically included diagnostic posterior-anterior (PA) chest X-rays. In addition, through 1982, Pantex required a single set of preemployment lumbar spine radiographs, both anterior-posterior (AP) and lateral (LAT) views, for some male employees but not for women.

Selected workers received annual chest X-rays.

3.2.2 Frequencies for 1982 to the Present

Beginning in 1982, the preemployment lumbar spine radiographs were generally discontinued.

The frequency of PA chest X-rays was changed to approximately every 5 yr for selected workers beginning in 1982.

3.3 EQUIPMENT AND TECHNIQUES

No records have been discovered at Pantex describing the manufacturers and models of X-ray equipment used before 1967. Information has been obtained that requires special consideration of Pantex worker dose for collimation and techniques used before 1971.

3.3.1 Photofluorography

X-ray film records for long-term Pantex workers, who began work in the early 1950s, were examined to determine if photofluorography techniques for chest X-rays were used. All the records showed full-size 14- by 17-in. films for all years, including 1952, 1954-1956, 1958-1959, 1962, 1964-1966, 1968, 1970-1979, and 1982. The current X-ray technologist at Pantex says that the Plant has used full-size films since she began work in 1986 and that she has never seen a “small X-ray” film in a worker’s medical record at Pantex (Strom 2004). These observations led to the conclusion that photofluorography was never used at Pantex.

3.3.2 X-Ray Machines

There have been at least four X-ray machines at Pantex as described in the following sections.

3.3.2.1 General Electric

The earliest record found of a specific X-ray machine at Pantex involved a survey of the diagnostic X-ray facilities at Pantex on September 26, 1967, performed by an inspector from the State of Texas. The inspector identified the “Control Panel Manufacturer” and “Tube Head Manufacturer and Model” as “General Electric.” The film was identified as “GAF Supreme” with “RADLIN T” intensifying screens (Texas 1967). The State of Texas performed another survey of the diagnostic X-ray facilities at Pantex from August 13 to 18, 1970; the State inspector found a “General Electric” control panel and a “Profexray Model AZ Type 2” tube head. A memorandum from February 10, 1972, states:

> *A survey of your X-ray machine … has indicated serious deterioration in the output of the X-ray tube. The observed output was from ten to twenty times lower than the previous output using the same parameters. This deterioration results in poor quality X-rays for diagnostic uses as well as presenting an unassessable risk to patients. Therefore I recommend that the X-ray machine be discontinued from use until the malfunction has been diagnosed, corrected, and surveyed by the Safety Department* (Alexander 1972a).

A memorandum from July 7, 1972, further explains the situation in that “[t]he chief difficulty noted is that low quality film was being used” (Alexander 1972b). Pantex switched back to Kodak film shortly thereafter. The specific impact in terms of exposure to workers can be assessed because radiographs are available for each worker for each examination.

3.3.2.2 Picker

From approximately July 11, 1972, through 1984, a Picker X-Ray Pictronic 500 with a Picker X-Ray Style 2098 tube head was used. A half-value layer (HVL) measurement in 1972 showed filtrations of greater than 0.6 mm Al at 49 kVp and less than 1.6 mm Al at 70 kVp. In 1983, an evaluation of the actual number of pulses that occurred with different timer settings showed a -10% (at 0.5 s) to +33% (at 1/15 s) variation from the time setting. Timer problems with this machine persisted through its replacement in the spring of 1984. In 1983, HVL measurements were greater than 0.6 mm Al at 45 kVp, greater than 1.6 mm Al at 70 kVp, and greater than 2.6 mm Al at 90 kVp. Kodak BB-5 Blue brand film and DuPont Par screens were used.

3.3.2.3 Universal

A Universal X-Ray, Inc., control panel with a Eureka X-Ray Tube Company Model Sapphire 150 tube head was installed between March 19 and May 25, 1984. The unit was in service through at least November 1, 1993. All tested parameters were apparently excellent. HVL measurements were greater than 0.6 mm Al at 45 kVp, greater than 1.6 mm Al at 70 kVp, and greater than 2.6 mm Al at 90 kVp. Kodak BB-5 Blue brand film and DuPont Par screens were used through 1990, after which DuPont Cronex 7 film was used with Cronex Quanta III screens. The first patient entrance skin exposure (ESE) for PA chest radiography was measured at 4.4 mR on September 16, 1993, for a 23-cm-thick patient at 192 cm source-to-image distance (SID) at 300 mA and 72 kVp with a large focal spot and no grid.

3.3.2.4 Continental

A Continental TM-50 6626.235 X-ray machine was installed between November 1, 1993, and November 6, 1995. On November 6, 1995, an HVL measurement of 4.8 mm Al was obtained at 80 kVp. This machine uses *photo-timing* for chest films, which measures the incidence on the film directly, during exposure, to determine the exposure time. Output of this machine was shown by a certified medical physicist to vary as kVp raised to the 2.38 power between 60 and 70 kVp, and as kVp raised to the 2.03 power between 90 and 100 kVp (Huddleston 1995). This machine was still in use as of June 2004.

3.3.3 <u>Collimation before 1971</u>

A 1970 State of Texas survey of Pantex X-ray facilities concluded that collimation was inadequate:

> *At 40 inches target to film distance, the existing cones collimate the beam to 22 inches in diameter which exceeds the 15 1/2 inch diagonal length of a 10" × 12" film. At 70 inches target to film distance, the existing cones collimate the beam to 39 inches in diameter which exceeds the 22 inch diagonal length of a 14" × 17" film. For the above reasons none of the cones presently available should be used for either chest or extremity x-rays…* (Gidley 1970).

The letter continues later, "An aluminum filter of 2.5 mm in thickness should be provided for the unit. Except for the thickness, the dimensions can be the same as for the existing unit" (Gidley 1970).

A 39-in.-diameter circle centered on the chest includes the gonads and the entire head for most adults. A 22-in.-diameter circle centered over the lumbar spine in a PA projection includes most of the abdomen, but probably not the thyroid, for most adults.

Evidence of collimation measurements in 1981 was located, with the conclusion that it is acceptable, (i.e., within 2 in. of film size). This is expected to be representative of collimation through 2004.

The analysis for this TBD assumed that the collimation problem was corrected by January 1, 1971. For X-rays before 1971, in the absence of any additional information regarding filtration or collimation, it is assumed that:

- For chest radiographs, tissues and organs from mid-thigh to the top of the head were exposed to the primary X-ray beam.
- For lumbar spine radiographs, all abdominal tissues and organs were exposed to the primary X-ray beam.

3.3.4 Specific Technique Charts

A 1941 table of suggested X-ray techniques in Pantex Medical Department files shows that Pantex used a General Electric CRT 1 or CRT 2 X-ray tube operated "on full wave rectification" in the early days, along with "fast" film. Table 3-1 shows a transcription of 1967 X-ray technique charts. In the absence of other information, these techniques are assumed to have been used before the advent of the Continental X-Ray Equipment with photo-timing in the 1990s.

Table 3-1. 1967 X-Ray techniques for three procedures.[a]

Lumbar spine (AP) 1 s, 200 mA, 200 mAs 200 large focal spot Bucky In 40" SID		Lumbar spine (LAT) 3 s, 200 mA, 600 mAs 200 large focal spot Bucky In 36" SID		Chest film 0.1 s, 100 mA, 10 mAs 100 large focal spot Measurement of unexpanded chest	
cm	**kVp**	**cm**	**kV_p**	**cm**	**kVp**
13	50	21	58	16	54
14	52	22	60	17	56
15	54	23	62	18	58
16	56	24	64	19	60
17	58	25	66	20	62
18	60	26	68	21	64
19	62	27	70	22	66
20	64	28	72	23	68
21	66	29	74	24	70
22	68	30	76	25	72
23	70	31	78	26	74
24	72	32	80	27	76
25	74	33	82	28	78
26	76	34	84	29	80
27	78			30	82
28	80			31	84
				32	86
				33	88
				34	90
				35	92
				36	94

a. Copies of the charts combined in this table were obtained from Strom (2003). The originals were initialed on April 5, 1967, or April 10, 1967, by CS [probably Colette V. Stoddard per Texas (1967)]. Centimeter values are patient thickness measurements. Peak kilovolt (kVp) values are settings to be changed on machine.

The techniques in Table 3-1 show significant variability in patient doses. A note of Pantex instructions included in this reference summarized day-to-day selections as:

- Chest - use 300 mA, 1/30 s
- AP spine - use 100 mA, 1 s (may use 200 mA for extra-heavy person or check chart)
- LAT spine - use 100 mA, 2 s (may use 200 mA for extra-heavy person or check chart)

and, for each of these examinations, set the kVp from Table 3-1 according to the size of the patient. These instructions also identify as "Urgent" for the operator to check the cone for the size of film and that the distance to the table is 40 in.

Table 3-2 lists the ESE for PA chest radiographs. The ESE values range from 8.5 to 36.7 mR (a factor of 4.3).

Table 3-2. Calculated ESEs for PA chest technique.

Chest (PA) patient thickness (cm)	kVp	mR/mAs at 12 in.	mR/mAs at 182.88 cm (72 in.)	mR/mAs ESE	mR ESE at 10 mAs
16	54	23.08	0.64	0.85	8.5
17	56	24.96	0.69	0.93	9.3
18	58	26.92	0.75	1.02	10.2
19	60	28.96	0.80	1.11	11.1
20	62	31.08	0.86	1.20	12.0
21	64	33.28	0.92	1.31	13.1
22	66	35.56	0.99	1.41	14.1
23	68	37.92	1.05	1.53	15.3
24	70	40.36	1.12	1.65	16.5
25	72	42.88	1.19	1.77	17.7
26	74	45.49	1.26	1.91	19.1
27	76	48.18	1.34	2.05	20.5
28	78	50.95	1.42	2.19	21.9
29	80	53.80	1.49	2.35	23.5
30	82	56.74	1.58	2.51	25.1
31	84	59.76	1.66	2.68	26.8
32	86	62.87	1.75	2.86	28.6
33	88	66.06	1.84	3.05	30.5
34	90	69.34	1.93	3.25	32.5
35	92	72.69	2.02	3.45	34.5
36	94	76.14	2.11	3.67	36.7

Tables 3-3 and 3-4 list ESE values for the AP and LAT lumbar spine techniques, respectively. These tables show a range in ESE values of approximately a factor of 4.

3.4 ORGAN DOSE CALCULATIONS

Organ dose calculations for workers at Pantex from 1952 to the present involve three primary diagnostic medical radiographic procedures administered in connection with preemployment or regular medical examinations:

- PA 14- by 17-in. chest film (preemployment and annual through 1982; every 5 yr after that with the exception of asbestos workers (early 1980s on) and beryllium workers or beryllium associated workers (about 2000 on)

- AP lumbar spine film (men only; preemployment only)

- Lateral lumbar spine film (men only; preemployment only)

Table 3-3. Calculated ESEs for AP lumbar spine technique.

Lumbar spine (AP) patient thickness (cm)	kVp	mR/mAs at 12 in.	mR/mAs at 102 cm (40 in.)	mR/mAs ESE	mR ESE at 200 mAs
13	50	19.56	1.76	2.79	558
14	52	21.28	1.92	3.11	623
15	54	23.08	2.08	3.46	693
16	56	24.96	2.25	3.84	768
17	58	26.92	2.42	4.25	850
18	60	28.96	2.61	4.70	939
19	62	31.08	2.80	5.17	1,035
20	64	33.28	3.00	5.69	1,138
21	66	35.56	3.20	6.25	1,250
22	68	37.92	3.41	6.85	1,370
23	70	40.36	3.63	7.50	1,499
24	72	42.88	3.86	8.20	1,639
25	74	45.49	4.09	8.95	1,789
26	76	48.18	4.34	9.76	1,951
27	78	50.95	4.59	10.63	2,126
28	80	53.80	4.84	11.57	2,313

Table 3-4. Calculated ESEs for LAT lumbar spine technique.

Lumbar spine (LAT) patient thickness (cm)	kVp	mR/mAs at 12 in.	mR/mAs at 91.44 cm (36 in.)	mR/mAs ESE	mR ESE at 600 mAs
21	58	26.92	2.99	6.42	3,849
22	60	28.96	3.22	7.13	4,277
23	62	31.08	3.45	7.90	4,743
24	64	33.28	3.70	8.75	5,250
25	66	35.56	3.95	9.67	5,804
26	68	37.92	4.21	10.68	6,406
27	70	40.36	4.48	11.77	7,063
28	72	42.88	4.76	12.96	7,778
29	74	45.49	5.05	14.26	8,556
30	76	48.18	5.35	15.67	9,404
31	78	50.95	5.66	17.21	10,328
32	80	53.80	5.98	18.89	11,334
33	82	56.74	6.30	20.72	12,432
34	84	59.76	6.64	22.72	13,629

Therefore, the analysis for this TBD evaluated only the doses from these three techniques. Other radiographic examinations of Pantex employees that could have occurred were generally nonoccupational in the sense that they were typically associated with illness or injury and were not part of a routine examination process. There is no indication in the examined records that other diagnostic radiographic examinations were routinely administered as part of the occupational medical program.

3.4.1 Conversion of ESE to Organ Dose after 1970

Pantex X-ray equipment and procedures after 1970 were properly collimated, which allows conversion of ESE to organ dose using published conversion factors from the International Commission on Radiation Protection (ICRP) in Tables A2 through A9 of Publication 34 (ICRP 1982). The tables provide average absorbed organ doses for specific selected medical radiography procedures relative to an entrance air kerma without backscatter of 1 Gy for various beam qualities expressed in terms of HVL of aluminum. The tables do not include all organs identified in the Interactive RadioEpidemiological Program. Therefore, dose reconstructors should use a dose conversion coefficient for an included organ that is anatomically in proximity to the organ of interest to provide a reasonable estimate of the dose to the organ of interest. These are provided in ORAU (2003). The dose reconstructor should examine doses to tissues and organs as a function of the examination in question, as listed in Table 3-5. The dose to the female breast is negligible from lumbar spine views, and the dose to the testes is negligible from AP lumbar spine and PA chest views.

Table 3-5. Dose conversion factor to tissues and organs as a function of examination.[a]

Examination				**Dose conversion factor (mGy of absorbed dose to a tissue or organ per Gy of entrance kerma)**							
Projection	View	SID (cm)	HVL	Thyroid	Ovaries	Testes	Lungs	Female breast	Uterus (embryo)	Active bone marrow	Total body
Lumbar spine	AP	102	1.5	0.06	105	1.2	45	-	147	15	62
Lumbar spine	AP	102	2	0.2	160	2.5	62	-	217	24	83
Lumbar spine	AP	102	2.5	0.3	216	4.2	79	-	287	37	102
Lumbar spine	AP	102	3	0.6	274	6.4	95	-	355	53	121
Lumbar spine	***AP***	***102***	***3.5***	***0.9***	***331***	***9***	***109***	***-***	***421***	***71***	***137***
Lumbar spine	AP	102	4	1.3	386	11	123	-	482	93	152
Lumbar spine	Lat	102	1.5	0.01	17	0.2	6	-	11	9.4	26
Lumbar spine	Lat	102	2	0.01	31	0.5	10	-	20	15	38
Lumbar spine	Lat	102	2.5	0.01	47	0.8	14	-	31	22	43
Lumbar spine	Lat	102	3	0.01	67	1.2	17	-	45	31	51
Lumbar spine	***Lat***	***102***	***3.5***	***0.01***	***87***	***1.8***	***22***	***-***	***61***	***43***	***59***
Lumbar spine	Lat	102	4	0.01	110	2.6	26	-	78	55	66
Chest	PA	183	1.5	11	0.2	0.01	250	18	0.3	49	83
Chest	PA	183	2	21	0.6	0.01	355	32	0.7	69	108
Chest	PA	183	2.5	32	1	0.01	451	49	1.3	92	131
Chest	PA	183	3	46	1.8	0.01	535	69	2.3	117	153
Chest	***PA***	***183***	***3.5***	***62***	***3.2***	***0.01***	***610***	***91***	***3***	***146***	***174***
Chest	PA	183	4	78	5.2	0.01	674	116	5.2	178	192

a. Entrance kerma (Gy) = ESE (R) × 0.00873 Gy/R ≈ ESE (R) × 0.01 Gy/R.

This analysis assumed that an exposure of 1 R is equivalent to a kerma of 1 rad or to 10 mGy (ORAU 2003). The conversion to organ dose can be made easily if the beam quality is known or can reasonably be assumed. There is some kVp and filtration data for Pantex techniques, and an estimate of beam quality can be made from these data. Because absorbed organ dose increases as a function of HVL, the upper limit on the likely beam quality is calculated and rounded up to match the closest value in the tables in ICRP Publication 34 (ICRP 1982) for conservatism. The beam quality is assumed to be 3.5 mm Al in each case because this results in higher estimated doses to distal tissues and organs (shown in italicized bold text in Table 3-5).

Entrance kerma values of 0.02 Gy (2 rads), 0.10 Gy (10 rads), and 0.0003 Gy (0.03 rad) were chosen for AP lumbar spine, LAT lumbar spine, and PA chest, respectively, based on patient thicknesses of about 26, 31, and 33 cm, respectively, which are in the upper ranges of the 1967 posted technique charts at Pantex. From the historical information examined, there is not enough detail to make better assumptions, especially for periods before 1967. Because the 1967 techniques are similar to the 1941 techniques, this analysis assumed that they are representative for all years. Table 3-6 lists doses obtained using these values.

3.4.2 Organ Dose before 1971

Before 1971 and in the absence of additional information regarding filtration or collimation, Pantex X-ray units were apparently minimally collimated, which resulted in dose to many organs of the body for chest PA, AP lumbar spine, and LAT lumbar spine examinations. As such, dose conversion coefficients in Tables A2 through A9 of ICRP Publication 34 (ICRP 1982) are not adequate to calculate the dose to organs that would typically be outside a properly collimated beam (ORAU 2003). The recommended approach for the respective examinations is:

Table 3-6. Organ dose to be assigned for each post-1970 X-ray examination.

Tissue[a]	Dose conversion factor (mGy to tissue/Gy entrance kerma)			Examination dose (rad)		
	Lumbar spine			Lumbar spine		
	AP	LAT	PA chest	AP	LAT	PA chest
Thyroid	0.9	0.01	62	1.80E-03	1.00E-04	1.90E-03
Ovaries	331	87	3.2	6.62E-01	8.70E-01	1.00E-04
Testes	9	1.8	0.01	1.80E-02	1.80E-02	3.00E-07
Lungs	109	22	610	2.18E-01	2.20E-01	1.83E-02
Female breast	-	-	91			2.70E-03
Uterus (embryo)	421	61	3	8.42E-01	6.10E-01	9.00E-05
Active bone marrow	71	43	146	1.42E-01	4.30E-01	4.40E-03
Total body	137	59	174	2.74E-01	5.90E-01	5.20E-03
Entrance skin exposure	1,000	1,000	1,000	2.00E+00	1.00E+01	3.00E-02

- For chest PA examinations, tissues and organs from the mid-thigh to the top of the worker's head were exposed to the primary X-ray beam. Dose reconstructors should assign the maximum default organ dose (0.09 rem) from ORAU (2003, Table 4.0-1) for the chest PA X-ray examination to the organ of interest.

- For lumbar spine AP and LAT radiographs, potentially many if not all abdominal tissues and organs were exposed to the primary X-ray beam. Guidance for the AP and LAT lumbar spine examinations is not included in ORAU (2003). Dose reconstructors should use guidance in the RFP TBD for AP and LAT lumbar spine radiographs for the period from 1952 through 1974 because the techniques and chest PA organ doses are similar. The recommended default doses for the organ of interest are summarized in Table 3-7.

Table 3-7. Organ dose for each pre-1971 X-ray examination.

Organ	Organ dose in rad		
	Chest PA[a]	AP lumbar spine[b]	Lateral lumbar spine[b]
Thyroid	3.48E-02	5.00E-04 (2.96)	1.00E-04 (1.90)
Eye/brain	6.4E-3	5.00E-04 (2.96)	1.00E-04 (1.90)
Ovaries	2.5E-2	5.00E-04 (2.96)	2.25E-01 (2.10)
Urinary bladder	2.5E-2	5.00E-04 (2.96)	2.25E-01 (2.10)
Colon/rectum	2.5E-2	5.00E-04 (2.96)	2.25E-01 (2.10)
Testes	5.0E-3	2.55E-02 (3.10)	3.97E-01 (1.51)
Lung	8.38E-2	1.22E-01 (2.53)	6.36 E-02 (2.00)
Liver/gall bladder/spleen	9.02E-2	1.22E-01 (2.53)	6.36 E-02 (2.00)
Thymus	9.02E-2	1.22E-01 (2.53)	6.36 E-02 (2.00)
Esophagus	9.02E-2	1.22E-01 (2.53)	6.36 E-02 (2.00)
Stomach	9.02E-2	1.22E-01 (2.53)	6.36 E-02 (2.00)
Bone surfaces	9.02E-2	1.22E-01 (2.53)	6.36 E-02 (2.00)
Remainder	9.02E-2	1.22E-01 (2.53)	6.36 E-02 (2.00)
Female breast	9.80E-3	1.35E-00 (2.40)	1.37E-00 (1.90)
Uterus	2.5E-2	4.36E-01 (2.60)	1.51E-01 (2.10)
Bone marrow	1.84E-2	5.75E-02 (2.60)	1.10E-01 (2.10)
Skin	2.7E-1	1.79E-00 (2.44)	5.79E-00 (1.84)

a. Source: ORAU (2003, Table 4.0-1)
b. Source: ORAU (2004, Table 3.4.2-2)

Pantex workers typically received periodic chest PA X-ray examinations and only occasional lumbar spine examinations. The U.S. Department of Energy provides medical X-ray examination information for each claim.

3.5 UNCERTAINTY

Primary sources of uncertainty in occupational medical dose, which are described in ORAU (2003), are generically valid for the Pantex X-ray program. That analysis showed a combined uncertainty of ±30% at 1 sigma for a single ESE or derived organ dose.

3.6 INSTRUCTION GUIDE FOR DOSE RECONSTRUCTORS

Pantex medical records provide the history of PA chest, AP lumbar spinal, and LAT lumbar spinal examinations for each claim. From the claim documentation, dose reconstructors should identify the tissue of interest. Using that tissue, the reconstructor should assess the dose as follows:

- After 1970, use Table 3-6 for each examination.
- Before 1971, use Table 3-7 for each examination.

The dose to the organ or tissue of interest for each examination is in rad.

REFERENCES

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GLOSSARY

absorbed dose

The energy imparted per unit mass by ionizing radiation to matter at a specified point. The International System unit of absorbed dose is joules per kilogram. The special name for this unit is the gray (Gy). The previously used special unit of absorbed dose, rad, is being replaced by the gray (1 rad = 0.01 Gy; 1 Gy = 100 rad).

Atomic Energy Commission

Original agency established for nuclear weapons and power production; a predecessor to the U.S. Department of Energy.

anterior-posterior (AP)

Irradiation geometry in which the radiation passes from the front of a person to the back.

lateral (LAT)

Irradiation geometry in which the radiation passes from one side of a person to the other.

posterior-anterior (PA)

Irradiation geometry in which the radiation passes from the back of a person to the front.

rad

The unit for absorbed dose (1 rad = 100 erg/gram)

technique or technic

In diagnostic radiology, the combination of source-to-image distance (SID), accelerating potential (peak kilovoltage), tube current (milliampere), 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, expressed in milliampere-seconds or millicoulomb. Any combination of time and tube current that produces a given product in milliampere-seconds will produce the same exposure for a fixed peak kilovoltage.

X-ray

(1) Ionizing electromagnetic radiation of external nuclear origin. (2) An image generated by exposing a detector (e.g., film) to X-rays.