ORAU Team **Dose Reconstruction Project for NIOSH** Technical Basis Document for the Argonne National Laboratory–West – Occupational Medical Dose	Document Number: ORAUT-TKBS-0026-3 Effective Date: 05/16/2005 Revision No.: 00 PC-1 Controlled Copy No.: _____ Page 1 of 11
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ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
ANL-W	Argonne National Laboratory - West
AP	anterior-posterior
cm	centimeter
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ERDA	Energy Research and Development Administration
ICRP	International Commission on Radiological Protection
INEEL	Idaho National Engineering and Environmental Laboratory
IREP	Interactive RadioEpidemiological Program
kerma	Kinetic Energy Released to Matter
kg	kilogram
kV	kilovolt
kVp	kilovolt peak
LAT	lateral
lb	pound
mA	milliampere
mm	millimeter
mrad	millirad
msec	millisecond
PA	posterior-anterior
U.S.C.	United States Code

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 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 mean an "atomic weapons employer facility" or a "Department of Energy facility" as defined in the Energy Employees Occupational Illness Compensation Program Act (EEOICPA; 42 U.S.C. 7384l (5) and (12)).

This TBD discusses the occupational medical dose workers received during employment at the Argonne National Laboratory - West (ANL-W) which operated from February, 1951 to present. The site required pre-employment and periodic physical examinations as part of its occupational health and safety program. At first, the U.S. Atomic Energy Commission (AEC) provided these medical examinations for all onsite Federal and contractor personnel. Later, they became the responsibility of the site prime contractor.

The examinations typically included diagnostic chest X-rays. The dose from these procedures depended not only on the characteristics of the X-ray machine and the procedure used, but also on the frequency of examinations. This document discusses various X-ray techniques and equipment used over the years at the Idaho National Engineering and Environmental Laboratory (INEEL). Attachment 3A contains tables for use by dose reconstructors in determining a worker's occupational medical dose. The primary source of information on medical X-rays is a report by Collings and Creighton (2002) prepared at NIOSH request.

3.2 EXAMINATION FREQUENCIES

A review of the NIOSH OCAS Claimant (NOCTS) contents for ANL-W claimants shows that x-ray records are provided. From this I conclude that chest x-rays were given annually from 1959 to about 1975. I assume they were also given annually before that time. This contradicts the practice at the INEEL even though these x-rays were given through the INEEL medical organization.

The Appendix to AEC Manual Chapter 0528 (AEC 1969) specified the following:

- A chest X-ray would be part of a medical examination.
- Workers under 40 would receive an exam at a frequency influenced by several factors.
- Workers over 40 would receive an exam at least every 2 years (approximately annually when indicated).

The 1971 Annual Report (AEC 1972) states the schedule for examinations is "at time of hire, at ages 25, 30, 34, 37, and 40, every two years until age 62 and then annually." This is identical to that reported by Collings and Creighton (2002) and is assumed to apply from 1975 to 1976.

Beginning in 1976, physicals occurred every 2 years for workers under age 45 and every year for those over age 45 (Collings and Creighton 2002). On February 1, 1978, INEEL eliminated routine chest X-rays on periodic physicals with the exception of high-risk (as determined by the physician) individuals, in which case they were performed every 4 years. Records from the exposures are reported in each worker's medical file.

3.3 EQUIPMENT AND TECHNIQUES

The standard distance from source to image was 72 inches (183 cm).

To the best of our knowledge, none of the INEEL exams used fluoroscopic techniques (Creighton 2003). The 1971 Annual Report (AEC 1972) identifies a medical van as taking 22% of the 4,426 X-ray examinations. In addition, this report mentions the Idaho Falls Navy dispensary for doing X-ray examinations. Both of these facilities performed standard chest X-rays and did not do photofluoroscopy. A key word search of the INEEL records system using the terms *collimation*, *fluoroscopic*, *Health and Safety*, *Health and Safety Services*, *Medical X-ray*, *photofluorography*, and *x-ray* resulted in nothing that indicated the use of fluoroscopic techniques (Vivian and Rockhold 2003).

From 1954 to February 1990, X-ray examinations were performed with a single-phase General Electric Model DXD350 machine. The voltage was 90 kVp, the current was 300 mA, and the duration of the exposure was 1/15 sec (67 msec). Added filtration of 2 mm Al was used, and a 10:1 grid was used to reduce scatter radiation (Collings and Creighton 2002). Tube window thickness is assumed to be about 0.5 mm. Based on Table A16 of International Commission on Radiological Protection (ICRP) Publication 34, *Protection of the Patient in Diagnostic Radiology* (ICRP 1982), the half-value layer at 90 kVp and 2.5-mm total aluminum filtration is 2.58 mm Al.

From February 1990 to the present, X-rays have been performed with a three-phase Gendex Model 110-0030G2. The voltage is 100 kVp, the current is 300 mA, and the duration is 32 msec. Added filtration of 2 mm Al was used, and a 10:1 grid was used to reduce scatter radiation (Collings and Creighton 2002). Tube window thickness is assumed to be about 0.5 mm. Based on Table A17 of ICRP (1982), the half-value layer at 100 kVp and 2.5-mm total aluminum filtration is 3.3 mm Al.

Practices before 1954 are unclear. Offsite facilities might have been contracted to perform the examinations. The default value for entrance kerma of 200 mrad (Kathren 2003) is assumed for that period.

From 1954 to 1970, the chest X-ray consisted of a single posterior-anterior (PA; back to front) image. From 1970 to 1978, the procedure consisted of both PA and lateral (LAT) views. From 1978 to 1990, the LAT view was dropped and only a PA view was made. For the period from 1990 to the present, there were both PA and LAT views. For lateral views, the exposure time was about 1.25 times that of the PA view. In Collings and Creighton (2002), the terms PA and AP (anterior-posterior, front to back)

appear somewhat interchangeably. Creighton attributed this presumed interchangeable usage to a typographical error. The August 21, 1975, Energy Research and Development Administration (ERDA) requirement for occupational medical programs (replaced in 1982) specified the minimum requirements for chest X-rays and specified a PA view at least once every 5 years, as well as when transferring to a job with cardiorespiratory system stress (ERDA 1975).

Collimation and control of scatter for INEEL facilities generally followed the state of the medical art as it improved. However, in the absence of particular information about collimation, we will use the dose conversion factors in Table 4.0-1 of Kathren (2003) for the pre-1970 timeframe.

3.4 ORGAN DOSES

The entrance air kerma for 100 mA sec can be determined from Table B3 of National Council on Radiation Protection and Measurements (NCRP) Report 102 (NCRP 1989) and the beam voltage, distance, and total filtration. Tables A2 to A9 of ICRP (1982) list Monte Carlo calculation results of the ratio of organ doses to air kerma, for a 70-kg (154-lb) male or female, for the thyroid, ovaries, testes, lungs, female breast, uterus (embryo), active bone marrow, and total body under different exposure conditions. For organs where there is a difference for males and females, the larger value is used. A linear interpolation, applicable to the pre-1990 and post-1990 years, was used between the dose ratios for half-value layers of 2.5, 3.0, and 3.5 mm Al to the values of 2.58 and 3.3 mm Al. The skin entrance surface was assumed to be 30 cm from the film for the PA view and 40 cm from the film for the LAT view. These distances account for body thickness and any other space between the person and the film. The dose to the skin is the product of the entrance skin exposure and a backscatter factor taken from NCRP 102 Table B-8.

The organ dose from a PA image is the product of the two table values, an inverse square correction, and the product of exposure current and time. Table 3A-1 in Attachment 3A lists these values. For LAT images, a similar calculation was performed and added to the PA result.

Cancers in several other organs, as listed in the Interactive RadioEpidemiological Program (IREP), are compensable. The ratio of doses for two organs is affected by the relative atomic numbers of the tissue (bone dose is higher than dose in nearby muscle), the relative positions of the organ and the X-ray beam, and the depth in the body. Attachment 3A lists these other organs and the organs from ICRP (1982), which were used to estimate the dose. Table 3A-1 lists these organs in the third row.

3.5 UNCERTAINTY

Uncertainties in the occupational medical dose result from uncertainties in the current, voltage, and time for exposures. In addition, organ doses are influenced by the size of the person. If an analog organ is used from the ICRP (1982) organs, the IREP organs are generally deeper in the body so the dose will be lower than the analog organ. No estimate is made of this one-sided uncertainty because it cannot lead to a larger dose.

The uncertainties assigned in the Savannah River Site (SRS) Technical Basis Document (ORAU 2003) are generically valid for X-ray programs. The uncertainty at one sigma due to voltage was 9%, that due to current was 5%, and that due to time was 25%. The uncertainty for voltage assumes a 5% voltage uncertainty and, because the output has a $V^{1.7}$ dependence, results in a 9% uncertainty. Output is directly proportional to current, which is assumed to have a 5% uncertainty. The usually unfiltered voltage output from the voltage rectifier causes a pulsed character to the X-ray output at 120 Hz (twice the supply frequency). For the short exposure times this results in only a few pulses and thus a fairly large uncertainty due to time.

All Monte Carlo calculations have an uncertainty determined by the length of the run and the number of events scored for each calculation. For the organ dose calculations from ICRP (1982), this uncertainty was not stated. Based on judgment, it is assumed to be 5% at 1 sigma, which would require at least 400 counts in each scoring unit.

The error due to patient thickness has two causes: (1) an increase for a larger person being closer to the source and (2) a decrease due to additional attenuation in the body. The Monte Carlo calculations in ICRP (1982) assumed 70-kg (154-lb) male and female geometries. The 10% uncertainty assigned in the SRS TBD (ORAU 2003) was due to the first cause; but, because the effects counteract, that value is appropriate for the combined effect. This should be taken as 1 sigma on a normal distribution. These sources of uncertainty added in quadrature result in a combined uncertainty of ±30 % at 1 sigma or 84% confidence.

REFERENCES

AEC (U.S. Atomic Energy Commission), 1961*, Annual Report of the Health and Safety Division,* Report No. IDO-12019, Idaho Operations Office, Idaho Falls, Idaho

AEC (U.S. Atomic Energy Commission), 1969, AEC Manual Chapter 0528, Appendix, *Occupational Health Program*, December 5.

AEC (U.S. Atomic Energy Commission), 1972*, 1971 Annual Report of the Health Services Laboratory,* Report No. IDO-12076, Idaho Operations Office, Idaho Falls, Idaho

Collings, L. H. and Creighton, P., 2002, *Idaho National Engineering and Environmental Laboratory (INEEL) History of the Occupational Medical Program (OMP) X-Ray Process*, April 8.

Creighton, P. N., 2003, "Transmittal of Medical X-ray Information for the INEEL," letter to L. Johnson (Intrepid Technology and Resources), Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID, June 24.

ERDA (Energy Research and Development Administration), 1975, *Contractor Occupational Medical Program Handbook*, ERDA Manual Appendix 0528-A, August 21.

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

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

Kathren, R. L., 2003, *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Projections*, ORAU-OTIB-0006, Rev.00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, November 14.

ORAU (Oak Ridge Associated Universities), 2003, *Technical Basis Document for the Savannah River Site to be Used for EEOICPA Dose Reconstructions*, Rev. 0, Oak Ridge, Tennessee, July 15.

Sommers, J. F., 1961, "Routine Blood Sampling Program at the MTR-ETR," Som-165-61A-M, memorandum, December 15.

Spickard, J. (Physician and Medical Director at INEEL 1960-1988), Phone conversation of 11/12/03 with Norman Rohrig.

Vivian, K. A. (DOE-ID) and Rockhold, L. E. (BBWI), 2003, "Transmittal of Medical Documents from the INEEL," letter to Norman Rohrig (Intrepid), November 18.

GLOSSARY

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

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

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

posterior-anterior
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 gm^{-1}

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

ATTACHMENT 3A
OCCUPATIONAL MEDICAL DOSE

The following are analogs for IREP organs not included in ICRP (1982):

Anatomical location	ICRP (1982) reference organ	IREP organ analogs
Head	Thyroid	Eye Brain
Thorax	Lung	Thymus Esophagus Bone surface Stomach /Spleen Liver/gall bladder
Abdomen	Ovaries	Urinary bladder Colon Uterus

ANL-W conducted initial and periodic X-ray examinations as part of the medical examinations. The skin entrance air KERMA values in mrad are shown below.

Air kerma (mrad)	PA	LAT
Pre 1954	200	500
1954 to Jan 1990	52	74
Feb 1990 to present	53	76

Table 3A-1 lists the frequencies and doses. Table 3A-1, row 2 lists the organs identified in ICRP (1982) and row 3 lists the organs identified in IREP that are not listed in ICRP (1982). The uncertainties at the 84% confidence limit (1 sigma) are ±30%.

Table 3A-1. Organ doses from occupational medical exposures at the ANL-W.

		ICRP 34 organs		Organ doses (mrad) from ANL-W chest X-ray						
				Thyroid	Testes	Lungs	Breast	Ovary Embryo	Bone marrow	
		Other organs		Eye Brain		Thymus Esophagus Stomach Bone surface Liver / Spleen Gall bladder		Uterus Bladder Colon		Skin
Period	Frequency	Geometry								
Before 1954	No information Assume annual		PA	69	1.8	93	10	34	19	272
1954 to 1974	Annual	New hires	PA	18	0.5	24	2.7	8	5	70
1975 to 1976	25, 30, 34, 37, 40 Biennial Annual	New hires 40 to 62 >62	PA, Lat	10	0.008	41	22	0.1	8	171
1977 to 1978	Biennial Annual	New hires <45 >45	PA, Lat							
1979 to Jan 1990	4 years	New hires High risk only	PA	1.8	0.001	24	2.7	0.1	5.0	70
Feb 1990 to present			PA, Lat	14	0.008	53	27	0.3	11	180