DOE Review Release 05/02/2019

Summary Site Profile for the S-50 Oak Ridge Thermal Diffusion Plant	ORAUT-TKBS-0054	Rev. 01
	Effective Date:	04/15/2019
	Supersedes:	Revision 00

Subject Expert(s): Michalene Rodriguez

Document Owner Approval:	Signature on File Michalene Rodriguez, Document Owner	Approval Date:	04/10/2019
Concurrence:	Signature on File John M. Byrne, Objective 1 Manager	Concurrence Date:	04/10/2019
Concurrence:	Signature on File Scott R. Siebert, Objective 3 Manager	Concurrence Date:	04/10/2019
Concurrence:	Vickie S. Short Signature on File for Kate Kimpan, Project Director	Concurrence Date:	04/10/2019
Approval:	Signature on File James W. Neton, Associate Director for Science	Approval Date:	04/15/2019

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
12/08/2006	00	New document to describe the S-50 Liquid Thermal Diffusion Project to enable the preparation of dose reconstructions. First approved issue. Attributions and Annotations added to document. Incorporates formal internal and NIOSH review comments. There is no change to the assigned dose and no PER is required. Training required: As determined by the Task Manager. Initiated by Paul A. Szalinski.
04/15/2019	01	Revision initiated to update Section 3.0 on occupational medical dose with updated K-25 information. Added Section 1.3 to describe the Special Exposure Cohort class applicable to S-50 employees. Provided additional information in Section 2.0 about site operations. Updated boilerplate language and references. No changes occurred as a result of formal internal review. Incorporates formal NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Michalene Rodriguez.

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ACRONYMS AND ABBREVIATIONS

AWE	Atomic Weapons Employer
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ft	foot
kW	kilowatt
lb	pound
NEPA	Nuclear Energy for the Propulsion of Aircraft (Project)
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
PER	program evaluation report
psig	pounds per square inch gauge
SEC	Special Exposure Cohort
SRDB Ref ID	Site Research Database Reference Identification (number)
U.S.C.	United States Code
§	section or sections

1.0 INTRODUCTION

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular Department of Energy (DOE) or Atomic Weapons Employer (AWE) facilities or categories of DOE or AWE facilities. They will be revised in the event additional relevant information is obtained about the affected DOE or AWE facility(ies). These documents may be used to assist NIOSH staff in the evaluation of Special Exposure Cohort (SEC) petitions and the completion of the individual work required for each dose reconstruction.

In this document the word “facility” is used to refer to an area, building, or group of buildings that served a specific purpose at a DOE or AWE facility. It does not mean nor should it be equated to an “AWE facility” or a “DOE facility.” The terms AWE and DOE facility are defined in sections 7384l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), respectively. An AWE facility means “a facility, owned by an atomic weapons employer, that is or was used to process or produce, for use by the United States, material that emitted radiation and was used in the production of an atomic weapon, excluding uranium mining or milling.” 42 U.S.C. § 7384l(5). On the other hand, a DOE facility is defined as “any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the [DOE] (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program);” and with regard to which DOE has or had a proprietary interest, or “entered into a contract with an entity to provide management and operation, management and integration, environmental remediation services, construction, or maintenance services.” 42 U.S.C. § 7384l(12). The Department of Energy (DOE) determines whether a site meets the statutory definition of an AWE facility and the Department of Labor (DOL) determines if a site is a DOE facility and, if it is, designates it as such.

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

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

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

1.1 PURPOSE

This document provides guidance for partial dose reconstructions for EEOICPA-covered employees who worked at the S-50 Oak Ridge Thermal Diffusion Plant (S-50) from July 9, 1944, through December 31, 1951.

1.2 SCOPE

Section 1.3 discusses the SEC applicable to S-50 employees. Section 2.0 describes the site and its operations. Section 3.0 provides guidance for the determination of occupational medical dose. Sections 4.0 through 6.0 discuss environmental, internal, and external dose, respectively. Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 7.0

1.3 SPECIAL EXPOSURE COHORT

The Secretary of the U.S. Department of Health and Human Services has designated a class of S-50 employees as an addition to the SEC based on the findings and recommendations of NIOSH and the Advisory Board on Radiation and Worker Health Board (Leavitt 2006):

July 9, 1944, through December 31, 1951

> *Employees of the Department of Energy predecessor agencies and their contractors or subcontractors who were monitored or should have been monitored while working at S-50 Oak Ridge Thermal Diffusion Plant (S-50) for a number of work days aggregating at least 250 work days during the period from July 9, 1944 through December 31, 1951, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.*

NIOSH has determined that there is insufficient information either to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class or to estimate the radiation doses of members of the classes more precisely than a maximum dose estimate (NIOSH 2006). However, NIOSH intends to use any available information to conduct partial dose reconstructions for this period for workers who do not meet the class definition. NIOSH has determined that only occupational medical dose can be reconstructed (NIOSH 2006). Partial dose reconstructions can be conducted using the information in this technical basis document.

2.0 <u>SITE DESCRIPTION</u>

2.1 S-50 OAK RIDGE THERMAL DIFFUSION PLANT

S-50 was a wartime uranium enrichment facility constructed in 1944 adjacent to the Oak Ridge Gaseous Diffusion Plant (K-25) in Oak Ridge, Tennessee, by H. K. Ferguson Company and operated by Fercleve Corporation, a wholly owned subsidiary of H. K. Ferguson Company that was organized for the sole purpose of operating the plant. Groundbreaking for the facility took place on July 9, 1944, and construction was complete on October 31, 1944. The main process building dimensions were 522 ft long by 62 ft wide by 75 ft high; the building had a concrete floor and foundation with steel frames, sides, and roof (MED 1947). The building housed 2,142 columns, each 48 ft tall and 5 in. in diameter. Uranium enrichment began on September 16, 1944, before construction was complete. Thermal diffusion operations shut down on September 9, 1945 (Prince 2005). Figure 2-1 shows the thermal diffusion plant and associated buildings.

Figure 2-1. S-50 plant (left of power plant for K-25) and auxiliary buildings (Fandom 2019).

The S-50 plant was originally intended to supply high concentrations of ^{235}U feed to the Y-12 Plant until the gaseous diffusion process at K-25 could get into large-scale production (Author unknown ca. 1947). However, in June 1945 S-50 feed material was first fed to K-25 instead of Y-12 (Author unknown ca. 1947). There was a tremendous amount of emphasis placed on high production output at this facility. Processed uranium from the plant was eventually used as feed material for the Y-12 facility, where it was further enriched; some of this material was used in the bomb dropped over Hiroshima ("Little Boy"). Operations at S-50 generally continued around the clock. The number of individuals Fercleve employed reached a maximum of 1,600 in April 1945 (MED 1947).

Feed material came from Harshaw Chemical Company of Cleveland, Ohio, in nickel shipping containers as uranium hexafluoride (UF_6). The liquid thermal diffusion process at S-50 increased ^{235}U enrichment from natural (0.71%) to 0.85% (MED 1947).

The process to enrich uranium at S-50 consisted of isotope separation columns, each of which contained three concentric pipes. One-hundred and two columns were arranged to form an operating unit called a rack (MED 1947). High-pressure (1,000-psig) steam passed through the innermost nickel pipe, which was inside a copper pipe. UF_6 was batch-charged into the gap between the nickel and copper pipes at about 1,500 psig. The nickel and copper pipes were inside the outermost steel pipe. Cold water passed between the steel pipe and the outer wall of the copper pipe. The enrichment process used convective flow, whereby the lighter ^{235}U molecules tended to move upward along the hot nickel pipe wall while the heavier ^{238}U molecules moved downward along the cold copper wall (MED 1947). A graph of the production output from S-50 (Percentage of Original Theoretical Maximum Output) showed the racks operated at less than 5% until January 1945, at which time the production increased gradually to a maximum of approximately 90% in June 1945 (MED 1947).

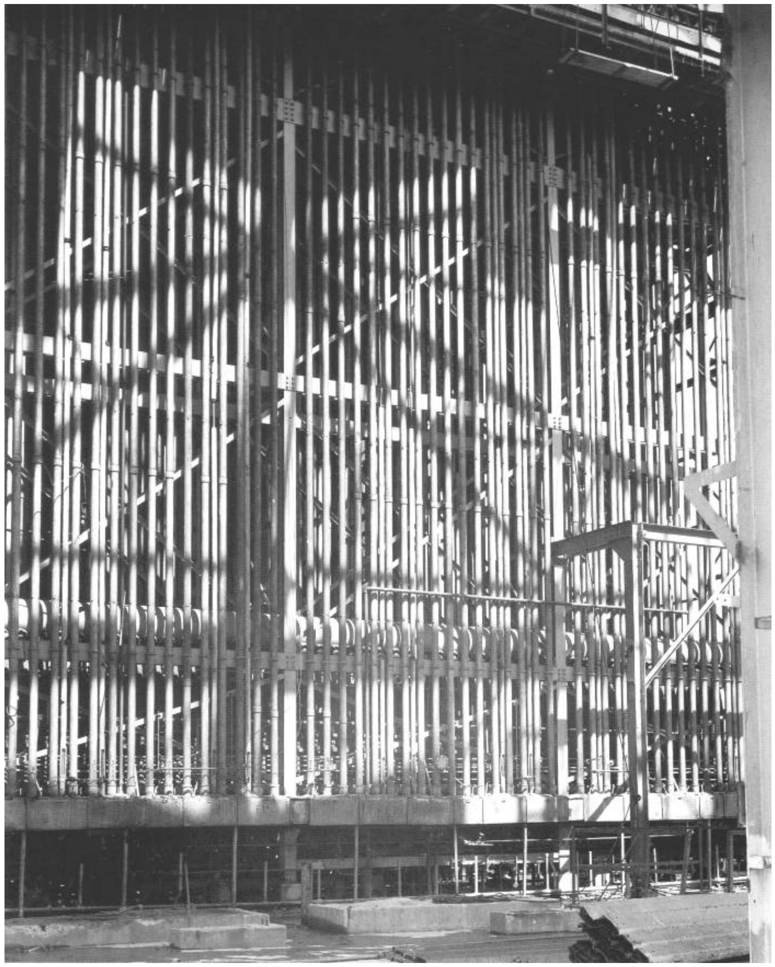

Figure 2-2. Isotope separation columns (Wikipedia 2019).

Losses of UF_6 were common during S-50 operations, with UF_6 often escaping into the air or cooling water (MED 1947). The losses usually resulted from internal or external breaks in columns or other parts of the process, which were caused by failure of the materials under the high operating pressures. Other losses resulted from improper handling of open connections and from operational mistakes due, in part, to the number of new employees at the facility and the emphasis on high production rates. From March through July 1945, monthly losses of UF_6 ranged from 247 to 1,826 lb (Prince 2005). Accountability records showing losses for other months of operation are unavailable. The released UF_6 would rapidly oxidize and form uranyl fluoride (UO_2F_2) (Prince 2005), which would either exhaust through the building roof or settle to the process building floor. Operators were required to have a gas mask on their persons at all times for emergencies (MED 1947).

The S-50 plant ceased enrichment operation in September 1945, shortly after the war ended (MED 1947). The uranium enrichment process at S-50 was unique in that it was the only production-scale liquid thermal diffusion facility ever built. S-50 closed because it had become evident that the liquid thermal diffusion process would not be competitive with the gaseous diffusion process. Once the

S-50 plant was placed in standby mode, the Carbide and Carbon Chemical Corporation assumed custody of the facility (MED 1945).

In 1946, Carbide and Carbon Chemical Corporation performed an inspection of the S-50 plant. Due to the cost, labor, and necessary security it would take to maintain the plant in standby mode, it was recommended that certain buildings not being used at the S-50 plant be dismantled for salvage (see Table 2-1) (Author unknown ca. 1947). A memorandum dated January 22, 1948 (Belcher 1948), reveals the main process building, F-01, had been demolished. Radiation surveys of the concrete floor slab revealed beta/gamma radiation was below the U.S. Atomic Energy Commission tolerance levels; however, fixed alpha contamination was present (Belcher 1948). It should be noted that the survey results of the slab were not attached to this document. The condition and the timeframe of the demolition of the remaining auxiliary buildings is unknown: Laboratory No. 1 (housed mass spectrometer equipment), Laboratory No. 2 (housed alpha-counting equipment), administration building, cafeteria, canteen, tank farm, change house (showers and lockers), machine shop, storage shed (stored raw material), warehouse, and switch house.

Table 2-1. S-50 building and/or equipment number and description.

Building and/or equipment number	Description
F-01	Main Process Building
F-02	Pump House
F-03	Water Treatment Plant
F-06	Boiler Plant
F-07	Materials and Conditioning Building
F-24	Propane Tank
F-25	Transfer Rack
F-26	Time Office
F-28	Time Office
F-29	Gasoline Filling Station
F-31	Inflammable Storage

2.2 NUCLEAR ENERGY FOR THE PROPULSION OF AIRCRAFT PROJECT

From May 1, 1946, through December 31, 1951, the S-50 facilities were used to conduct feasibility studies for the Nuclear Energy for the Propulsion of Aircraft (NEPA) project. The NEPA operations were conducted by Fairchild Engine and Aircraft Corporation (NIOSH 2006).

Documentation indicates that in 1950 NEPA was involved with Oak Ridge National Laboratory (ORNL) to (1) perform studies to delineate the most feasible types of supersonic aircraft nuclear power plants, (2) perform research aimed at solving the problems involved in the liquid-metal-cooled type of reactor with the aim of constructing a 1,000-kW prototype in Oak Ridge, and (3) exploratory research on problems of other reactor cycles that might be employed in future models (Ellis and Thompson 1950). In addition, joint ORNL-NEPA groups were established to develop the details of the shielding and control system designs (Ellis and Thompson 1950).

Additional information was obtained through the telephone interviews with S-50 claimants (NIOSH 2006) and one follow-up interview with an S-50 claimant (ORAUT 2006). It was learned from these interviews that S-50 (NEPA) employees fabricated blocks that contained enriched uranium and graphite as potential fuel for a nuclear-powered airplane. In addition, the employees recovered enriched uranium using nitric acid solutions. The recovered enriched uranium was used to fabricate the uranium and graphite blocks. One interviewee stated, “the place was highly radioactive given the enriched ^{235}U they were handling” (ORAUT 2006). According to documented interviews with other claimants, activation analysis studies might have taken place at S-50 on items that had been irradiated at ORNL. In addition, employees during this period might have been exposed to contamination remaining from the earlier liquid thermal diffusion projects in this facility. To date it is unknown which building or buildings on the S-50 grounds housed the NEPA project. Also unknown are the radiological conditions of the buildings occupied by NEPA employees.

3.0 OCCUPATIONAL MEDICAL DOSE

In October 1944, the Fercleve Corporation began its official medical program with preemployment and termination examinations performed at the Carbide and Carbon Chemicals Corporation dispensary. Preemployment physical examinations were required for all S-50 employees and included their medical history, a physical examination, blood and urine samples, and an X-ray of the chest (MED 1946). S-50 employees also received interval examinations, including a film of the chest, based on the employee's exposure to hazardous materials, but the frequency of these examinations is unknown (MED 1946). On termination, S-50 workers received a physical examination, blood and urine analysis, and a chest X-ray (MED 1946).

A review of medical records for S-50 employees did not reveal any medical X-ray examinations. However, X-ray information can be derived from K-25 knowledge because both plants shared the Carbide dispensary. NIOSH (2006) concluded that adequate reconstruction of medical dose for S-50 workers is possible by using assumptions that are favorable to claimants based on the information in the technical basis document for K-25 (ORAUT 2013) and by using applicable protocols in ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures* (ORAUT 2018).

Dose reconstructors should follow the guidance in the current version of ORAUT-TKBS-0009-3, *Oak Ridge Gaseous Diffusion Plant (K-25) – Occupational Medical Dose* (ORAUT 2013), and/or ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures* (ORAUT 2018) when evaluating the dose from X-rays for S-50 employees. It should be noted that the medical dispensary at K-25 did not have X-ray equipment available until October 1944 (MED 1946). Before this date, K-25 employees received their medical X-rays at the Oak Ridge Hospital in Oak Ridge, Tennessee (MED 1946). The dose from X-rays can be included from the Oak Ridge Hospital because it is a covered facility (ORAUT 2017). For July 9 through September 30, 1944, even though this time is before the inception of their official medical program, it is also assumed that S-50 workers received their medical X-rays at the Oak Ridge Hospital. For all years of employment, the frequency and type of procedures should be obtained from the current version of the technical basis document for K-25 (ORAUT 2013). Depending on the date of employment, dose values should be obtained from the documents listed in Table 3-1.

Table 3-1. X-ray guidance for S-50 workers.

Applicable dates	Facility	Document for dose values
07/09/1944–09/30/1944	Oak Ridge Hospital	ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures* (2018)
10/01/1944–12/31/1951	Oak Ridge Gaseous Diffusion Plant	ORAUT-TKBS-0009-3, *Oak Ridge Gaseous Diffusion Plant (K-25) - Occupational Medical Dose* (2013)

4.0 OCCUPATIONAL ENVIRONMENTAL DOSE

NIOSH determined in the SEC petition evaluation report (NIOSH 2006) that it lacks sufficient personnel monitoring, air monitoring, or source term data to adequately reconstruct any internal or external occupational exposures at the S-50 plant. As a consequence, NIOSH finds that it is not feasible to estimate with sufficient accuracy the radiation doses from internal or external ambient exposures at the S-50 plant.

5.0 OCCUPATIONAL INTERNAL DOSE

Review of the available information concludes that bioassays were not obtained during the years of concern (1944 to 1951). This conclusion is based on the lack of information on bioassays and monitoring and the recommendations for treatment of exposures to workers and medical personnel when a worker “breathed process material” (MED 1947; Various ca. 1945).

NIOSH determined in the SEC petition evaluation report (NIOSH 2006) that it lacks sufficient personnel monitoring, air monitoring, or source term data to adequately reconstruct the internal exposures at S-50. As a consequence, NIOSH finds that it is not feasible to estimate with sufficient accuracy the radiation doses from internal exposures during S-50 operations.

6.0 OCCUPATIONAL EXTERNAL DOSE

NIOSH considers the available external monitoring data and methods inadequate for performing external dose reconstruction at S-50. NIOSH determined in the SEC petition evaluation report (NIOSH 2006) that it lacks sufficient personnel monitoring, area monitoring, or source term data to adequately reconstruct the external exposures at S-50. As a consequence, NIOSH finds that it is not feasible to estimate with sufficient accuracy the radiation doses from external exposures during S-50 operations.

7.0 ATTRIBUTIONS AND ANNOTATIONS

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

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Wikipedia, 2019, image of isotope separation columns, Wikimedia Foundation, San Francisco, California. [SRDB Ref ID: 175496]

GLOSSARY

contamination
Radioactive material in undesired locations including air, soil, buildings, animals, and persons.

dose
In general, the specific amount of energy from ionizing radiation that is absorbed per unit of mass. Effective and equivalent doses are in units of rem or sievert; other types of dose are in units of rad, rep, or grays.

dose reconstruction
Process of analyzing the available information including evaluation of historical methods and data to estimate the dose a person could have received from one or more radiation exposures.

enrichment
Isotopic separation process that increases the percentage of a radionuclide in a given amount of material above natural levels. For uranium, enrichment increases the amount of ^{235}U in relation to ^{238}U. Along with the enriched uranium, this process results in uranium depleted in ^{235}U.

exposure
(1) In general, the act of being exposed to ionizing radiation. (2) Measure of the ionization produced by X- and gamma-ray photons in air in units of roentgens.

gaseous diffusion enrichment
Process by which uranium hexafluoride (UF_6) is filtered through a series of semipermeable molecular barriers to separate the lighter ^{235}U from the heavier, more naturally abundant ^{238}U.

gaseous diffusion plant
Facility where uranium hexafluoride (UF_6) gas is filtered to enrich the ^{235}U and separate it from ^{238}U. The process requires enormous amounts of electric power and results in an increase in ^{235}U enrichment from 1% to about 3%.

ionizing radiation
Radiation of high enough energy to remove an electron from a struck atom and leave behind a positively charged ion. High enough doses of ionizing radiation can cause cellular damage. Ionizing particles include alpha particles, beta particles, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, photoelectrons, Compton electrons, positron/negatron pairs from photon radiation, and scattered nuclei from fast neutrons.

liquid thermal diffusion
Uses the transfer of heat across a thin liquid to accomplish isotope separation. By cooling a vertical film on one side and heating it on the other, the lighter ^{235}U gas molecules will diffuse toward a hot surface, while the heavier ^{238}U gas molecule will diffuse toward a cold surface.

monitoring
Periodic or continuous determination of the presence or amount of ionizing radiation or radioactive contamination in air, surface water, groundwater, soil, sediment, equipment surfaces, or personnel (for example, bioassay or alpha scans). In relation to personnel, monitoring includes internal and external dosimetry including interpretation of the measurements.

occupational medical dose

Dose from X-ray procedures performed for medical screening of workers as part of an occupational health program. Doses from X-rays used to diagnose diseases or injuries, even if incurred on the job, are not considered occupational and are therefore not eligible to be included in dose reconstruction under the Energy Employees Occupational Illness Compensation Program Act of 2000.

radiation

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

radiograph

Static images produced on radiographic film by gamma rays or X-rays after passing through matter. In the context of the Energy Employees Occupational Illness Compensation Program Act of 2000, radiographs are X-ray images of the various parts of the body used to screen for disease.

X-ray

See *radiograph*.