

SEC Petition Evaluation Report Petition SEC-00137

Report Rev 0

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Subject Expert(s):	Lara Hughes
Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Qualification Date	DOE/AWE Facility Name
SEC-00137	83.13	February 17, 2009	Oak Ridge Hospital

Petitioner Class Definition

All workers who worked in any location at the Oak Ridge Hospital in Oak Ridge, Tennessee, from June 30, 1958 through December 31, 1959

Class Evaluated by NIOSH

All employees who worked in any location at the Oak Ridge Hospital in Oak Ridge, Tennessee, from May 15, 1950 through December 31, 1959

NIOSH-Proposed Class(es) to be Added to the SEC

All employees who worked in any location at the Oak Ridge Hospital in Oak Ridge Tennessee, for a number of work days aggregating at least 250 work days from May 15, 1950 through December 31, 1959, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
SEC00033	83.13	Oak Ridge Institute for Science and Education	Evaluation Completed

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
Revised Evaluation Report for Oak Ridge Institute for Nuclear Studies	Oak Ridge Institute for Science and Education

OCAS Health Physicist: Laura Hughes

Peer Review Completed By:	<u>[Signature on File]</u> <i>Lara Hughes</i>	<u>6/09/2009</u> <i>Date</i>
SEC Petition Evaluation Reviewed By:	<u>[Signature on File]</u> <i>J. W. Neton</i>	<u>6/12/2009</u> <i>Date</i>
SEC Evaluation Approved By:	<u>[Signature on File]</u> <i>Larry Elliott</i>	<u>6/15/2009</u> <i>Date</i>

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Evaluation Report Summary: SEC-00137, Oak Ridge Hospital

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addresses a class of employees proposed for addition to the Special Exposure Cohort (SEC) per the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 U.S.C. § 7384 *et seq.* (EEOICPA) and 42 C.F.R. pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

Petitioner-Requested Class Definition

Petition SEC-00137, qualified on February 17, 2009, requested that NIOSH consider the following class: *All workers who worked in any location at the Oak Ridge Hospital in Oak Ridge, Tennessee, from June 30, 1958 through December 31, 1959.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH expanded the petitioner-requested class for evaluation. NIOSH evaluated the following class: *All employees who worked in any location at the Oak Ridge Hospital in Oak Ridge, Tennessee, from May 15, 1950 through December 31, 1959.*

NIOSH-Proposed Class(es) to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes *all employees who worked in any location at the Oak Ridge Hospital in Oak Ridge Tennessee, for a number of work days aggregating at least 250 work days from May 15, 1950 through December 31, 1959, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.* The class under evaluation was expanded (see Section 3.0 below) because of the potential radiation exposures incurred by Oak Ridge Hospital personnel supporting the operations of the cancer hospital of the Oak Ridge Institute for Nuclear Studies (ORINS) Medical Division from 1950-1959. The NIOSH-proposed class dates correspond to the start of operations at the ORINS cancer hospital (May 15, 1950) and the end of the covered period for the Oak Ridge Hospital facility under EEOICPA.

Feasibility of Dose Reconstruction

Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it does not have access to sufficient information to: (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class; or (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. The information collected from all available resources is not sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specified period.

Health Endangerment Determination

NIOSH did not identify any evidence supplied by the petitioners or from other resources that would establish that the proposed class was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures. However, evidence indicates that some workers in the proposed class may have accumulated substantial chronic exposures through episodic intakes of radionuclides, combined with external exposures to gamma and beta radiation. Consequently, NIOSH has determined that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under their employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

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SEC Petition Evaluation Report for SEC-00137

ATTRIBUTION AND ANNOTATION: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by OCAS Health Physicist: Lara Hughes. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked in any location at the Oak Ridge Hospital in Oak Ridge, Tennessee, from May 15, 1950 through December 31, 1959. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

This report does not make any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH. This report also does not contain the final determination as to whether the proposed class will be added to the SEC (see Section 2.0).

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. pt. 83, and the guidance contained in the Office of Compensation Analysis and Support's (OCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services (HHS) add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.¹

42 C.F.R. § 83.13(c)(1) states: *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose.*

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, then NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation

¹ NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. pt. 82 and the detailed implementation guidelines available at <http://www.cdc.gov/niosh/ocas>.

during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). However, ORAU (formerly Oak Ridge Institute for Nuclear Studies, ORINS) has a conflict of interest for this site, since the former cancer research hospital operated by ORINS was closely affiliated with Oak Ridge Hospital. NIOSH therefore completed the evaluation itself, ORAU did not participate in this evaluation. Once completed, NIOSH provides the report to both the petitioner(s) and to the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.²

3.0 SEC-00137 Oak Ridge Hospital Class Definitions

The following subsections address the evolution of the class definition for SEC-00137, Oak Ridge Hospital. When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-proposed class. If some portion of the petitioner-proposed class is qualified, NIOSH will specify that class along with a justification for any modification of petitioner's class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00137, qualified on February 17, 2009, requested that NIOSH consider the following class for addition to the SEC: *all workers who worked in any location at the Oak Ridge Hospital in Oak Ridge, Tennessee, from June 30, 1958 through December 31, 1959.*

The petitioner provided information and statements in form of an affidavit in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Oak Ridge Hospital workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00137 for evaluation:

² See 42 C.F.R. pt. 83 for a full description of the procedures summarized here. Additional internal procedures are available at <http://www.cdc.gov/niosh/ocas>.

As identified in item F.1 of the SEC00137 Form B and discussed in a February 4, 2009 phone call, the petitioner asserted by affidavit that the energy employees who meet the proposed worker class at the Oak Ridge Hospital were not monitored for radiation exposure, despite working in the same work area where the Oak Ridge Institute for Nuclear Studies was located (Affidavit, 2009).

Based on its research and data capture efforts related to Oak Ridge Hospital and the Oak Ridge Institute for Nuclear Studies, NIOSH determined that it has access to very limited personnel monitoring data and source term information for Oak Ridge Hospital workers during the time period under evaluation and that these personnel monitoring and source term information records are not complete either for all time periods or for all radionuclides. NIOSH therefore concluded that there is sufficient documentation to support the petition basis that internal/external radiation exposures and radiation doses were not adequately monitored at Oak Ridge Hospital, either through personal monitoring or area monitoring during the evaluated period. The information and statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH expanded the petitioner-proposed class. Although the petitioner requested an evaluation date from June 30, 1958 through December 31, 1959, NIOSH decided that the evaluation should encompass the entire period during which the Oak Ridge Hospital was connected to the ORINS cancer research hospital. This was based on the preliminary information that that no personal internal or external monitoring data were available to NIOSH for any employee of the Oak Ridge Hospital while potentially in close contact to operations from ORINS, which used a large variety of radionuclides for internal and external cancer treatments of patients. Therefore, NIOSH defined the following class for further evaluation: all employees who worked in any location at the Oak Ridge Hospital in Oak Ridge, Tennessee, from May 15, 1950 through December 31, 1959. The NIOSH-evaluated class dates correspond to the start of operations at the ORINS cancer hospital (the first patient was admitted for treatment on May 15, 1950) and the end of the covered period for the Oak Ridge Hospital facility under EEOICPA (December 31, 1959), after which the Oak Ridge Hospital moved to a facility that was separate from ORINS.

3.3 NIOSH-Proposed Class(es) to be Added to the SEC

Based on its research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees who worked in any location at the Oak Ridge Hospital in Oak Ridge Tennessee, for a number of work days aggregating at least 250 work days from May 15, 1950 through December 31, 1959, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

As a standard practice, NIOSH completed an extensive database and Internet search for information regarding Oak Ridge Hospital. The databases searched included the DOE Legacy Management Considered Sites database, the DOE Office of Scientific and Technical Information (OSTI) database, the Energy Citations database, the Atomic Energy Technical Report database, and the Hanford Declassified Document Retrieval System. In addition to general Internet searches, the NIOSH Internet search included OSTI OpenNet Advanced searches, OSTI Information Bridge Fielded searches, Nuclear Regulatory Commission (NRC) Agency-wide Documents Access and Management (ADAMS) web searches, the DOE Office of Human Radiation Experiments website, and the DOE-National Nuclear Security Administration-Nevada Site Office-search. Attachment One contains a summary of Oak Ridge Hospital documents. The summary specifically identifies data capture details and general descriptions of the documents retrieved.

In addition to the database and Internet searches listed above, NIOSH identified and reviewed numerous data sources to determine information relevant to determining the feasibility of dose reconstruction for the class of employees under evaluation by determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. This included data requests to the present day Oak Ridge Hospital (Methodist Medical Center of Oak Ridge), the Oak Ridge Associated Universities, and the Tennessee Department for Environment and Conservation (TDEC). In addition, a records search was conducted at the National Archives and Records Administration in Atlanta, GA as well as a general search of the published scientific literature for worker exposures from handling of medical radioisotopes. The following subsections summarize the data sources identified and reviewed by NIOSH.

4.1 Site Profile Technical Basis Documents (TBDs)

NIOSH has not prepared a Site Profile to support dose reconstructions for the Oak Ridge Hospital site.

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. An ORAU Procedure provides specific requirements and guidance regarding EEOICPA project-level activities, including preparation of dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs and procedures as part of its evaluation:

- ORAUT-OTIB-0006, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, Rev. 03 PC-1; Oak Ridge Associated Universities, December 21, 2005; SRDB Ref ID: 20220
- ORAUT-PROC-0061, *Occupational X-Ray Dose Reconstruction for DOE Sites*; Rev. 02, January 2, 2008, SRDB Ref ID: 39338

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed three individuals; one was a retired physician from Oak Ridge Hospital and two were former employees of ORINS who were employed during the time when the facility was closely affiliated with Oak Ridge Hospital. The interviews were conducted via telephone by an OCAS Health Physicist and each interview lasted approximately 20 minutes. One interview was completed on the spot; two were completed after an initial phone call to set up a time convenient for the interviewee.

- Personal Communication, 2009, *Personal Communication with Retired Oak Ridge Hospital Physician*; Telephone Interview by NIOSH; February 17, 2009; SRDB Ref ID: 64061
- Personal Communication, 2009, *Personal Communication with Retired ORINS Scientist*; Telephone Interview by NIOSH; February 23, 2009; SRDB Ref ID: 64060
- Personal Communication, 2009, *Personal Communication with Retired ORINS Technician*; Telephone Interview by NIOSH; February 24, 2009; SRDB Ref ID: 64059

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH OCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of May 12, 2009)

Table 4-1: No. of Oak Ridge Hospital Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	17
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (May 15, 1950 through December 31, 1959)	12
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	10
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	0
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	0

NIOSH reviewed each claim, as well as transcripts from the computer-assisted telephone interviews (CATIs), to determine whether internal and/or external personal monitoring records could be obtained for the employee. Of the 12 claims that are within the evaluated period of this report, all have received responses to requests for site data, but none contained personnel monitoring information related to

employment at Oak Ridge Hospital. Of the 10 claims where the associated individual dose reconstructions have been completed, all 10 cases have been submitted to the Department of Labor (DOL).

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the evaluation of the proposed class. Sixty-four documents in this database were identified as pertaining to the Oak Ridge Hospital and 72 documents in the SRDB were identified as pertaining to the Oak Ridge Institute for Nuclear Studies. These documents were evaluated for their relevance to this petition. The documents include historical background on facility operations, the relationship between Oak Ridge Hospital and ORINS, the types and quantities of radionuclides used for medical applications and the extent of the radiological control program and personnel monitoring.

4.6 Other Technical Sources

The Oak Ridge Hospital was closely affiliated with the ORINS cancer hospital. Radiological activities conducted at the ORINS Cancer Hospital were not typical of operations for the DOE weapons complex. The facility conducted research in nuclear medicine, particularly for the treatment of cancer. Therefore, NIOSH also searched published nuclear medicine literature for evaluations of occupational exposure hazards in nuclear medicine and radiology during the 1950's. While there are numerous publications that would be relevant to the subject, NIOSH identified 8 documents that were used to evaluate the exposure potential encountered by Oak Ridge Hospital personnel. These included an article providing information concerning radioisotope hazards in medical applications from the ORINS cancer hospital. This report (Brucer, 1951), entitled *Radioisotope Hazards and Protection in a Hospital*, and published in the Journal of the American Medical Association, was authored by Dr. Marshall Brucer, head of the ORINS Medical Division at the time.

4.7 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following documents submitted by the petitioners:

- *Petition Form B including affidavit from Survivor and employment record of energy employee, January 14, 2009; OSA Ref ID: 107870*

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at the Oak Ridge Hospital from May 1950 to December 1959 and the information available to NIOSH to characterize particular operations and radioactive source materials. From available sources NIOSH has gathered operational and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing processes through which radiation exposures may have occurred

and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 Oak Ridge Hospital Operations Description

The Oak Ridge Hospital was a community hospital to provide medical services for the town of Oak Ridge, Tennessee. The original 50-bed hospital facility was completed in 1943 with the first patient being admitted in November of that year (Annual Report, 1951). Immediately upon completion, the hospital was expanded due to the rapidly increasing population of Oak Ridge, with the addition of three additional wings (two with 100 beds each, and one 60-bed wing), eventually reaching a capacity of 310 beds in 1945. Often up to 375 beds were simultaneously occupied as the facility operated above capacity. After the end of World War II, the hospital capacity was reduced to 250 beds due to the decreasing Oak Ridge population, and the 60-bed E-wing was placed in standby condition. The hospital staff was transferred from military to civilian status by January 1946 (Annual Report, 1951; MDH, 1946).

When it opened in 1943, the hospital was operated by the University of Rochester for the Manhattan Engineer District (MED), but in December 1943 the Roane-Anderson Company took over operations until December 1948, when the facility became Oak Ridge Hospital Inc. (Annual Report, 1951-1955; Oak Ridge Hospital, 1944). Until March 31, 1959 the Oak Ridge Hospital operated under contract AT-40-1-gen-252 with the Atomic Energy Commission (AEC) (AEC contract, 1952; Ford, 1960). In 1959 the hospital became privatized (i.e., operations ceased to be subsidized by the AEC), was moved to a new facility and was renamed the Oak Ridge Hospital of the Methodist Church.

Radiological operations at the Oak Ridge hospital consisted of routine hospital X-ray diagnostics and treatments, medical radioisotope applications (starting around 1952), and the support of operations of the cancer hospital operated by the Medical Division of the Oak Ridge Institute for Nuclear Studies (ORINS) from 1950-1959.

The radiology department of the Oak Ridge Hospital operated standard hospital X-ray equipment suitable for diagnostic radiography and fluoroscopy as well as for therapeutic applications. Based on the available annual reports, the number of treatments ranged from 11860 diagnostic and therapeutic treatments in 1951 to 13313 treatments in 1955, most of which were for diagnostic purposes (Annual Report, 1951, 1952, 1955).

In 1952 the AEC authorized Oak Ridge Hospital to use radiophosphorus (P-32) and radioiodine (I-131) for medical applications, and by 1954 a technician had been added to the staff to administer the radioisotope therapies (Annual Report 1952, 1954). The 1953 annual report also cites that studies using radium and Co-60 applicators were planned (Annual Report 1953). A radioactive materials license issued in 1956 permitted the Oak Ridge Hospital to use up to 10 mCi each of I-131 and P-32, and by 1959 the license had been expanded to the amounts listed in Table 5-1 (TDEC, 2009). No license information was located to indicate the quantities of medical isotopes that might have been in use before 1956. Table 5-1 lists the chemical forms and applications that were planned for medical isotopes at the Oak Ridge Hospital based on the information in the byproduct materials license.

Table 5-1: Medical Isotopes used by Oak Ridge Hospital 1956-1959

Nuclide	Max. Amount (mCi)	Chemical Form	Condition to be treated
I-131	25	Iodide	Thyroid function diagnosis and treatment of hyperthyroidism
I-131	1	Iodinated human serum albumin	Blood and plasma volume determination
I-131	1	Triolein and/or Oleic acid	Fat absorption studies
Au-198	100	Colloidal	Intercavity treatment of pleural effusions and/or ascites
P-32	12	Soluble Phosphate	Treatment of polycythemia vera, leukemia and lymphosarcoma
Cr-51	1	Chromate	Plasma volume and red cell mass determination. Labeling of erythrocytes
Co-60	1	Labeled Vitamin B-12	Diagnosis of pernicious anemia
I-192	200	Seeds encased in Nylon Ribbon	Interstitial treatment of cancer

The ORINS Medical division was established in 1948 to investigate new methods to treat cancer patients using internally and externally administered radioisotopes. For that purpose, the ORINS was assigned the unused E-wing of the Oak Ridge Hospital. An additional two-story expansion was added to one end of the E-wing, with the other end remaining connected to the Oak Ridge Hospital. By May 15, 1950 the ORINS clinical facility admitted its first patient (Pollard, 1948, 1980). Ever since the start of operations, the 30-bed ORINS hospital relied heavily on basic services provided by the much larger Oak Ridge Hospital, which included hospital staff performing duties at the ORINS facility and ORINS using the facilities of the Oak Ridge Hospital as needed. Contract agreements existed between the two facilities from 1950 to 1959, based on which the Oak Ridge Hospital provided the following services to the ORINS facility (Pollard 1955, 1956; AEC Contract, 1951; AEC Contract 1959):

- Physicians: provided services as needed; the pathologist and anesthesiologist each had a joint contract with both facilities.
- Nurses: were required to be specially trained in handling patients who had been injected with radioactive isotopes. In 1952 employment of part of the routine nursing staff was taken over by ORINS, but additional nursing staff could be drawn from the hospital as needed (ORINS, 1952).
- Housekeeping (maids, orderlies and janitorial staff): per contract agreement they were not to enter controlled areas at ORINS.
- Morgue and pathology facilities: required deceased patients to be taken into Oak Ridge Hospital facility. ORINS-related autopsies counted about 3 per month, but were “more involved” than regular post-mortem examinations (Brucer, 1951)
- Operating rooms: ORINS did not have its own operating room until 1955
- Diagnostic and therapeutic X-rays: ORINS patients received these treatments in the Oak Ridge Hospital radiology department
- Kitchen and dietary services: Oak Ridge Hospital kitchen was providing meals for ORINS patients
- General Services: pharmacy, blood bank, general hospital supply and routine medical laboratory services were all provided by the Oak Ridge Hospital
- Patient care if the patient could not suitably be cared for by ORINS facility, per contract stipulation the patient must not pose a radiological hazard.

In return, the Oak Ridge Hospital used the ORINS facility clinical chemical laboratory and the Co-60 teletherapy unit as needed for patient treatment. The two facilities had separate laundry services; the ORINS laundry was sent to the Oak Ridge National Laboratory for contamination checking and washing, while Oak Ridge Hospital used a commercial service.

Although the Oak Ridge Hospital's own radiological operations were limited to the radiology department, the close affiliation with the ORINS cancer research facility clearly provided a radioactive exposure potential for the part of the hospital staff who either worked in locations of the Oak Ridge Hospital that supported ORINS operations, such as kitchen, operating rooms, morgue and the radiology department, or worked in the ORINS facility itself per contract agreement (such as physicians, nurses, maids, janitors, etc.).

Beginning in 1950, the ORINS Medical Division employed a variety of experimental cancer treatment methods, either by internal administration of radioisotopes or by use of teletherapy devices (external application of radiation). During the first year of operations (1950-1951), a total of 18 different radioisotopes were used by ORINS, totaling almost 25 Ci of radioactivity (Brucer, 1951). Using the available data from ORINS annual and progress reports from 1950-1959 (ORISE, 1994, ORINS 1950-1959), the following list of operations was developed by NIOSH. Due to the large variety and experimental nature, the list may not contain all isotopes that may have been used in a given year.

Table 5-2: Major Activities of the ORINS Medical Division 1950-1959

Year	Activities (list may not be complete)
1950	<ul style="list-style-type: none"> • Radioiodine Treatment for thyroid cancer (I-131) • Gallium-72 administration for therapeutic uses and tracer studies, mainly for bone cancer • Administration of gold-198 for peritoneal and pleural metastases and bladder cancer • Therapeutic doses of radiophosphorus (P-32) for circulation studies and tumor uptake studies • Tracer studies using radiosulfur (S-35) • Studies with cobalt-56 and cobalt-57 labeled vitamin B-12 • Use of sodium-24 and potassium-42 for investigative studies
1951	<ul style="list-style-type: none"> • Radioiodine Treatment for thyroid cancer (I-131) • Use of cobalt-60 for teletherapy (200 Ci source) • Gallium-72 administration for therapeutic uses and tracer studies, mainly for bone cancer • Administration of Au-198 for peritoneal and pleural metastases and treatment of pleural effusions and ascites • Therapeutic doses of radiophosphorus (P-32) for circulation studies and tumor uptake studies • Tracer studies using radiosulfur (S-35) • Studies with cobalt-56 and cobalt-57 labeled vitamin B-12 • Use of sodium-24 and potassium-42 for investigative studies
1952	<ul style="list-style-type: none"> • Radioiodine treatment for thyroid cancer (I-131) • Use of cobalt-60 for teletherapy (200-curie source) • Gallium-67 and -72 ingestion for treatment of bone cancer • Administration of gold-198 for palliation of advanced neoplasms
1953	<ul style="list-style-type: none"> • Internal administration of a variety of radioisotopes, including: phosphorous-32, sulfur-35, potassium-42, iron-59, gallium-67, rubidium-86, yttrium-90, antimony-122, antimony-124, iodine-131, leutecium-177 and gold-198 • 800-curie cobalt-60 Irradiator (modified from 200-curie to 800-curie in July, 1952)

Year	Activities (list may not be complete)
1954	<ul style="list-style-type: none"> Internal administration of a variety of radioisotopes, including: phosphorous-32, potassium-42, gallium-67, rubidium-86, yttrium-90, yttrium-91, antimony-122, antimony-124, iodine-131, holmium-166, leutecium-177 and gold-198 A 300-600 curie cobalt-60 Teletherapy unit and a kilo-curie cesium-137 moving beam unit were used for external delivery of radiation.
1955	<ul style="list-style-type: none"> Internal administration of a variety of radioisotopes, including: phosphorous-32, chromium-51, iron-59, gallium-67, strontium-85, rubidium-86, yttrium-90, iodine-131, promethium-147, leutecium-177 and gold-198 A 300-600 curie cobalt-60 Teletherapy unit and a kilo-curie cesium-137 moving beam unit were used for external delivery of radiation. Thyroid uptake calibration program using barium-133 and cesium-137
1956	<ul style="list-style-type: none"> Internal administration of a variety of radioisotopes, including: phosphorous-32, gallium-67, yttrium-90, iodine-131, leutecium-177, and gold-198. A 300-600 curie cobalt-60 Teletherapy unit and a kilo-curie cesium-137 moving beam unit were used for external delivery of radiation. Thyroid uptake calibration program continued using barium-133 and cesium-137 Portable strontium-barium X-ray source
1957	<ul style="list-style-type: none"> Same as 1956
1958	<ul style="list-style-type: none"> Internal administration of a variety of radioisotopes, including: phosphorous-32, chromium-51, iron-59, gallium-67, yttrium-90, iodine-131, leutecium-177 and gold-198 A 300-600 curie cobalt-60 Teletherapy unit and a kilo-curie cesium-137 moving beam unit were used for external delivery of radiation Thyroid uptake calibration program continued using barium-133 and cesium-137 Portable strontium-barium X-ray source A leak occurred in the cobalt-60 Teletherapy unit Design of a whole-body counter Evaluation of the use of a radium source for treatment of carcinoma of the cervix
1959	<ul style="list-style-type: none"> Internal administration of a variety of radioisotopes, including: phosphorous-32, calcium-47, chromium-51, iron-59, copper-64, arsenic-74, yttrium-90, iodine-131, iodine-132, lanthanum-140, leutecium-177 and gold-198 Thyroid uptake calibration program continued using barium-133 and cesium-137 Continued design of a whole-body counter Construction and installation of a total body irradiator (The unit contained 8 – 500 curie cesium sources)

5.2 Radiological Exposure Sources from Oak Ridge Hospital Operations

The following subsections provide an overview of the internal and external exposure sources for the Oak Ridge Hospital class under evaluation.

5.2.1 Internal Radiological Exposure Sources from Oak Ridge Hospital Operations

No significant internal exposure potential existed at the Oak Ridge Hospital from the beginning of the covered period in 1943 to May 15, 1950, when ORINS operations started. Radioactive exposures during that time would have been external exposures to personnel involved with routine hospital radiology operations (diagnostic and therapeutic X-rays). With the startup of ORINS hospital operations in May 1950 and the start of a radioisotope laboratory in the Oak Ridge Hospital around 1952, internal exposures were possible as a result of the preparation, administration and disposal of medical radioisotope materials as well as the collecting and analyzing of samples, cleaning up spills and caring for patients who had been treated with these isotopes.

5.2.1.1 Radioiodine (I-131)

Iodine -131 is a beta and gamma emitter that concentrates in the thyroid gland and is mainly used for diagnostic and therapeutic treatments of thyroid conditions. The major concern for internal exposures from the isotopes used at Oak Ridge Hospital and ORINS would have been internal exposure from volatile I-131 compounds, which were limited to diagnostic applications at the Oak Ridge Hospital, but included a variety of therapeutic and experimental applications at the ORINS hospital starting with the first ORINS patient (Annual report, 1955; ORISE, 1994; ORINS 1954). The Oak Ridge Hospital was licensed to use up to 25 mCi of I-131 by 1959 (TDEC, 2009). At the ORINS facility, up to 69.7 mCi of I-131 were administered to a single patient in 1951 (ORISE, 1994; 1951 quarterly progress report, pg. 269) and the 1951 and 1958 ORINS annual reports (ORINS 1954, 1958) indicate that in those years the annual amounts of I-131 used were above 3000 mCi.

The potential for intakes of staff of nuclear medicine departments who administered radioiodine to patients has only been studied since the mid-1970's (Browning et al., 1978; Carey et al., 1979; Jönssen and Mattsson, 1998; Landon et al., 1980; Nishiyama et al., 1980). Since the article by Brucer (1951) clearly shows that ORINS was aware of some worker radiation exposures, the absence of thyroid counting for ORINS personnel indicates that the internal hazard to medical staff from volatile radioiodine must have been largely unknown at the time. As shown by Browning et al. (1978), the handling of I-131 preparations in mCi amounts can lead to significant airborne concentrations of I-131, potentially leading to the accumulation of I-131 in the thyroid of the worker handling solutions. It is therefore likely that Oak Ridge Hospital and ORINS staff involved with the preparing, administering and disposing of liquids containing I-131, and also from activities such as collecting samples from patients and cleaning up spills, received internal radioiodine exposures.

5.2.1.2 Other Isotopes from Oak Ridge Hospital and ORINS operations

By 1959, the Oak Ridge Hospital was licensed to use a small variety of internally and externally administered radioisotopes in the forms and quantities listed in Table 5-1 (TDEC 2009). The 1955 Oak Ridge Hospital annual report indicates that the number of patients treated was fairly small and that therefore the internal exposure potential from in-house operations other than from the use of radioiodine was likely limited.

The potential for internal exposures to the Oak Ridge Hospital personnel from ORINS operations was likely limited, but is impossible to quantify due to the large variety of isotopes in use and the experimental nature of their use in patient treatments. Most preparations used by ORINS were in liquid form, most radioisotopes used had short half-lives and the preparation of medicines containing radioisotopes for cancer treatment took place in fume hoods which were designed to prevent inhalation of fumes. However, the administration of medicines to patients orally or through injections; the control and disposal of biological waste (e.g., urine, feces, cancerous organs and other contaminated waste); and exposure to, and control of, airborne contaminants created during spills of radioactive medicines and biological waste could have created an internal exposure potential. Spills of radioactive fluids were not uncommon due to "unpredictable patient behavior" (Hayes, 1950). In addition, at least one incident is documented when a leak from the Co-60 teletherapy source caused significant surface contamination in the ORINS area (Brucer, 1960). The close association between ORINS and the Oak Ridge Hospital makes it impossible to conclude that only the ORINS staff could

have been exposed as a result of those activities. An example of specific concerns regarding exposures of personnel was described in a memorandum by Hayes (1950) that indicated the eating utensils used by ORINS patients left radioactive residues on the used dishes and utensils (which were subsequently returned to the kitchen at the Oak Ridge Hospital for cleaning). The use of operating rooms and morgue facilities by ORINS would have involved the handling and cleanup of a variety of fluids and solids from radioactive patients.

5.2.2 External Radiological Exposure Sources from Oak Ridge Hospital Operations

External exposures to personnel at Oak Ridge Hospital consisted of diagnostic and therapeutic X-Ray treatments of patients, the use of radioisotopes for medical treatments and the effect the ORINS operations had on the hospital facility by introducing radioactive patients or contaminated materials to the Oak Ridge Hospital facility. External exposures would have been due to photon and beta-emitting radionuclides only. There is no indication that any of the Oak Ridge Hospital or ORINS operations could have produced an exposure potential to neutrons; therefore neutron exposures are not considered in this evaluation.

5.2.2.1 Photon

The Oak Ridge Hospital radiology department performed standard diagnostic and therapeutic X-ray procedures on patients, the majority of which were for diagnostic applications. Exposures to workers in radiology departments have long been recognized and a recent analysis of historical exposures to radiology technicians in the United States from 1916 to 1984 has been published by Simon et al. (2006), who estimated that the median exposure to a hospital radiology technician in the 1950-1959 period was about 1.1 rem/year.

An additional exposure potential to Oak Ridge Hospital personnel from gamma-emitting radionuclides was introduced around 1952 by the radionuclides used in the radioisotope laboratory, which by 1959 likely included most or all of the isotopes listed in Table 5-2.

The ORINS facility used a large variety of beta and gamma-emitting radionuclides, almost all of which created an external exposure potential to workers and patients and some of which may have been introduced into the Oak Ridge Hospital facility over the course of routine operations. The major radioisotopes used by ORINS and the Oak Ridge Hospital and their respective decay energies are listed in Table 5-3 (Nuclides, 2009), with Ga-72, Au-198 and I-131 being the isotopes used in the largest quantities (Brucer, 1951; ORINS, 1954).

Table 5-3: Radioisotope Decay Characteristics

Isotope ^a	Half-life	Major Decay Type and Energy in MeV (decay fraction) ^b
P-32	14.26 d	Beta: 1.71 (1.00)
K-42	12.36 hr	Beta: 2.00 (0.176), 3.52 (0.819) Gamma: 1.524 (0.181)
Co-60	5.27 yr	Beta: 0.318 (0.999) Gamma: 1.173 (0.999), 1.332 (1.00)
Co-57	271.74 d	Gamma: 0.122 (0.856), 0.136 (0.107)
Ga-67	3.26 d	Gamma: 0.933 (0.388), 0.185 (0.214), 0.300 (0.166)
Ga-72	14.1 hr	Beta: 0.659 (0.15), 0.676 (0.217), 0.966 (0.277), 3.167 (0.103) Gamma: 0.630 (0.248), 0.834 (0.956), 2.202 (0.259), 2.508 (0.128)

Isotope ^a	Half-life	Major Decay Type and Energy in MeV (decay fraction) ^b
Rb-86	18.64 d	Beta: 1.77 (0.914) Gamma: 1.077 at < 10 % abundance
Y-90	64.0 hr	Beta: 2.280 (1.00)
Sb-122	2.72 d	Beta: 1.419 (0.667), 1.984 (0.261) Gamma: 0.564 (0.707)
Sb-124	60.2 d	Beta: 0.611 (0.512), 2.302 (0.232), Gamma: 0.603 (0.978), 0.723 (0.108), 1.691 (0.476),
Cs-137	30.08 yr	Beta: 0.513 (0.947) Gamma: 0.662 (0.851)
I-131	8.025 d	Beta: 0.606 (0.896) Gamma: 0.364 (0.815)
Eu-152	13.54 yr,	Gamma: 0.122 (0.287), 0.964 (0.147), 1.086 (0.102), 1.112 (0.137), 1.408 (0.211)
Eu-154	8.59 yr	Beta: 0.249 (0.286), 0.571 (0.363), 0.841 (0.168), 1.845 (0.100) Gamma: 0.123 (0.406), 0.723 (0.201), 0.873 (0.122), 0.996 (0.105), 1.004 (0.179), 1.274 (0.35)
Lu-177	6.65 d	Beta: 0.177 (0.116), 0.498 (0.794) Gamma: 0.208 (0.103)
Hf-183	1.07 hr	Beta: 1.152 (0.680), 1.550 (0.250) Gamma: 0.073 (0.380), 0.459 (0.270), 0.784 (0.660)
Ir-192	73.8 d	Beta: 0.539 (0.414), 0.675 (0.48) Gamma: 0.296 (0.287), 0.308 (0.297), 0.317 (0.827), 0.468 (0.478)
Au-198	2.695 d	Beta: 0.315 (0.990) Gamma: 0.412 (0.956)

^a Includes isotopes used in quantities exceeding 100 mCi/year by ORINS based on ORINS (1954, 1958), Brucer (1951)

^b Includes decay energies with decay fractions greater than 10 % (Nuclides, 2009), beta energies are endpoint.

In particular, the high-energy (> 2 MeV) gamma radiation of Ga-72 used in the early years of ORINS operation caused gamma exposure challenges at ORINS as discussed by Brucer (1951) and Hayes (1950). Both reported on Ga-72 gamma rays easily penetrating building walls, and Hayes (1950) reports on readily detectable radiation fields outside the hospital on the sidewalk resulting from patients treated with the isotope. Physicians and nurses who had to spend up to an hour per day near the patient were likely to exceed a weekly exposure limit of 300 mR (Brucer, 1951). The storage and disposal of patient urine samples also posed a problem because the samples were too radioactive for disposal in the sanitary sewer and had to be stored in a shielded space until some of the activity had decayed. The memorandum by Hayes (1950) also mentions that the Health Physics group at the ORNL voiced concerns about the occasionally “alarming” radiation intensities that were observed coming from the ORINS laundry. These contaminated items would have been handled by a nurse, maid or orderly before being sent to the laundry at ORNL, likely creating an external exposure potential to that worker.

External exposures to ORINS personnel were measured and documented in personnel records and in technical publications (Brucer 1951). In that article, external exposures were outlined for a three-month period from December 1950-February 1951 at the ORINS facility, as shown in Table 5-4 below.

Table 5-4: Routine Film Badge Exposures of Selected ORINS Personnel (Dec. 1950 – Feb. 1951)

Type of Employee	No. with Blank Badge	No. Exposed	Avg. mR/day Exposure		Largest Avg. Exposure in Group (mR/day)
			Open Window	Closed Window	
Staff (M.D. or Ph.D)	3	10	9.1	9.1	55.7
Part-time Staff	1	3	2.0	3.9	10.9
Technicians	2	9	10.3	11.9	28.5
Nurses	0	12	4.9	3.9	10.6
Nurse aides	0	6	4.1	3.7	5.9
Orderlies	0	2	12.2	11.4	15.9
Maids	0	2	1.8	1.8	3.1
Maintenance Men	4	3	0.6	0.6	0.6
Administrative	1	4	1.5	1.3	4.2
Total Personnel	11	51	6.1	6.1	55.7

Table 5-4 shows the dose levels measured for ORINS medical division personnel while working on ORINS projects. It is noteworthy that even the administrative personnel received non-zero external exposures. It is therefore likely that exposures would also be acquired by Oak Ridge Hospital staff who went to ORINS to provide services (such as the physicians, nurses and housekeeping staff), as well as by Oak Ridge Hospital staff supporting such activities as surgeries and post-mortem examinations of patients whom were brought into the Oak Ridge Hospital. Exposures during these procedures are also discussed by Brucer (1951) who lists the external exposures obtained by the surgeon and his support staff during several different types of surgeries and an autopsy on patients injected with various radioisotopes. These values are shown in Table 5-5 (adapted from reference). Since these data were acquired in 1950-1951, these procedures would have taken place in the Oak Ridge Hospital facility, since ORINS did not have an operating room until 1955 (Pollard, 1955).

Table 5-5: Exposures received during Surgical Procedure (mR/hr)

Operation	Surgeon			First Assistant			Assistant/Anesthetist		
	Left Hand	Right Hand	Total Body	Left Hand	Right Hand	Total Body	Left Hand	Right Hand	Total Body
Laparotomy ¹ , 5 mCi ⁷² Ga, 0.5 hr	n/a	n/a	20	n/a	n/a	20	n/a	n/a	20
Laparotomy, 100 mCi ¹⁹⁸ Au, lesser omentum, 2.5 hr	62	30	16	14	14	4	20	n/a	4
Laparotomy, 100 mCi, ¹⁹⁸ Au, peritoneal cavity, 2 hr	245	90	40	145	300	40	15	n/a	5
Implant Radium Needles, 45 mCi, 0.5 hr	1400	860	180	720	940	180	n/a	n/a	n/a
Autopsy 102 mCi ¹⁹⁸ Au, peritoneum, 1.3 hr	115	107	46	n/a	n/a	27	n/a	n/a	n/a
Pneumonectomy ¹ , 20 mCi ⁷² Ga, 2.5 hr	160	160	12						16

¹Laparotomy is a surgical procedure involving an incision through the abdominal wall to gain access to the abdominal cavity, pneumonectomy refers to the removal of the lung or part thereof.

5.2.2.2 Beta

Exposure to beta-emitting radionuclides was a result of the diagnostic and therapeutic administration of various beta and gamma-emitting radionuclides to patients as described in the previous section. Several radioisotopes with strong beta energies were used by ORINS and the Oak Ridge Hospital and the handling of preparations or fluids from patients who have received doses of beta-emitters would also contribute to the beta dose to the hands and eyes of the personnel handling these solutions. According to Brucer (1951), ORINS was aware of the situation and supplied palm and finger badges, wrist and forehead chambers for procedures that would involve extremity exposure, such as surgeries, autopsies, and preparations of new compounds. This is evident from the extremity data presented in Table 5-5.

5.2.3 Incidents

NIOSH did not identify any documented accidents at the Oak Ridge Hospital that resulted in exceptionally high personnel exposure levels (such as a criticality event). However, in 1958 a leak developed in one of the ORINS Co-60 teletherapy units located in the E-wing, which resulted in widespread contamination of the room and adjacent hallways. It is possible that this contamination also spread to the Oak Ridge Hospital, since the ORINS teletherapy room and the contaminated hallway were close to the connecting doors between the two facilities (and the doors were not “closed and sealed” until 6 days after the leak was discovered). The hallway surface contamination on the ORINS side ranged from 0.05 to 0.1 $\mu\text{Ci}/\text{ft}^2$. The report by Brucer (1960), which includes a floor plan of the area, details the efforts undertaken to clean a worker’s personal belongings (such as furniture) after it was found that the contamination had been tracked to the worker’s home. However there is no indication that contamination surveys were taken at the Oak Ridge Hospital side of the doors (which must have seen some foot traffic, based on the amount of services the Oak Ridge Hospital provided to ORINS). It is estimated that the leak started sometime between September 1-4 but was not discovered until September 8. The overall release in the form of Co-60 oxide was estimated to be less than 100 mCi (Brucer, 1960).

6.0 Summary of Available Monitoring Data for the Class Evaluated by NIOSH

The following subsections provide an overview of the state of the available internal and external monitoring data for the Oak Ridge Hospital class under evaluation.

6.1 Available Oak Ridge Hospital Internal Monitoring Data

NIOSH has searched the data resources listed in Section 4.0 of this report and has not located any internal monitoring data for Oak Ridge Hospital employees for the evaluated period either in the form of bioassay or air monitoring. No claimant files contain internal monitoring data and no information listed in the claimant CATI interviews indicated that internal monitoring was done for employment at the Oak Ridge Hospital. This is in agreement with the findings published by NIOSH in its evaluation report for SEC00033 (OSA 101295) for the ORINS Cancer Research Hospital, for which no internal monitoring data were located either. A report published after the 1958 Co-60 leak incident has limited

internal data, but that was limited to four individuals who received nasal swipes, urine bioassay and whole-body counting (and intakes were measured between 0.003 μCi to 0.18 μCi) (Brucer, 1960). The lack of routine internal monitoring data is consistent with the reports of Oak Ridge Hospital and ORINS employees who have stated there was no internal monitoring program during this period (Personal Communication, 2009a, 2009b, 2009c; NIOSH 2006).

6.2 Available Oak Ridge Hospital External Monitoring Data

NIOSH has reviewed the data sources listed in Section 4.0 of this report and has located only a very limited amount of external monitoring data for Oak Ridge Hospital employees for the evaluated period.

As early as 1946 the Manhattan Engineering District (MED) had ordered that the personnel of the radiology department should be monitored using 6 film badges supplied by ORNL, and that films should be exchanged and read weekly. The first distribution of these films to the hospital was to take place on April 29, 1946. The memorandum containing this information also stated that the resulting reports were to be sent to the MED, not to the Oak Ridge Hospital (Wirth, 1946). No reports on the results of these film badges have been located and it is not known for how long this practice was continued.

With the acquisition of a radioactive materials license, the Oak Ridge Hospital may have been required by the AEC to monitor for radioactive exposure, but based on memos included with the radioactive materials license, film badge service was only obtained in 1958 from ORNL. Monitoring appeared to have been limited to the radiology department personnel (TDEC, 2009). Searches for any of this monitoring information proved unsuccessful.

ORINS personnel were monitored for external radiation exposure as discussed in the SEC00033 Evaluation Report and in the article by Brucer (1951). The data included in ORINS claimant files contain records of external radiation exposure monitoring in the form of dose cards listing penetrating dose. The majority of the records list only an annual summary of external exposure, with a few exceptions for whom monthly film badge information is available. During the records investigation for ORINS cancer hospital, ORAU provided NIOSH a spreadsheet with annual external monitoring summaries for ORINS employees from 1950-1961. The spreadsheet addressed external exposures to 504 ORINS employees and contains only penetrating dose values. Those dose levels are shown in Table 6-1 for the 1950-1959 timeframe and indicate the exposure levels at ORINS. Limited whole-body and extremity exposure information is available from Brucer (1951), who discusses whole-body exposures as well as exposure to the hands of surgeons during a non-routine operation as outlined in Section 5. It appears that some of the Oak Ridge Hospital personnel were monitored under the ORINS program as well, based on name matching in the spreadsheet with information in the annual reports. As an example, ORINS and Oak Ridge Hospital shared the services of the pathologist and the anesthesiologist, and both were included in the ORINS external monitoring program. However, there are no external monitoring data for the general worker pool at the Oak Ridge Hospital who may have supported ORINS operations either in the Oak Ridge Hospital or the ORINS facility. This was corroborated in a telephone interview with a former Oak Ridge Hospital physician, who recalled that he routinely went to the ORINS facility to help out, but states that he was not monitored for radiation exposure (Personal Communication, 2009a).

Table 6-1: Summary of External Exposure Data at ORINS

Year	No. Employees Monitored	Lowest dose recorded (mrem)	Mean dose recorded (mrem)	Highest dose recorded (mrem)
1950	83	30	526	7051
1951	144	30	554	7310
1952	135	30	272	1090
1953	116	30	280	2675
1954	104	30	371	3901
1955	114	30	350	2330
1956	149	30	191	1210
1957	138	30	256	2305
1958	148	30	322	1360
1959	158	30	295	2215

Area monitoring of radiation fields was performed at ORINS on a routine basis to limit the radiation exposure from radioactive patients to workers, visitors and other patients. The nursing staff was specially trained in the use of the GM survey meter, which was calibrated to a 6.25 mR/hr “red” mark, above which limitations existed regarding access to patients. According to Brucer (1951) there were no restrictions to personnel working in areas below the 6.25 mR/hr limit. It is not clear if surveys of this nature were performed when patients or operations were transferred to the Oak Ridge Hospital.

6.3 Source Term Information

NIOSH reviewed available data sources for radiological source term information. Besides the Oak Ridge Hospital AEC license information (Table 5-2), the annual reports of the ORINS Medical Division contain listings of the radioisotopes used and the quantities handled in a given year. As an example, Table 6-1 identifies the isotopes and activities used by the Medical Division in 1951, 1954 and 1958 (Brucer, 1951, ORINS 1954, 1958). Table 6-2 shows the large variety of different isotopes that was in use at ORINS and how the types and quantities of isotopes used by ORINS changed as time progressed, with new isotopes included in the experimental treatments while others were abandoned. The major isotopes in use at the ORINS facility were Au-198, Ga-72, I-131 and Co-60; the latter was used for teletherapy applications (external irradiation of tissues or whole body).

Table 6-2: Isotopes Used by the ORINS Medical Division

Isotope	1951 Activity (mCi)	1954 Activity (mCi)	1958 Activity (mCi)
Antimony-121, 124		225	
Antimony-122	207		
Barium-133			8
Calcium-45		7	1
Carbon-14	5		
Cerium-presodymium-144			20
Cesium-134		10	
Cesium-137			5 plus 1500 sealed source
Chromium-51		8	19
Cobalt-56-57	10		
Cobalt-60	2220	275 Milligrams plus 450 Ci sealed source	1.3x10 ⁶

Isotope	1951 Activity (mCi)	1954 Activity (mCi)	1958 Activity (mCi)
Europium-152, 154		1.5	736
Gallium-67	1	2587.4	
Gallium-72	10920		
Gold-198	6858	8275	2680
Hafnium-183	100		
Holmium-166		64.3	
Indium-114	30		
Iron-59		3.65	6.25
Iodine-131	3715	1350	3698
Iodine-132			10
Lutecium-177		192	
Manganese-54	10		
Nickel-63	3		
Niobium-95			2
Phosphorus-32	110	472	289
Potassium-42	123	390	20
Promethium-147			20
Rubidium-86		145	20
Ruthenium-106	50	50	
Scandium-46			3
Sodium-24	90	12	23
Sulfur-35	114	2	63
Thulium			1
Yttrium-90		82.6	595
Yttrium-91		40	75
Zirconium-95	1		

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

The feasibility determination for the class of employees under evaluation in this report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(1). Under that Act and rule, NIOSH must establish whether or not it has access to sufficient 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 to members of the class more precisely than a maximum dose estimate. If NIOSH has access to sufficient information for either case, NIOSH would then determine that it would be feasible to conduct dose reconstructions.

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class. If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.5.

This approach is discussed in OCAS's SEC Petition Evaluation Internal Procedures which are available at <http://www.cdc.gov/niosh/ocas>. The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00137 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Oak Ridge Hospital Data

This subsection answers questions that need to be asked before performing a feasibility evaluation. Data Pedigree addresses the background, history, and origin of the data. It requires looking at site methodologies that may have changed over time; primary versus secondary data sources and whether they match; and whether data are internally consistent. All these issues form the bedrock of the researcher's confidence and later conclusions about the data's quality, credibility, reliability, representativeness, and sufficiency for determining the feasibility of dose reconstruction. The feasibility evaluation presupposes that data pedigree issues have been settled.

Performing internal and external dose reconstructions either requires worker monitoring data or sufficient source term and process information. It is possible to use coworker monitoring data as a means of calculating claimant-favorable and maximum potential radiation doses for class members who were unmonitored or have gaps in their monitoring records.

However, in the case of this evaluation, NIOSH has found that the lack of internal and external monitoring data in combination with a highly complex and varied source term are insufficient for estimating internal radiation doses with sufficient accuracy for members of the proposed class. Therefore, further evaluations of the pedigree of any of the data were not performed.

7.2 Evaluation of Bounding Internal Radiation Doses at Oak Ridge Hospital

The principal sources of internal radiation doses for members of the class under evaluation were the potential inadvertent inhalation and ingestion of radioactive contaminants as a result of the operation of a medical radioisotope laboratory at the Oak Ridge Hospital as well as the support operations that were provided to the ORINS cancer research facility by the Oak Ridge Hospital. These operations may have involved the following activities that could have created airborne contamination (especially from solutions containing radioiodine): (1) preparation of medicines containing radioisotopes for diagnoses and treatment of illnesses; (2) administration of medicines to patients either orally or through injections; (3) collection, control and disposal of biological waste (e.g., urine, feces, cancerous organs and other contaminated waste); and (4) patient care and cleaning up spills of radioactive medicines.

Any internal monitoring data would allow direct reconstruction of an individual claimant's internal dose, but as shown in Section 6.1, no internal monitoring data are available and there are no indications that workers were monitored for internal exposure except after the Co-60 source leak, which was an isolated incident. Also, no air monitoring data are available that could be used for the development of an internal exposure model. Lacking these data, NIOSH considered the sufficiency of source term and process data for developing an internal exposure model for Oak Ridge Hospital employees covered by this evaluation. As indicated in Section 6.3, a number of source terms existed at the ORINS facility and some data are available for the isotopes used in the radioisotope laboratory located in the radiology department (Table 5-1). Even though NIOSH has these source term data for 1950-1959, there is no information defining exactly how much activity of each isotope was used at what procedure and in what chemical forms the radioisotopes were present. There is no information that would allow estimating what types and quantities of radioisotopes could have been introduced into the Oak Ridge Hospital facility from ORINS activities. In lieu of bioassay data, this information is necessary to develop an exposure model with sufficient accuracy.

As a result of these limitations, NIOSH cannot establish a maximum internal exposure scenario that addresses all of the internal exposure potential for the petitioning class, and therefore cannot estimate internal doses for members of this class with sufficient accuracy.

7.3 Evaluation of Bounding External Radiation Doses at Oak Ridge Hospital

The principal source of external radiation doses for members of the proposed class was photon and beta exposures from: (1) patient diagnostic and therapeutic X-rays; (2) radioactive medicines prepared and administered to patients; (3) removal and disposal of cancerous organs containing activities of radioisotopes; (4) care of patients containing activities of radioisotopes; and (5) radiation-generating devices used in cancer research.

The available data indicate that there may have been some external monitoring of personnel in the radiology department at the Oak Ridge Hospital in 1946 and after 1958. No data have been located for the period under evaluation. All persons working at ORINS were monitored for external radiation exposure, as documented by Brucer (1951) and the summary data provided by ORAU. The latter included names and annual dose summaries from ~ 6 employees from the Oak Ridge Hospital (some last name match only) who went to the ORINS facility to provide services or treat patients, but these data are very limited and did not include all workers as indicated by the statements from an Oak Ridge Hospital physician (Personal Communication, 2009a). It is therefore not possible to conclude that all workers from the Oak Ridge Hospital who provided services to ORINS would have been included under the ORINS external monitoring program.

NIOSH has concluded in its earlier SEC00033 evaluation report that external dose information available for ORINS employees is sufficient to reconstruct external doses for ORINS workers, based on individual claimant data that are available and the summary spreadsheet that was provided by ORAU, which contained external annual summaries for deep dose measurements. It is therefore possible that external doses could be reconstructed for an Oak Ridge Hospital worker if that worker was included in the ORINS external monitoring program.

Indications are that workers in the radiology department of the Oak Ridge Hospital might have been monitored for external radiation exposure but these data were not available for dose reconstruction, since no records have been located. In this case it is possible for NIOSH to estimate a worker's dose based on available cohort data for X-ray technologists. External occupational doses to a cohort of radiologic technologists working in the United States from 1916 to 1984 have been estimated in a paper by Simon et al. (2006), who analyzed film badge data from hospitals over six decades. In this retrospective dose estimate, a radiology technician working during the period from 1950-1959 in a typical hospital radiology department was estimated to receive an annual median dose of 1.1 rem with a geometric standard deviation (GSD) of 0.39 rem. NIOSH can use this information to reconstruct doses to workers of the Oak Ridge Hospital radiology department.

However, since Oak Ridge Hospital personnel were also potentially exposed to an unknown amount of external radiation as a result of operations of the ORINS facility, NIOSH has concluded that there is insufficient information available that would allow it to bound the external dose to all workers of the Oak Ridge Hospital.

7.3.1 Medical X-Ray Dose

In most industrial facilities associated with operations of the nuclear weapons complex, workers received regular medical X-rays to screen for lung disease and occupational problems, and NIOSH is required to include the dose resulting from occupationally-required X-rays in a worker's dose reconstruction. Information about the type and frequency of such examinations is often included in the worker's files or confirmed during the worker phone interview. NIOSH's review of the current individual claims and additional information in the SRDB did not lead to the conclusion that workers at the Oak Ridge Hospital received routine annual X-ray examinations. Only one of the 17 claimants indicated that the deceased employee received occupational X-rays for employment related to the Oak Ridge Hospital. If such examinations took place, their frequency is unknown, but generally a hospital worker would not be expected to receive more than a single examination per year. In cases where available information exists that a worker received occupational X-rays, an upper bound for this exposure can be established using the procedure Occupational X-Ray Dose Reconstruction for DOE Sites (ORAUT-PROC-0061). NIOSH can reconstruct the medical X-ray dose for workers of the Oak Ridge Hospital with sufficient accuracy.

7.4 Evaluation of Petition Basis for SEC-00137

The following subsections evaluate the assertions made on behalf of petition SEC-00137 for the Oak Ridge Hospital.

7.4.1 Oak Ridge Hospital staff was not monitored for radiation exposure

SEC-000137: The petitioner made the assertion that workers employed at the Oak Ridge Hospital were not monitored for internal or external radiation exposure despite there being an exposure potential as a result of the operations at the ORINS facility, which was housed in the same work area as the Oak Ridge Hospital (OSA 107870).

NIOSH concurs with the petitioner's assertions that most Oak Ridge Hospital personnel were not monitored for radiation exposure. Although the Oak Ridge Hospital and the ORINS cancer hospital were separate organizations under separate contracts with the AEC, existing contract information indicates that the cooperation and sharing of facilities between the Oak Ridge Hospital and the ORINS facility were extensive and that based on the large quantity, variety and experimental nature of the ORINS operations there existed an exposure potential for some of the staff of the Oak Ridge Hospital, who were involved in support operations to ORINS. NIOSH has been unable to locate information that would allow it to bound the worker dose for workers of the Oak Ridge Hospital who worked from May 1950 to December 1959.

7.5 Summary of Feasibility Findings for Petition SEC-00137

This report evaluates the feasibility for completing dose reconstructions for employees at the Oak Ridge Hospital from May 1950 through December 1959. NIOSH found that the available monitoring records, process descriptions and source term data available are not sufficient to complete dose reconstructions for the evaluated class of employees.

Table 7-1 summarizes the results of the feasibility findings at Oak Ridge Hospital for each exposure source during the time period May 1950 through December 1959.

Table 7-1: Summary of Feasibility Findings for SEC-00137

(May 1950 through December 1959)

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal¹		X
- Radioiodine (I-131)		X
- various other radionuclides		X
External²		X
- Gamma	X (only X-ray technician)	X (except X-ray technicians)
- Beta		X
- Occupational Medical X-ray	X	

¹ Internal includes an evaluation of urinalysis (in vitro), airborne dust, and lung (in vivo) data (if available)

PARTIAL DOSE RECONSTRUCTION INFORMATION:

² EXTERNAL: Using the available ORINS external monitoring data for some of the Oak Ridge Hospital workers some external doses could be reconstructed in support of a partial DR for claims with non-presumptive cancers and those with less than 250-days of employment

As of May 15, 2009, a total of 12 claims have been submitted to NIOSH for individuals who worked at the Oak Ridge Hospital and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for 10 individuals (~83 %).

8.0 Evaluation of Health Endangerment for Petition SEC-00137

The health endangerment determination for the class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(3). Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. Section 83.13 requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

NIOSH has located no internal or external monitoring data or sufficiently detailed source term information to bound worker exposures at the Oak Ridge Hospital. An exposure potential was created by the hospital's radioisotope laboratory as well as the hospital's cooperation with the ORINS cancer treatment facility. NIOSH's evaluation determined that it is not feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy based on the sum of information available from available resources. Modification of the class definition regarding health endangerment and minimum required employment periods therefore is not required.

9.0 Class Conclusion for Petition SEC-00137

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees who worked in any location at the Oak Ridge Hospital in Oak Ridge Tennessee, for a number of work days aggregating at least 250 work days from May 15, 1950 through December 31, 1959, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.. The class under evaluation was expanded because NIOSH has determined that an exposure potential existed over the entire timeframe of the proposed class during which no monitoring data exist.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Database (SRDB), for information relevant to SEC-00137. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science.

Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining the feasibility or infeasibility of reconstructing dose for the class under evaluation.

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10.0 References

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42 C.F.R. pt. 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 2, 2002; SRDB Ref ID: 19392

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Table A1-1: Data Capture Synopsis for Oak Ridge Hospital			
Data Capture Information	Data Captured Description	Date Completed	Uploaded
Primary Site/Company Name: Oak Ridge Hospital (Methodist Medical Center of Oak Ridge), DOE 1943-1959 Other names: Oak Ridge Hospital, 1943-1948 Oak Ridge Hospital Inc. (1948-1959)	Negotiated with Ms. Lisa Hellard (Medical Records division) and Ms. Susan Hughes (HIM Director) of the Methodist Medical Center of Oak Ridge to determine the existence of personal monitoring data from Oak Ridge Hospital during the covered period.	04/13/2009	0
State Agency: Tennessee Department of Environment and Conservation (TDEC)	Entire folder with AEC radioactive materials license information for Oak Ridge Hospital from 1956-1963	04/01/2009	1
Comprehensive Epidemiologic Data Resource (CEDR)	No relevant data identified	03/10/2009	0
DOE Hanford Declassified Document Retrieval System (DDRS)	No relevant data identified	03/11/2009	0
DOE Open Net	Annual reports, contract information, operational history, radioisotope use and quantity (ORINS), facility details	04/14/2009	16
DOE OSTI Energy Citations	No relevant data identified	04/14/2009	0
DOE OSTI Information Bridge	No relevant data identified	04/14/2009	0
Google	Oak Ridge Hospital history information and current hospital newsletter.	04/28/2009	2

Table A1-1: Data Capture Synopsis for Oak Ridge Hospital			
Data Capture Information	Data Captured Description	Date Completed	Uploaded
NARA Atlanta	Contract information between Oak Ridge Hospital and ORINS, external monitoring memorandum, miscellaneous facility information, general operational history	04/28/2009	32
National Academies Press (NAP)	No relevant data identified	04/14/2009	0
National Nuclear Security Administration (NNSA) – Nevada Site Office	No relevant data identified	04/13/2009	0
NRC Agencywide Document Access and Management (ADAMS)	No relevant data identified	04/12/2009	0
ORAU (formerly ORINS)	ORINS annual reports	04/28/2009	2
U.S. Transuranium and Uranium Registries	No relevant data identified	04/15/2009	0
Unknown	ORINS annual external data summaries	06/20/2006	1
PubMed data base	Various scientific articles regarding worker exposure from radiology and handling medical radioisotopes	04/28/2009	8
TOTAL			62

Table A1-2: Database Searches for Oak Ridge Hospital

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
DOE Open Net http://www.osti.gov/opennet/advancedsearch.jsp	“Oak Ridge Hospital” (177), “Manhattan District Hospital (2)”, US Army + Hospital (964), “Oak Ridge Institute for Nuclear Studies” (1347), ORINS (354), AEC + hospital (1910), “Oak Ridge Hospital” + ORINS (190), “Oak Ridge Hospital”+ contract (830), “AT-40-1-gen-252” (0), “AT-40-1-gen-33” (5), Annual report + “Oak Ridge” (1166), Brucer (author) (54), Pollard (author) (51) ORAU* (Document number) (25), ORINS* (document number) (6)	7081	16
DOE Hanford Declassified Document Retrieval System (DDRS)	“Oak Ridge Hospital” “Oak Ridge” “Oak Ridge Institute for Nuclear Studies” ORINS	0	0

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
DOE OSTI Energy Citations http://www.osti.gov/energycitations/	“Oak Ridge Hospital” (1897), “Manhattan District Hospital” (212), US Army + Hospital (1124), “Oak Ridge Institute for Nuclear Studies” (13479), “Oak Ridge Institute for Nuclear Studies”+ 1943-1959 (267) “Oak Ridge Hospital” + ORINS (34), “Oak Ridge Hospital”+ contract (1518), “AT-40-1-gen-252” (0), “AT-40-1-gen-33” (26), Annual report + “Oak Ridge”, + 1943-1959 (277), Brucer (author) (75), Pollard W. G. (author) (44) ORAU* (document number) (403), ORINS* (ID number) (34)	> 10,000	0
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp	“Oak Ridge Hospital” (1790), “Manhattan District Hospital” (25), US Army + Hospital (1049), “Oak Ridge Institute for Nuclear Studies” (13130), “Oak Ridge Institute for Nuclear Studies”+1943-1959 (254) “Oak Ridge Hospital” + ORINS (32), “Oak Ridge Hospital”+ contract (1510), “AT-40-1-gen-252” (0), “AT-40-1-gen-33” (0), Annual report + “Oak Ridge”+1943-1959 (207), Brucer (author) (0), Pollard W. G. (author) (1) ORAU* (Document number) (0), ORINS* (document number) (33)	> 10,000	0

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
Google www.google.com Search based on standard list of keywords used for all data capture searches	americium OR Am241 OR Am-241 OR "AM 241" OR 241Am OR 241-Am OR "241 Am" AND "Oak Ridge Hospital"	12	2
	ionium OR Th230 OR Th-230 OR "Th 230" OR 230Th OR 230-Th OR "230 Th" AND "Oak Ridge Hospital"	2	
	neptunium OR Np237 OR Np-237 OR "Np 237" OR 237Np OR 237-Np OR "237 Np" AND "Oak Ridge Hospital"	7	
	polonium OR Po210 OR Po-210 OR "Po 210" OR 210Po OR 210-Po OR "210 Po" AND "Oak Ridge Hospital"	53	
	thorium OR Th232 OR Th-232 OR "Th 232" OR 232Th OR 232-Th AND "Oak Ridge Hospital"	22	
	"232 Th" OR "Z metal" OR myrnalloy OR "chemical 10-66" OR "chemical 10-12" AND "Oak Ridge Hospital"	0	
	ionium OR UX1 OR UX2 OR Th-230 OR Th230 OR "Th 230" OR 230-Th OR "230 Th" AND "Oak Ridge Hospital"	2	
	230Th OR Th-234 OR Th234 OR "Th 234" OR 234-Th OR 234Th OR "234 Th" AND "Oak Ridge Hospital"	1	
	tritium OR H3 OR H-3 OR mint OR HTO AND "Oak Ridge Hospital"	254	
	uranium OR U233 OR U-233 OR "U 233" OR 233U OR 233-U OR "233 U" AND "Oak Ridge Hospital"	469	
U234 OR "U 234" OR U-234 OR 234U OR 234-U OR "234 U" AND "Oak Ridge Hospital"	3		

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
	U235 OR "U 235" OR U-235 OR 235-U OR 235U OR "235 U" OR U238 AND "Oak Ridge Hospital "	18	
	"U 238" OR U-238 OR 238-U OR 238U OR "238 U" AND "Oak Ridge Hospital"	6	
	U308 OR "U 308" OR U-308 OR 308-U OR 308U OR "308 U" OR "uranium extraction" OR "black oxide" OR "brown oxide" AND "Oak Ridge Hospital"	3	
	"green salt" OR "orange oxide" OR "yellow cake" OR UO2 OR UO3 AND "Oak Ridge Hospital"	6	
	UF4 OR UF6 OR C-216 OR C-616 OR C-65 OR C-211 OR U308 AND "Oak Ridge Hospital"	6	
	plutonium OR Pu-238 OR Pu238 OR "Pu 238" OR 238Pu OR 238-Pu OR "238 Pu" AND "Oak Ridge Hospital "	169	
	Pu-239 OR Pu239 OR "Pu 239" OR 239Pu OR 239-Pu OR "239 Pu" AND "Oak Ridge Hospital"	7	
	Pu-240 OR Pu240 OR "Pu 240" OR 240Pu OR 240-Pu OR "240 Pu" AND "Oak Ridge Hospital"	3	
	Pu-241 OR Pu241 OR "Pu 241" OR 241Pu OR 241-Pu OR "241 Pu" AND "Oak Ridge Hospital"	2	
	radium OR Ra-226 OR Ra226 OR "Ra 226" OR 226-Ra OR 226Ra OR 226-Ra AND "Oak Ridge Hospital"	359	
	Ra-228 OR Ra228 OR "Ra 228" OR 228Ra OR 228-Ra OR "228 Ra" AND "Oak Ridge Hospital"	2	
	radon OR Rn-222 OR Rn222 OR "Rn 222" OR 222Rn OR 222-Rn OR "222 Rn" AND "Oak Ridge Hospital"	329	

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
	thoron OR Rn-220 OR Rn220 OR "Rn 220" OR 220Rn OR 220-Rn OR "220 Rn" AND "Oak Ridge Hospital"	3	
	protactinium OR Pa-234m OR Pa234m OR "Pa 234m" OR 234mPa OR 234m-Pa OR "234m Pa" AND "Oak Ridge Hospital"	2	
	strontium OR Sr-90 OR Sr90 OR "Sr 90" OR 90-Sr OR 90Sr OR "90 Sr" AND "Oak Ridge Hospital"	23	
	oralloy OR postum OR tuballoy OR "uranyl nitrate hexahydrate" OR UNH OR K-65 OR "sump cake" AND "Oak Ridge Hospital"	9	
	"uranium dioxide" OR "uranium tetrafluoride" OR "uranium trioxide" AND "Oak Ridge Hospital"	6	
	"uranium hexafluoride" OR "air count" AND "Oak Ridge Hospital"	9	
	accident AND "Oak Ridge Hospital"	516	
	"air dust" OR "air filter" OR "airborne test" AND "Oak Ridge Hospital"	2	
	"alpha particle" OR "belgian congo ore" OR bioassay OR bio-assay AND "Oak Ridge Hospital"	10	
	breath OR "breathing zone" OR BZ OR calibration OR "chest count" OR collimation OR columnation AND "Oak Ridge Hospital"	571	
	contamination OR curie OR denitration OR "denitration pot" AND "Oak Ridge Hospital"	103	
	derby OR regulus OR dose OR dosimeter AND "Oak Ridge Hospital"	491	
	dosimetric OR dosimetry OR electron OR environment AND "Oak Ridge Hospital"	452	

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
	"Ether-Water Project" OR exposure OR "exposure investigation" OR "radiation exposure" AND "Oak Ridge Hospital"	350	
	external OR "F machine" OR fecal OR "feed material" OR femptocurie OR film OR fission OR fluoroscopy AND "Oak Ridge Hospital"	208	
	"Formerly Utilized Sites Remedial Action Program" OR FUSRAP OR gamma-ray OR "gas proportional" OR "gaseous diffusion" AND "Oak Ridge Hospital"	111	
	Health OR "health instrument" OR "health physics" OR "H.I." OR HI OR HP OR "highly enriched uranium" OR HEU AND "Oak Ridge Hospital"	68,600	
	hydrofluorination OR "in vitro" OR "in vivo" OR incident OR ingestion OR inhalation OR internal AND "Oak Ridge Hospital"	517	
	investigation OR isotope OR isotopic OR "isotopic enrichment" OR "JS Project" OR Landauer OR "liquid scintillation" AND "Oak Ridge Hospital"	292	
	log OR "log sheet" OR "log book" OR "low enriched uranium" OR LEU AND "Oak Ridge Hospital"	158	
	"maximum permissible concentration" OR MPC OR metallurgy OR microcurie OR millicurie AND "Oak Ridge Hospital"	153	
	"mixed fission product" OR MFP OR monitor OR "air monitoring" OR nanocurie OR "nasal wipe" OR neutron OR "nose wipe" AND "Oak Ridge Hospital"	234	
	nuclear OR Chicago-Nuclear OR "nuclear fuels" OR "nuclear track emulsion" OR "type A" AND "Oak Ridge Hospital"	1490	

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
	NTA OR "occupational radiation exposure" OR occurrence OR "ore concentrate" OR "PC Project" AND "Oak Ridge Hospital"	85	
	permit OR "radiation work permit" OR "safe work permit" OR "special work permit" OR RWP OR SWP AND "Oak Ridge Hospital"	165	
	"phosphate research" OR photofluorography OR photon OR picocurie OR pitchblende OR "pocket ion chamber" OR PIC OR problem OR procedure AND "Oak Ridge Hospital"	456	
	radeco OR radiation OR radioactive OR radioactivity OR radiograph OR radiological AND "Oak Ridge Hospital"	648	
	"Radiological Survey Data Sheet" OR RSDS OR radionuclide OR raffinate OR reactor AND "Oak Ridge Hospital"	575	
	respiratory OR "retention schedules" OR roentgen AND "Oak Ridge Hospital"	506	
	sample OR "air sample" OR "dust sample" OR "general area air sample" AND "Oak Ridge Hospital"	151	
	"solvent extraction" OR source OR "sealed source" OR spectra OR spectrograph OR spectroscopy AND "Oak Ridge Hospital"	580	
	spectrum OR standard OR "operating standard" OR "processing standard" AND "Oak Ridge Hospital"	993	
	survey OR "building survey" OR "routine survey" OR "special survey" OR "technical basis" AND "Oak Ridge Hospital"	304	

Database/Source	Keywords (Hits per keyword)	Total Hits	Uploaded
	"thermal diffusion" OR "thermoluminescent dosimeter" OR TLD OR "Tiger Team" AND "Oak Ridge Hospital"	19	
	"tolerance dose" OR urinalysis OR urine OR "whole body count" OR WBC AND "Oak Ridge Hospital"	1160	
	"working level" OR WL OR X-ray OR "X ray" OR Xray OR "x-ray screening" AND "Oak Ridge Hospital"	585	
National Academies Press (NAP) http://www.nap.edu	"Oak Ridge Hospital" (253), "Oak Ridge"+Hospital (6)	259	0
National Nuclear Security Administration (NNSA) – Nevada Site Office www.nv.doe.gov/main/search.htm	"Oak Ridge Hospital" "Oak Ridge" + Hospital	0	0
NRC Agencywide Document Access and Management (ADAMS) http://www.nrc.gov/reading-rm/adams/web-based.html	"Oak Ridge Hospital" (20) "Oak Ridge" (1000+) "Oak Ridge" + Hospital (0) "Oak Ridge" and contract (0) ORINS and contract (1000+)	> 1,000	0
U.S. Transuranium and Uranium Registries http://www.ustur.wsu.edu/	"Oak Ridge Hospital" (0) "Oak Ridge" (19)	19	0
PubMed data base http://www.ncbi.nlm.nih.gov/pubmed/	Radioisotope + hospital + 1943-1959 Nuclear Medicine + I-131 + 1950-1980, Radioiodine + thyroid Radiology Radiologic technologist	> 10,000	8