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Feed Materials Production Center – Introduction

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PUBLICATION RECORD

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02/14/2004	00	New Technical Basis Document for the Department of Energy Fernald Environmental Management Project - Introduction. Incorporates formal internal and NIOSH review comments. First approved issue. Initiated by Terry A. Kuykendall.
03/17/2004	01	Approved issue of Revision 01. Incorporates formal internal and NIOSH review comments. Initiated by Terry A. Kuykendall.
08/05/2016	02	Revision initiated to change title to Feed Materials Production Center, to add Special Exposure Cohort information, and to incorporate minor changes and corrections to ensure consistency across this site profile. Includes editorial changes. 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 Billy P. Smith and Karen S. Kent.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
AWE	atomic weapons employer
CFR	Code of Federal Regulations
DCAS	Division of Compensation Analysis and Support
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
EA	Exposure Area
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
FMPC	Feed Materials Production Center
gal	gallon
lb	pound
MTU	metric tons of uranium
NIOSH	National Institute for Occupational Safety and Health
NLO	National Lead Company of Ohio
ORAU	Oak Ridge Associated Universities
RMI	Reactive Metals, Inc.
SEC	Special Exposure Cohort
SRDB Ref ID	Site Research Database Reference Identification (number)
TBD	technical basis document
U.S.C.	United States Code
§	section or sections

1.1 INTRODUCTION

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide 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

1.1.1 Purpose

This technical basis document (TBD) introduces the Feed Materials Production Center (FMPC) site profile and provides specific information concerning documentation of historic radiological practices at the Fernald, Ohio, facility. Since operations ended in 1988, the Fernald site has been variously named the Fernald Environmental Management Project, the Fernald Closure Project, and is now the Fernald Preserve. The site profile can be used by dose reconstructors to evaluate internal and external dosimetry data for unmonitored and monitored workers and can serve as a supplement to, or substitute for, individual monitoring data. This document provides a site profile of FMPC that contains technical basis information to be used by the Oak Ridge Associated Universities (ORAU) Team to evaluate the total occupational radiation dose for EEOICPA claimants. It provides information on buildings, operations, site conditions, modes and methods of potential radiological exposure, and inferred best estimates of dose parameters where data are missing or might be inaccurate.

In addition, this document provides supporting technical data to evaluate, with assumptions favorable to claimants, the total Fernald occupational radiation dose that can reasonably be associated with worker exposures. This dose results from exposure to external and internal radiation sources in Fernald buildings, occupationally required diagnostic X-ray examinations, and onsite environmental releases. The discussion includes the doses that workers could have incurred while not monitored as well as doses that could have been missed for other reasons. The information in this site profile has been assembled to assist in the evaluation of worker dose from FMPC processes and activities using the methodology in the OCAS-IG-001, *External Dose Reconstruction Implementation Guideline* (NIOSH 2007) and OCAS-IG-002, *Internal Dose Reconstruction Implementation Guideline* (NIOSH 2002).

1.1.2 Scope

This site profile consists of the latest versions of six TBDs: this Introduction, Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dose. Each TBD contains supporting tables and attachments as necessary. This Introduction provides information about SEC classes relevant to FMPC and a summary description of the remaining TBD sections.

1.1.3 Special Exposure Cohort

The Secretary of the U.S. Department of Health and Human Services has designated three classes of employees at Fernald as additions to the SEC:

Thorium, 1968 through 1978

> *All employees of DOE, its predecessor agencies, and their contractors, or subcontractors who worked at the Feed Materials Production Center in Fernald, Ohio, from January 1, 1968 through December 31, 1978, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees included in the SEC* (Sebelius 2012).

It was determined that NIOSH lacked sufficient information to allow it to estimate with sufficient accuracy the potential internal doses from exposure to thorium, to which employees at this facility may have been subjected (Sebelius 2012).

Thorium, 1954 through 1967

> *All employees of the DOE, its predecessor agencies, and their contractors and subcontractors who worked at the Feed Materials Production Center in Fernald, Ohio,*

> *from January 1, 1954, through December 31, 1967, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort* (Sebelius 2013a).

It was determined that NIOSH lacked sufficient information to allow it to estimate with sufficient accuracy the potential internal doses from exposure to thorium, to which employees working at this facility may have been subjected (Sebelius 2013a).

Uranium, 1951 through 1983 [applies only to subcontractors]

> *All employees of the Feed Materials Production Center in Fernald, Ohio, who were not employed by National Lead of Ohio, NLO, or the Department of Energy or its predecessor agencies, who worked at FMPC from January 1, 1951, through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort* (Sebelius 2013b).

It was determined that NIOSH lacked sufficient information to allow it to estimate with sufficient accuracy the potential internal doses from exposure to uranium, to which some employees of FMPC working at this facility may have been subjected.

This dose reconstruction infeasibility for the period from 1951 through 1983 applies only to subcontractors. NIOSH has access to an electronic dataset that contains the results of the uranium urinalysis bioassay program for all years of FMPC operations, and the overwhelming majority of employees of the prime contractor National Lead Company of Ohio (later named NLO) have results in the bioassay dataset. However, the dataset does not contain bioassay results for employees of companies other than the prime contractor (i.e., non-prime contractor employees). NIOSH has obtained a limited number of bioassay samples from non-prime contractor employees through data captures, but cannot be certain that all non-prime contractor employee bioassay data were retained by the site or captured by data capture efforts. In addition, there are some reasons to conclude that the prime contractor did not consistently evaluate whether non-prime contractor employees should be monitored for radiation exposure because of the transitory nature of their work (Sebelius 2013b).

Dose reconstruction guidance in this document for the period from January 1, 1954, to December 31, 1983, is presented to provide a technical basis for partial dose reconstructions for claims not compensated under the SEC (i.e., nonpresumptive cancers and SEC employment less than 250 days). Although it is not possible to completely reconstruct internal radiation doses for all workers for this period, NIOSH has determined, and the U.S. Department of Health and Human Services has concurred, that it is feasible to reconstruct external radiation doses for all FMPC workers for this period (Sebelius 2013b).

1.2 SUMMARY

Section 2.0, Site Description (ORAUT 2014a), describes the buildings and processes that have been used at the Fernald site for the manufacture and development of nuclear materials. It includes discussion of remediation activities after the cessation of operations.

FMPC operations played an important role in the U.S. nuclear weapons program and were instrumental in the nuclear materials production process. The processes conducted at FMPC included nuclear material processing and machining, fuel fabrication, radiochemical processing, and waste management.

During the Cold War, the Fernald site produced high-purity uranium metal products for the nation's weapons production program. The site's history began in 1951, when the U.S. Atomic Energy Commission (AEC) awarded a $113 million contract to the George A. Fuller Company of New York to construct a uranium processing plant on a 1,050-acre parcel of land 18 miles from Cincinnati, Ohio. The AEC also contracted the Catalytic Construction Company as the architectural and engineering design firm for the site.

Fernald had a primary mission to produce high-purity uranium metal products in the form of ingots, derbies, billets, and fuel cores for other sites in the nuclear weapons complex. Some sites used the products as fuel for nuclear reactors to produce plutonium. The Fernald site was a uranium processing facility; it did not contain a nuclear reactor, and it did not produce or handle explosive devices, nuclear weapons, or significant quantities of highly radioactive material.

The AEC awarded a prime contract in 1951 to National Lead Company of Ohio (NLO), a wholly owned subsidiary of National Lead Company, to manage and operate the site. In 1986, DOE awarded the management contract to Westinghouse Materials Company of Ohio, a subsidiary of Westinghouse Electric Corporation.

Five months after the May 1951 groundbreaking, NLO initiated operations on a plant-by-plant basis. As construction of each production plant was completed, NLO tested the processes and started operations. In October 1951, the Pilot Plant became the first production plant to operate; all plants were fully operational by 1954. By the time construction was complete, 19 acres of the 136-acre production area were under roof, 4 miles of railroad tracks were installed, and 24 acres of paved roads and storage areas were constructed, equivalent to a 20-mile stretch of highway.

During its 38 years of operations, the Fernald site played a critical role in the nuclear weapons complex, delivering nearly 170,000 metric tons of uranium (MTU) metal products and 35,000 MTU of intermediate compounds such as uranium trioxide and uranium tetrafluoride. From the mid-1950s to the early 1960s, metal production peaked. Many of the production plants were enlarged in the mid-1950s as part of a sitewide plant expansion effort. In 1975, the site's metal production rate dropped. Production picked up again in the 1980s, but by 1989 demand for uranium feed material was low due to the cessation of the Cold War. This decrease in demand, coupled with an increase in environmental compliance and waste management issues, led to the site management decision to shut down plant operations.

The 1,050-acre operation was designed as a large-scale, integrated site capable of converting uranium ore and recycled material into uranium metal through a series of chemical and metallurgical conversions. The actual production processes used about 136 acres in the center of the site; the remainder included administration buildings, laboratories, waste storage areas, and buffer zones. The production area contained nine primary plants, each with a specific function in the uranium metal production process.

The first step in the production process was the purification of uranium. In the early years, the site processed uranium ore, including pitchblende from the Belgian Congo, through a series of chemical processes. In later periods, Fernald extracted uranium from scrap metal or recycled material (i.e., floor sweepings, dust collector and production residues) from onsite operations and other nuclear weapons sites.

Incoming material was weighed, sampled, dried, ground, and classified in Plant 1, then drummed and transported to Plants 2 and 3 where the material was converted to uranium trioxide. First, the material was dissolved in nitric acid to produce a crude uranyl nitrate solution for solvent extraction purification. Purified uranyl nitrate was concentrated by evaporation and thermally denitrated to uranium trioxide, called "orange oxide." The orange oxide was either shipped to the gaseous diffusion plant in

Paducah, Kentucky, or transported to Plant 4, where it was converted to uranium tetrafluoride, called "green salt," for reduction to metal.

As an intermediate step, uranium trioxide was converted to uranium dioxide, called "brown oxide," by reducing it with hydrogen. The brown oxide was reacted with anhydrous hydrogen fluoride to produce green salt. Fernald also produced green salt from uranium hexafluoride from other sites in the nuclear weapons complex.

The green salt was packaged in 10-gal cans and transported to the metal production operations in Plant 5, where it was blended with magnesium metal granules, placed in a closed reduction pot, and heated until the contents reacted, producing a uranium mass called a "derby." The product, which resembled the top of a derby hat, weighed up to 370 lb.

Fernald shipped some derbies to other DOE sites but most was remelted in a vacuum induction furnace and poured into preheated graphite molds to form ingots. Ingots varied in weight, size, and shape and weighed up to 1,400 lb. Fernald sent ingots to Reactive Metals, Inc. (RMI) in Ashtabula, Ohio, where most were extruded and sent back to the Fernald site for heat treatment and final machining to target element cores for the Savannah River Site in South Carolina. Enriched uranium ingots were prepared by RMI to produce a billet for direct shipment to the Hanford Site in Washington. In Plant 6, ingots were cut to various lengths and then machined to very tight specifications for the Savannah River Site.

The Fernald site served as the thorium repository for DOE, and maintained long-term storage areas for a variety of thorium materials. On several occasions from 1954 through 1975, the site produced small amounts of thorium in Plant 8, Plant 9, and the Pilot Plant.

Throughout the production years, products from the Fernald site were used at many different sites in the nuclear weapons complex. From 1952 through 1976, depleted, normal, and enriched uranium cores and fuel core elements were fabricated for the Hanford and Savannah River Sites. From 1976 until 1989, the main products were depleted uranium fuel elements for the Savannah River Site, enriched extrusion ingots and billets for Hanford, derbies for the Oak Ridge Reservation in Tennessee and the Rocky Flats Plant in Colorado, and slab billets for the Rocky Flats Plant.

In July 1989, Fernald site management shut down uranium metal production to focus on environmental compliance and waste management issues. Later that year, the U.S. Environmental Protection Agency added Fernald to its National Priorities List of Federal Facilities that required remediation. Since that time, the Fernald workforce has been dedicated to cleanup, waste management, and restoration of the site.

In 1991, Congress approved the final closure of site production operations and authorized an environmental remediation mission. To reflect this new mission, DOE changed the name of the site to the Fernald Environmental Management Project. In 2002 after the majority of remediation, the site became the Fernald Closure Project. When those activities were complete in late 2006, DOE renamed it to the Fernald Preserve.

Section 3.0, Occupational Medical Dose (ORAUT 2014b), provides information about the dose that individual workers received from medical X-ray examinations that were required as a condition of employment. Under the requirements of EEOICPA, only the dose from medical X-rays received for screening and as a condition of employment is eligible to be included in dose reconstruction.

Section 4.0, Occupational Environmental Dose (ORAUT 2015), discusses the dose workers received when working outside the buildings on the site from inhalation of radioactive materials in the air, direct radiation from plumes, contact with particles on the skin, and from direct exposure to radionuclides in

the soil. The occupational environmental dose includes the dose that was received by individuals who worked in radioactive waste areas or administration areas inside or outside the fenced production areas. The primary radiation exposure pathways are inhalation of airborne radionuclides and exposure to direct radiation from materials in the process plants and radioactive waste storage areas.

Due to the various locations of radiation sources at FMPC, the dose that was received by the worker is highly dependent on the amount of time spent in specific work areas. For dose reconstruction, the FMPC Occupational Environmental Dose TBD has divided FMPC into 11 smaller areas, designated as Exposure Areas (EAs), on a grid that provides a realistic estimated representation of radiological conditions where claimants might have worked.

The technical basis for occupational environmental internal dose is presented as airborne radionuclide concentrations and annual uptakes of individuals, and direct radiation exposure is provided as annual exposure to ambient radiation in millirem in each EA from 1951 to 2012.

From 1951 through 1988, the FMPC production years, airborne radionuclide concentrations were derived from routine emissions from operations, including handling and storage of radioactive wastes. From 1989 on, after the end of uranium production, emission quantities from specific remediation and decommissioning activities are not readily available. The resulting radionuclide concentration was derived using environmental air monitoring data from the annual site environmental reports.

Direct radiation dose is the result of photon radiation (i.e., gamma and X-rays) emitted from radionuclides stored on the site. The ambient direct radiation field at FMPC was developed primarily from the waste stored in the K-65 silos and the materials FMPC handled in the radioactive waste pit area.

ORAUT 2015 also provides discussion and summary information on the radon sources at FMPC, and a method for evaluating personnel radon exposure records.

Section 5.0, Occupational Internal Dose (ORAUT 2016), discusses the internal dosimetry program at the Fernald site and which radionuclides can or cannot be evaluated within the context of the approved SECs. Internal doses were highly dependent on specific plants and operations and are discussed on a location-specific basis in relation to Section 2.0, the Site Description. Each process involved some releases that could have resulted in uptakes and internal dose. ORAUT 2016 discusses the *in vitro* minimum detectable activities (MDAs), the analytical methods, and the reporting protocols for the radionuclides at Fernald. In addition, ORAUT 2016 discusses the *in vivo* MDAs, the analytical methods, and the reporting protocols.

Section 5.0 also addresses the issue of potential missed internal dose and coworker dose for unmonitored workers. It discusses the changing radiation detection techniques and equipment at Fernald during the period of interest.

Section 6.0, Occupational External Dose (ORAUT 2014c), discusses the program for measuring skin and whole-body doses to the workers from radiation sources outside the body. The methods for evaluating external doses to workers have also evolved over the years as new techniques and equipment have been developed. In addition, concepts in radiation protection have changed. As in the internal dose discussion, Section 6.0 describes the potential for missed external dose and provides coworker dose for unmonitored workers.

Occupational external radiation exposure occurred at every manufacturing and waste storage building on the FMPC site. The major contributors to external dose were plants that contained large inventories of raw materials, finished products, or wastes and the radioactive elements in those materials. The products were uranium metals, some containing technetium when recycled uranium

was introduced. Thorium also was handled and stored at FMPC. The wastes included those from the production processes along with radium from materials that were stored in concrete silos. Additionally, from 1955 until 1978, a variety of neutron sources were used to perform analytical neutron activation analysis procedures, which are further described in Section 6.0.

Early dosimetry programs complied with the precedents established by the Oak Ridge Reservation and used Oak Ridge dosimeters until FMPC converted to a commercial DOE accredited system. By that time the FMPC mission had changed; for all practical purposes, production had ceased and planning for the retirement of plants had started. Since that time, worker exposures have been well within established limits.

1.3 ATTRIBUTIONS AND ANNOTATIONS

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

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