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July 2, 2007

Mr. David Staudt
Center for Disease Control and Prevention
Acquisition and Assistance Field Branch
Post Office Box 18070
626 Cochrans Mill Road – B-140
Pittsburgh, PA 15236-0295

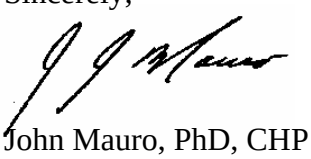
Re: Contract No. 200-2004-03805, Task Order 5: Transmittal of Draft SCA-SEC-TASK5-0056, Revision 1, *Review of the Feed Material Production Center (FMPC) Special Exposure Cohort (SEC) Petition-00046 and the NIOSH SEC Petition Evaluation Report*

Dear Mr. Staudt:

SC&A, Inc., is pleased to submit its draft report titled *Review of the Feed Material Production Center (FMPC) Special Exposure Cohort (SEC) Petition-00046 and the NIOSH SEC Petition Evaluation Report*, SCA-SEC-TASK5-0056, Revision 1. This revision of the draft report has been reviewed for Privacy Act information and edited accordingly. It is being presented to the Advisory Board for review.

If you have any comment or questions, please contact me at 732-530-0104.

Sincerely,



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ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

Review of the Feed Materials Production Center (FMPC) Special Exposure Cohort (SEC) Petition-00046 and the NIOSH SEC Petition Evaluation Report

Contract No. 200-2004-03805
Task Order No. 5
SCA-SEC-TASK5-0056, Rev. 1

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June 2007

Disclaimer

This document is made available in accordance with the unanimous desire of the Advisory Board on Radiation and Worker Health (ABRWH) to maintain all possible openness in its deliberations. However, the ABRWH and its contractor, SC&A, caution the reader that at the time of its release, this report is pre-decisional and has not been reviewed by the Board for factual accuracy or applicability within the requirements of 42 CFR 82. This implies that once reviewed by the ABRWH, the Board's position may differ from the report's conclusions. Thus, the reader should be cautioned that this report is for information only and that premature interpretations regarding its conclusions are unwarranted.

S. COHEN & ASSOCIATES: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-SEC-TASK5-0056 Effective Date: Draft — June 27, 2007 Revision No. 1 – PA Reviewed Draft
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Task Manager: _____ Date: _____ U. Hans Behling, PhD, MPH	Supersedes: Rev. 0 – May 31, 2007
Project Manager: _____ Date: _____ John Mauro, PhD, CHP	

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1.0 INTRODUCTION

1.1 SCOPE AND PURPOSE OF SEC REVIEW

During the meeting of the Advisory Board (the Board) on Radiation and Worker Health held in Mason, Ohio, on February 8, 2007, S. Cohen & Associates (SC&A) was directed by the Board to perform a full review of the Feed Materials Production Center (FMPC) Special Exposure Cohort (SEC) Petition-00046 and the NIOSH SEC Petition Evaluation Report (ER) for said petition.

Firstly, the scope of this review addresses specific issues of concern raised in the petition and NIOSH's response to these concerns as given in the ER. (Because the ER makes frequent reference to (or defers to) the Fernald Site Profile (ORAUT-TKBS-0017), our review included the FMPC Site Profile.)

Secondly, SC&A reviewed hundreds of documents that were considered relevant to the petition. documents reviewed include the following:

- FMPC documents that were referenced and/or enclosed in the petition
- Documents referenced/cited in the ER
- Documents contained in the NIOSH Site Research Query Database

The purpose of this review is to provide the Board with an independent assessment of issues and concerns that surround the petition and NIOSH's response and proposed methods for accommodating these issues/concerns. Findings identified in our review are expected to provide the Board with a **preliminary** overview of potential issues that may impact the feasibility of dose assessment. Following a formal, multi-step resolution process, any unresolved findings may then be used by the Board for determining whether radiation doses can be estimated with sufficient accuracy, as defined in 42 CFR §83.13(c)(1):

> *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.*

1.2 TECHNICAL APPROACH AND REVIEW CRITERIA

The approach used by SC&A to perform this review follows the protocols described in the draft report prepared by SC&A entitled *Board Procedures for Review of Special Exposure Cohort Petitions and Petition Evaluation Reports*, Revision 1 (SCA-TR-TASK5-0002, June 12, 2006) and the *Report to the Working Group on Special Exposure Cohort Petition Review* (Draft January 16, 2006). The latter is a set of draft guidelines prepared by a Board-designated working group for evaluation of SEC petitions performed by NIOSH and the Board. The former is a set of draft procedures prepared by SC&A and approved by the Board for use by SC&A on an

interim basis (Advisory Board meeting transcript of June 16, 2006, p. 132). The procedures are designed to help ensure compliance with Title 42, Part 83, of the *Code of Federal Regulations* (42 CFR 83) and implement the guidelines provided in the report of the working group.

Key review criteria identified in the report of the working group include the following:

- Timeliness
- Fairness
- Understandability
- Consistency
- Credibility and validity of the data set, including pedigree of the data, methods used to acquire the data, relationship to other sources of information, and internal consistency
- Representativeness and completeness of the exposure data with respect to the area of the facility, the time period of exposure, the types of workers and processes covered by the data

The working group guidelines also recommend that NIOSH include in its SEC evaluation a demonstration that it is feasible to reconstruct individual doses for the cohort, including sample dose reconstructions.

SC&A's implementation of the SEC Review process includes the following steps:

(1) Conduct a critical review of the petition and relevant reports, as well as documents and data that are enclosed and/or referenced in the petition/reports. For SEC Petition-00046, a major source of information included internal FMPC communiqués, letters, reviews, audits, and data sheets, which were cited in the petition as well as in the NIOSH Site Research Query Database.

(2) Meet with and interview petitioner/former FMPC workers for the purpose of gaining additional insight into work practices, workplace conditions, monitoring methods, and dates of operations.

(3) Identify additional issues/concerns that emerged from SC&A's document review, which are independent of those stated in the petition.

(4) As part of the SEC review, develop a preliminary technical position for issues identified in the petition, as well as SC&A's independent findings.

SC&A's draft report with its preliminary findings will subsequently undergo a multi-step resolution process. Resolution includes a transparent review and discussion of draft findings with members of the Board's working group, petitioner, claimants, and interested members of the public. This resolution process is intended to ensure that each finding is evaluated on its

technical basis in a fair and impartial basis. A final report will then be issued to the full Board for deliberation and a final recommendation.

1.3 ORGANIZATION OF THE REPORT

Following this introduction, Section 2.0 of this report provides summary data contained in the FMPC Site Profile. The site profile specifies relevant background information and methods to be used by NIOSH for the reconstruction of internal and external doses. Included herein are brief site profile summaries of materials and quantities processed, facility descriptions, and proposed methods for dose reconstruction.

Section 3.0 of this report summarizes specific concerns and issues raised in the SEC Petition-00046, as well as NIOSH's Evaluation Report of the petition. In the Petition Evaluation Report, NIOSH provided responses to the petition's concerns along with the conclusion that dose reconstruction is feasible for FMPC workers for the years 1951 through 1989.

As a result of our review of the petition, NIOSH's evaluation of the petition, the FMPC Site Profile, and other documents, SC&A identified a total of 29 findings, which are cited in Section 4 of this report. In behalf of each finding, a discussion is provided that serves to explain the technical basis for our concern. For most findings, support is also provided by one or more FMPC documents, which are enclosed as attachment(s), or are referenced (see Reference List in Section 6.0).

These attachments frequently contain empirical data and/or personal observations/opinions expressed by key individuals who were involved in FMPC operations, worker/workplace monitoring, and audits of the FMPC Health and Safety Program. As such, SC&A regards these historical documents as highly relevant, credible, and impartial. For this reason, the reader is encouraged to review the enclosed attachments and independently determine the degree to which they support each of the corresponding findings. For practical reasons, findings are grouped by category in the following subsection of Section 4.0:

- Subsection 4.1: Findings associated with urinalysis data for assessing intake of uranium.
- Subsection 4.2: Findings associated with dose assessments in behalf of raffinates and K-65 processes.
- Subsection 4.3: Findings associated with internal thorium dose estimates.
- Subsection 4.4: Limitations and findings associated with the use of MIVRML data for uranium and thorium dose estimates.
- Subsection 4.5: Findings associated with external exposure monitoring at FMPC.

Section 5.0 provides concluding comments regarding the impacts of our findings on dose reconstruction for FMPC workers.

2.0 KEY INFORMATION AND DATA PRESENTED IN THE FERNALD SITE PROFILE

The most current site profile for the Fernald Feed Materials Production Center (FMPC) consists of six Technical Basis Documents (TBDs) that were issued at various times (see Reference List for specific dates). These TBDs will be referenced throughout this report and include the following:

- ORAUT-TKBS-0017-1: Introduction
- ORAUT-TKBS-0017-2: Site Description
- ORAUT-TKBS-0017-3: Occupational Medical Dose
- ORAUT-TKBS-0017-4: Occupational Environmental Dose
- ORAUT-TKBS-0017-5: Occupational Internal Dose
- ORAUT-TKBS-0017-6: Occupational External Dose

Collectively, the six TBDs of the site profile are intended to provide core information, data, and guidance that are intended to assist in the dose reconstruction of individual workers who may have been exposed to internal and external occupational radiation at FMPC, as stated in ORAUT-TKBS-0017-1:

> *. . . This 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 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.* [Emphasis added.]

2.1 FEED STOCKS AND MATERIALS PRODUCED AT FMPC

FMPC was a large-scale production facility that used a wide variety of complex chemical, metallurgical, and mechanical processes to convert various uranium and thorium feed stocks into products used by other facilities of the U.S. nuclear weapons complex. Operations began in 1951, when the Atomic Energy Commission (AEC) contracted National Lead of Ohio (NLO) to process nuclear materials to produce high-purity uranium metal products in the form of derbies, ingots, billets, and fuel cores for other sites of the U.S. nuclear weapons complex. During its 38 years of operation that ended in 1989, FMPC produced a total of 980,048 metric tons of uranium compounds such as uranium trioxide (UO_3) and uranium tetrafluoride (UF_4). Major feedstocks for uranium products included uranium ore (including pitchblende from the Belgian Congo), as well as scrap/recycled uranium (RU) shipped from other nuclear weapon sites.

Although uranium processing was the principal function, FMPC also processed substantial quantities of thorium ore for the production of various thorium compounds and thorium metal. NIOSH estimated that a total of 2,855 metric tons of thorium were processed at Fernald but also

acknowledged that ". . . a large number of [thorium] records and files were destroyed in the early 1970s during declassification efforts . . . data reconstruction indicates that thorium processing was limited to three plants over short periods in the 38-year production history of FEMP."

In addition to thorium that was processed at Fernald, the site was appointed as the **national repository** for thorium in 1972. NIOSH further assumed that ". . . Approximately, two-thirds of the material in the repository was processed at the FEMP . . . [and] the remainder originated at other DOE facilities."

According to the FMPC Site Profile, of the three FMPC plants that processed thorium, the largest quantity (71% or 2,030 MT) was processed in the Pilot Plant between 1964 through 1979. An estimated 456 MT were processed in Plant 9 in 1954 and 1955; and 369 MT were processed in Plant 8 in the years 1966, 1969, 1970, and 1971.

2.2 PRODUCTION FACILITIES AND OTHER RELEVANT AREAS

Of the 1,050 acres that collectively define the FMPC site, about 136 acres represent areas that include production facilities. These consist of the Pilot Plant and Plants 1 through 9. Their physical size, dates of operation, and principal functions/source materials are briefly described below. These parameters are highly relevant for assessing the adequacy of air sampling, which was the principal method employed by FMPC Health and Safety personnel for monitoring and controlling worker exposures.

Pilot Plant. With a ground floor area of 23,500 ft^2, this facility operated from 1951 through 1989. Its principal function was to convert UF_6 to UF_4 for use in the uranium metal production. In addition to natural uranium, significant fractions of the UF_6 feedstock were derived from depleted uranium generated at gaseous diffusion plants and enriched uranium associated with recycled uranium. During various periods of facility operation, processes shifted to the production of thorium compounds and thorium metal.

Principal radioactive sources in the Pilot Plant were uranium in the form of UF_4 that corresponded to natural, depleted, and enriched uranium, the radioactive daughters associated with pitchblende, and select radioactive contaminants contained in RU.

Plant 1 – Sampling Plant. The Sampling Plant operated between 1953 and 1989 and has a ground floor area of 22, 040 ft^2. Principal functions include: (1) drying, crushing, milling, grinding and classifying feed materials for further processing, (2) sampling and storing large amounts of depleted, natural, and enriched uranium in open and covered storage areas, and (3) digesting enriched (5% to 20%) uranium -238 residues. Among the feed materials processed were Canadian ore containing thorium, pitchblende from the Belgian Congo (containing Ra-226 and daughters), and recycled uranium containing Np-237, Pu-238/-239/-240/-241, Tc-99, Sr-90, and other contaminants.

Plants 2/3 – Refinery. Built in 1953 and with a ground floor area of 36,604 ft^2, the refinery converted natural uranium ore and to a lesser extent, enriched recycled uranium to uranium oxide (UO_3). The conversion of uranium produced a **raffinate** that contained the radioactive

contaminants associated with pitchblende and RU feed stocks. According to NIOSH's SEC-00046 ER, in 1968, Plant 2/3 was **briefly** used to produce **thorium** nitrate and **thorium** oxide. However, the ER admits that ". . . few details are available regarding the process . . ."

Plant 4 – Green Salt Plant. This 26,500 ft^2 facility started operation in 1953 and operated until 1989. Its primary function was to convert UO_3 (produced in Plants 2/3) to green salt (UF_4). This two-step process involved the reduction of UO_3 to UO_2 (or brown oxide) and the conversion of UO_2 to UO_4 with anhydrous hydrogen fluoride. Since the UO_3 feed stock may have been derived from natural, depleted, and recycled uranium source material, the relative ratios of U-238, U-235, and U-234 in UO_4 varied.

Plant 5 – Metals Production Plant. At 58,620 ft^2 of floor area, this facility operated between 1953 and 1989. As part of the integrated production processes, Plant 5 received the UO_4 produced in Plant 4 and converted the UF_4 to pure uranium metal. The conversion of UF_4 to **depleted, natural**, and enriched uranium metal derbies was achieved by a process developed at Ames Laboratory. The highly exothermic reduction of UF_4 employed a magnesium chloride liner in electric resistance furnaces. Uranium derbies, in turn, had to be cleaned and recast into purified uranium ingots using vacuum induction furnaces. A fraction of ingots was also subjected to a variety of mechanical shaping by means of lathes, saws, grinders, and milling machines.

Plant 6 – Metals Fabrication Plant. At 206,270 ft^2 of floor area, the Metals Fabrication Plant was the largest. This facility operated between 1952 and 1989. Its primary function was to heat-treat uranium ingots and billet produced in Plant 5 to improve strength and grain structure. Heat-treated uranium billets and ingots were also extruded, cut, and machined for various production reactors.

(Note: As part of the site profile review, SC&A has identified the fact that pyrophoric stockpiles of **thorium residues** were oxidized in Plant 6 in order to "stabilize" this material. Oxidation of thorium residues was performed in the Plant 6 furnace from early 1960 to the middle of 1963.)

Plant 7 – Hexafluoride Reduction Plant. Plant 7 began operations in 1954 but ceased operations in 1956. During the first 2 years, the principal function was to convert UF_6 and UF_4 (green salt) in a gas-gas reaction with hydrogen at 100°F. Between 1956 and 1969, the facility remained idle after which time it was used to store drums of green salt.

Plant 8 – Scrap Metal Recovery Plant. This 25,500 ft^2 facility operated between 1953 and 1989. In Plant 8, residues and scrap from processes involving enriched uranium were subjected to furnacing, which removed oil, graphite, water, and metallic impurities before being sent to the refinery for extraction and recovery of residual uranium.

In addition to uranium residues, Plant 8 also processed thorium residues, which were first converted to thorium oxalate and then to thorium hydroxide. During the 4 years that included 1966, 1969, 1970, and 1971, an estimated 369 MT of thorium hydroxide were produced.

Plant 9 – Special Products Plant. This 48,500 ft^2 facility began operation in early 1954. For the first 2 years, the primary function of Plant 9 was to produce purified **thorium** metal by means of

processes developed in Iowa at the Ames Laboratory in which ThF_4 was blended with calcium and zinc chloride in a bomb retort and heated. In the highly exothermic chemical reaction, ThF_4 was reduced by the calcium to form a zinc-thorium derby. Following the de-zincing, the cleaned derby was remelted and recast into a purified thorium ingot. Ingots were further machined and shaped into a variety of thorium metal products. An estimated 380 metric tons of pure thorium metal were produced in the years 1954 and 1955 (and possibly into 1956). Thereafter operations at the Special Products Plant involved casting enriched uranium derbies and RU metal scrap into large diameter uranium ingots weighing up to 900 kg. Ingots were further subject to various shaping and machining processes.

Support Facilities – Waste Management Facilities. Each of the 10 production facilities created liquid and solid wastes and/or scrap materials, some of which were recycled while others were stored/disposed onsite. Most relevant to potential internal and external exposures to workers include two concrete silos containing K-65 residues, six waste pits, one burn pit, and buildings 64, 65, 67, and 68, which served as thorium storage facilities when FMPC was designated as DOE's thorium repository. Summary descriptions of these facilities are provided below:

- Thorium Buildings. Thorium compounds stored in Buildings 64, 65, 67, and 68 include thorium hydroxide, oxide, and oxalates that were generated in behalf of the aircraft nuclear propulsion (ANP) Program that was cancelled in 1961 and for the Light Water Breeder Reactor Program. Most of the stored thorium was in metal drums and cans that over time corroded, resulted in frequent fires, and required sampling and repacking.

- Waste Pits. Waste Pits 1 through 6 were constructed and operated at various times during the 38 years of FMPC operations. Radionuclide contaminants in these pits varied significantly in terms of their relative, as well as absolute, concentrations and total amounts. For most waste pits, the isotopes of uranium (U-238, U-235, U-234) were the dominant contributors to activity levels. Pit wastes associated with the processing of RU feed stocks also contained variable amounts of transuranics, Tc-99, and some fission products.

  For waste pits 1, 2, and 4, radiothoriums contributed a large fraction to the total radioactivity; and for pits 3 and 5, radiothoriums dominated. Table 1 provides a summary of activities contributed by isotopes of uranium and thorium.

  Inspection of Table 2.2-1 shows that the vast majority of **thorium** activity in waste pits is contributed by Th-230, which is **not** linked to the production of thorium metal, thoria gel, and other thorium products, but is the radioactive daughter of U-234. Thorium-230 has a half-life of 80,000 years and like Th-232 and Th-228 is an alpha emitter. Sources of Th-230 in pit waste are waste streams from the processing of **un**refined ores (e.g., Belgian Congo pitchblende and Canadian ores) that served as primary feedstocks for uranium products.

Table 2.2-1. Major Radionuclide Constituents in Pit Wastes

Isotope	Average Activity Concentration (pCi/g) of Waste					
	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6
U-234	558	3867	208	783	636	3418
U-235	56	1793	12	152	34	1042
U-238	1951	4725	442	4644	641	16,975
Th-228	20	63	12	115	31	<1
Th-230	1504	1435	4638	428	4475	31
Th-232	22	43	16	37	37	<1

- Burn Pit. This facility served as a disposal site for pyrophoric materials between 1957 and 1968. In 1984, contents of the burn pit were excavated and transferred to waste pit 4. Quantitative estimates of radionuclide-specific activity levels are not well documented, but may be assumed to parallel those of waste pit 4.

- K-65 Silos. The processing of unrefined ores that included pitchblende from the Belgian Congo produced waste streams (or raffinates) that contained high levels of Ra-226 (and daughter products) as well as Th-230. Large concrete tanks measuring 27 feet high and 88 feet in diameter were constructed in 1951 and 1952 for the interim storage of raffinate wastes. Pitchblende raffinates generated in Plant 2/3 were disposed by direct pipelines into Silos 1 and 2.

  In addition to raffinates generated at FEMP, African pitchlende had also been processed in earlier years by Mallinckrodt Chemical Works (MCW). Due to a shortage of storage space, raffinates from MCW were shipped in 55-gallon drums in 1951 and 1952 for interim storage. With Silos 1 and 2 completed in July of 1952, the contents of approximately 13,000 55-gallon drums from MCW were transferred into Silos 1 and 2 over a 6-year period that started in July 1952 and ended in September 1958.

  The transfer of 13,000 drums of MCW raffinates into the K-65 Silos 1 and 2 was a process performed by laborers, who manually transferred the drums' contents onto a conveyor belt that dropped raffinate waste into the storage silos. The total amount of raffinates stored in Silos 1 and 2 is estimated at 10,000 metric tons. In 1993, core samples taken from Silos 1 and 2 yielded activity values summarized in Table 2.2-2.

Table 2.2-2. Isotopic Composition of K-65 Silos 1 and 2

Isotope	Silo 1		Silo 2	
	Activity (nCi/gm)	Activity Fraction	Activity (nCi/mg)	Activity Fraction
Uranium – Total	1.68	1.61 E-3	2.37	3.04 E-3
Ac-227 (β)	7.67	7.36 E-3	6.64	8.50 E-3
Pa-231 (α)			4.04	5.17E-3
Pb-210 (β)	202	1.94 E-1	190	2.43 E-1
Po-210 (α)	281	2.70 E-1	231	2.96 E-1
Ra-226 (α)	477	4.58 E-1	263	3.36 E-1
Th-228 (α)	2.28	2.19 E-3	7.36	9.42 E-3
Th-230 (α)	68.9	6.62 E-2	76.2	9.75 E-2
Th-232 (α)	1.11	1.07 E-3	0.99	1.26 E-3

From data shown in Table 2.2-2, the following summary conclusions may be drawn:

- Ra-226 and the longer-lived daughters Pb-210 and Po-210 contribute the majority of activity.
- The specific activity in Silo 1 is significantly higher than that of Silo 2.
- There is a clear disequilibrium condition between Ra-226 and Po-210/Pb-210, which suggests that about 50% of Rn-222 is/has been released from the raffinate waste.
- As was the case for waste pits, thorium activity is dominated by Th-230.

In summary, FMPC was a large-scale integrated processing facility, which utilized various feed stocks of uranium and thorium. In turn, these processes produced a complex variety of intermediate products, waste streams, and finished products, which differed in their radiological, chemical, and physical properties. Table 2.2-3 identifies the various radiological source materials to which an estimated 7,000 FMPC workers were exposed.

Table 2.2-3. Radioactive Materials to Which Workers Were Exposed

Uranium – U-238, U-235, U-234, U-236 - Uranium ores from mines and mills - Pitchlende ore from Belgian Congo - Recycled uranium from spent fuel elements and transuranic production targets
Radioactive Daughters of Uranium Ores/Pitchblendes: - Th-230 - Ra-226 - Rn-222 - Pa-231 - Ac-227 - Rn-220
Contaminants Associated with RU: - Pu-238, Pu-239, Pu-240, Pu-241 - Np-237 - Tc-99 - Sr-90
Enrichments of Uranium: - DU - U_{nat} - EU (up to 20%)
Chemical Forms of Uranium: - Uranium metal - UO_2 – uranium-oxide high-fired; brown oxide - U_3O_8 – uranium-oxide/yellowcake - UO_4 – uranium tetraoxide - UF_4 – green salt - UF_6 – uranium hexafluoride gas - UO_3 – uranium trioxide (orange oxide) - UO_2F_2 – uranyl fluoride - $UO_2(NO_3)_2$ – uranyl nitrate
Thorium and Daughters: - Th-232 and Th-228 - Ra-228 - Ac-228 - Pb-212 - Rn-220, etc.
Thorium Chemical Forms: - Th-metal - ThO_2 – oxide - $Th(OH)_4$ – hydroxide or gel - $ThNO_3$ – oxalate

2.3 AN OVERVIEW OF NIOSH'S APPROACH TO THE RECONSTRUCTION OF INTERNAL DOSES

2.3.1 Internal Doses Associated with Uranium Processes

ORAUT-TKBS-0017-5 of the Fernald Site Profile provides the technical basis for estimating occupational internal dose to FMPC workers associated with uranium and thorium processes. This Technical Basis Document (TBD) contains pertinent information and assumptions for use by dose reconstructors. Due to the focused scope of an SEC evaluation, a comprehensive review of this TBD is neither warranted nor essential. Our review is, therefore, limited to the identification of core information, methods, and assumptions stated in the TBD that affect the ability to reconstruct internal doses. For simplification, direct quotations from the TBD Section 5 are cited when appropriate:

From Sections 5.1 and 5.2:

(1) *The original health and safety program was conducted with an **industrial hygiene** emphasis, based upon **uranium** heavy metal toxicology . . . Basic changes in the radiological protection program occurred with the contractor change in **1986** with the addition of **radiation** safety staff and a greater emphasis on radiation protection principles.* [Emphasis added.]

(2) *Due to the inherent nature of the processes, the **limitations of the ventilation and material confinement systems**, and the volume (and mass) of the materials, significant **environmental** and **in-plant releases** of radioactive materials occurred during FEMP operations. The work environs included a continuous/chronic potential for internal exposure, as demonstrated by the comprehensive air monitoring program and the urine sampling program for uranium (documented by air sample and urine uranium data sheets).* [Emphasis added.]

(3) *There are approximately seven steps in the process of conversion of uranium ore or other scrap recovery materials to metallic uranium. Those steps produce a number of compounds, each of which has specific chemical characteristics that are associated with **different internal exposure parameters**. Each of the compounds identified in Table 5-4 was handled in MT quantities. Most of the compounds were **dry powder** or **granular** in form and represented a **dust hazard** potential as the material was processed, transferred, and otherwise handled.* [Emphasis added.]

(4) *Production operations that involved handling dry uranium materials were generally equipped with **engineered ventilation systems** for controlling dusts. Standard operating procedures required the use of respiratory equipment when dusty conditions were anticipated. **Good housekeeping** involving the **immediate cleanup of spilled uranium** products was also a standing policy and practice. In spite of this emphasis on engineered and administrative contamination controls and policy to reduce the release of radioactive materials, spills and routine*

releases occurred. In addition to the routine releases at FEMP, there were frequent "upset" conditions (i.e., spills, effluent filter ruptures, etc.) that produced episodic airborne radioactivity in the work areas and plant effluents, and were of a magnitude that the ventilation systems were unable to contain all of the releases. [Emphasis added.]

(5) *A radiological controls program was in place from the beginning of FEMP operations. The internal dose control program consisted of:*

- *An air sampling program in all processing areas to evaluate internal exposure potential via inhalation*
- *Urine samples submitted after at least a two-day work break to allow elimination of uranium cleared rapidly via the GI tract (this material causes relatively little dose)*
- *In vivo analysis once a month for high exposure-potential workers on a frequent urinalysis program and once a year for workers with a low potential for internal intake.*

(6) *[For] uranium . . . its chemical toxicity can be the dominant hazard in cases of readily or moderately soluble compounds of depleted, natural, and low-enriched uranium. . .*

*The early basis for conducting routine **urine analysis** was to assure that uranium exposure controls were **adequate to prevent chemical toxicity**. . . .*

*Though the primary exposure control was based on **toxicity** concerns, some radiological exposures were reported in addition to a few work restrictions based upon radiological dose limits. The radiological dose determinations were based upon **in vivo lung counting**. In vivo lung counts were routine from 1968 to 1989 using a **Mobile In Vivo Radiation Monitoring Laboratory (MIVRML)** from ORNL Y-12. . . . The results were reported in **milligrams** of 235U and total **milligrams** of uranium (mg U) . . .* [Emphasis added.]

In summary, these statements imply the following:

- Although general air (GA) and breathing zone (BZ) air sampling was regarded by **FMPC personnel** as the primary means for controlling intakes below levels that could result in **chemical toxicity** to the kidneys, NIOSH has stated that, for dose reconstruction, photofluorometric urine bioassay data will be used as the primary tool for estimating internal exposure to uranium. In lieu of or in support of urinalysis data, in vivo lung counts and air sampling may also be used for dose reconstruction.
- Only **uranium** urinalysis was performed routinely from the 1950s to 1986. Thus, there were no direct measurements of either TRU contaminants or radioactive uranium

daughters, e.g., Th-230, Ra-226. (SC&A notes that a limited number of radon breath measurements were taken.)

- Because urinalysis was based on a photofluorometric method and reported in units of mg U/liter urine, the isotopic mixture of uranium isotopes is unknown.

- To account for RU contaminants (that include plutonium out of specification P005), the TBD allows for the presence of **Pu-239, Np-237, and Tc-99** in concentrations of 100, 3,500, and 9,000 ppb, respectively, as given in Table 5-12 of the TBD.

- Before DOE Order 5480.11 (effective in 1989), bioassay data at Fernald were not used to estimate intakes or internal organ doses.

- In 1968, in vivo lung monitoring began with the ORNL Y-12 MIVRML, which continued until 1989. Results of in vivo lung counting were calibrated in μCi of U-235 but reported in mg of U in the lung. The conversion of μCi to mg total uranium assumed a 1% enrichment.

2.3.2 Internal Doses Associated With Thorium Processes

Section 5.2.3 of the TBD acknowledged that:

> *Much of the thorium **production data** has been lost, and the **plant** and **bioassay** monitoring data recovered to date has been sparse. . . .* [and] *that a large number of records and files were destroyed in the early 1970s during declassification efforts . . .*
>
> *A fundamental difficulty of dose reconstruction for thorium processing is that either 1) in vitro bioassays for thorium were not performed or 2) data is not available until after 1986. An additional consideration is that air sampling data was not used to calculate intake and dose until after 1986. Air monitoring was used only to control exposures to levels below the MAC.* [Emphasis added.]

Given these limitations, the TBD recommends a "claimant-favorable default exposure" approach for assigning thorium intakes. This default approach model assumes the following:

- An intake exposure period of 100 hours per year at an air concentration of 10 MAC

- An intake for an exposure period of 500 hours per year at an air concentration of 0.1 MAC

- No respiratory protection

Using these assumptions, the default thorium intake model assigns a total of 1050 MAC-hours per year for thorium-232 and thorium-228, which are **assumed** to exist in secular equilibrium. This translates to an annual inhalation intake of about 30 nCi each for Th-232 and Th-228.

The TBD, however, states that this claimant-favorable default model may not be used for workers with in vivo chest counting data. The following guidance is provided:

> *. . . When available, the chest count data should be used to **constrain** an employee's intake. In other words if there are chest count results for an employee, the **smaller** of the **default** thorium intake or the chest count determined intake should be assigned for **full** dose reconstructions.* [Emphasis added.]

SC&A interprets these recommendations to imply that when **empirical in vivo monitoring** data suggest an intake that exceeds the 1050 MAC-hour **default** value, the dose reconstructor should ignore monitoring data and assign the smaller default-modeled dose of 1050 MAC-hours for dose reconstructions involving **best estimates**.

2.3.3 Internal Doses Associated with K-65 Silo Processes

From 1953 until 1958, pitchblende ore containing high concentrations of uranium and uranium daughter products was used as the raw material for the production of uranium products. This ore was obtained from the Shinkolobwe mine in the Belgium Congo. Uranium was separated from the pitchblende ore by the use of the three-phase Purex process: digestion, extraction, and denitration. The aqueous raffinate or waste from this process was pumped into one of two large concrete silos for storage. These residues, which were assigned the code name "K-65," contain small amounts of Th-232 and Th-228 and daughter products of uranium including Th-230, Ra-226, Rn-222, Pb-210, and Po-210. The raffinate was slurried from the refinery (Plant 2/3) through pipes into Silo 2.

The radium containing material in K-65 Silo 1 came from another source. Prior to 1952, large amounts of radium bearing radioactive waste were shipped to the Fernald Site from Mallinckrodt Chemical Works in St. Louis, and eventually stored in the K-65 Silo 1. When the waste material first arrived, however, it was placed in metal drums, which were temporarily stored on a concrete pad near Plant 1. An internal FMPC memorandum indicated that 13,000 55-gallon drums of K-65 material were received at the FMPC in the period September 25, 1951 to July 31, 1952. Other drums of K-65 material were stored in Plant 8 for long periods of time. The drummed material was transferred into Silos 1 and 2 over a 6-year period between July 1952 and September 1958.

The transfer of K-65 waste material from the 13,000 drums was a **manual** process that exposed workers internally to high airborne levels of contaminants, as well as externally to penetrating radiation.

Due to insufficient internal monitoring data associated with the K-65 processes, the TBD provides a default dose model that is described as "claimant-favorable and bounding." In addition to the default **particulate** intake model, the TBD also provides a means for modeling radon/radon daughter exposures associated with the initial lid removal of the 13,000 drums. Key parameters of the model assume a Rn-222 air concentration of 230 pCi/l in full equilibrium with the short-lived daughter products for an **annual** exposure of 2.9 WLM.

For "environmental" releases of radon from the K-65 silos, additional radon exposures to workers are based on an atmospheric dispersion model that assumes an annual release of about 5,000 Ci of radon from Silos 1 and 2.

2.4 EXTERNAL DOSES FROM BETA, GAMMA, AND NEUTRON EXTERNAL

For external penetrating radiation to the whole-body and for extremity/skin exposures, NIOSH intends to assign doses that reflect empirical measurements of personnel dosimeters that include film and thermoluminescent dosimeters.

Because neutron exposures were not monitored at FMPC, potential neutron doses will be based on a neutron-to-photon ratio model, which has as its 95th percentile value, a neutron-to-photon ratio of 0.23.

3.0 OVERVIEW OF THE SEC PETITION-00046 AND NIOSH'S EVALUATION REPORT

3.1 SEC PETITION-00046

SEC Petition-00046 qualified on April 6, 2006. The petition requested that NIOSH consider the following class: "All employees and all sub-contractors who worked at all locations at the Feed Materials Production Center (FMPC) in Fernald, Ohio, also known as the Fernald Environmental Management Project (FEMP), during the time period of January 1, 1951 through December 31, 1989.

While the core of the petition is relatively brief, the petition makes reference to and includes a large number of documents that support the petition's concerns. Critical elements defined in SEC-00046 include the following concerns:

- Issue #1: Failure to Monitor Internal Exposure to Contaminants in Recycled Uranium. Important contaminants for which there are no monitoring data include Pu-239/-240, Np-237, and Tc-99.

- Issue #2: Insufficient Monitoring of Worker Exposures to Thorium. Concerns raised in the petition focused on the absence of urinalysis monitoring for thorium, the incomplete documentation regarding the locations and time periods of thorium processing at FMPC, and thus, the incomplete air monitoring for all locations and all time periods.

- Issue #3: Failure to Monitor Internal Exposure to Radioactive Daughter Products Contained in Raffinates of Uranium Extracted from African Pitchblende and Canadian Ores. Identified among the radionuclides of concern were Ra-226 and Rn-222, along with its short-lived and long-lived daughter products.

- Issue #4: Failure to Monitor Exposure to Neutrons. Given the large quantities of alpha-emitting radionuclides processed at FMPC, concerns were raised about unmonitored neutron exposures resulting from alpha, neutron reactions between isotopes of U/Th, and atoms with low atomic number (e.g., fluorine, beryllium).

- Issue #5: Inappropriate Assumption Regarding the Protective Role of Respiratory Use During K-65 Silo Processes.

- Issue #6: The Historical Practice by FMPC to Control/Limit Worker Exposures Only to Levels Below Those Associated with Chemical Toxicity and With No Attempt to Convert Urinalysis and Air Sampling Data to Dose Estimates.

- Issue #7: Failure to Include Fecal Analysis as Part of a Routine Bioassay Program for Monitoring FMPC Workers.

- Issue #8: Falsification/Manipulation of Workplace Air Sampling.

3.2 SEC PETITION EVALUATION REPORT

On October 25, 2006, NIOSH issued its final SEC Petition Evaluation Report (ER) for SEC-00046. As stated in Section 1.0 of the ER, this report evaluated ". . . the feasibility of reconstructing doses for **all** subcontractors who worked at **all** locations at the Feed Materials Production Center (FMPC) in Fernald, Ohio . . ." [Emphasis added.]

Under 42 CFR § 83.13(c)(1), the feasibility to reconstruct doses includes:

> *. . . radiation doses [that] can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate **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 dose of members of the class more precisely than an estimate of the maximum radiation dose.* [Emphasis added.]

The Evaluation Report responded to specific concerns and issues raised in the SEC Petition-00046 as summarized in Section 3.1 above and concluded that:

> *. . . NIOSH has established that it has access to sufficient information to: (1) estimate the **maximum** radiation dose incurred by any member of the class; or (2) estimate radiation doses **more precisely** than a maximum dose estimate. Information available from the **site profile** and additional resources is 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.* [Emphasis added.]

Furthermore,

> *Per EEOICPA and 42 C.F.R. § 83.13(c)(3), NIOSH need not make a health endangerment determination, as it has determined that it has sufficient information to estimate dose for the members of the proposed class.*

Data and information employed by NIOSH in its evaluation are cited in Section 4.0 of the ER. The recommendation to deny the SEC status was principally based on information provided in Technical Basis Documents ORAUT-TKBS-0017-1, -2, -3, -4, -5 and -6, which collectively define the FMPC Site Profile. As previously quoted in Section 2.0 above, NIOSH stated that:

> *Dose reconstructors can use this Site Profile to evaluate internal and external dosimetry data for **monitored** and **unmonitored** workers, and to supplement or substitute for, individual monitoring data.* [Emphasis added.]

Other supportive documents reviewed and used by NIOSH to support its recommendation to deny the SEC status include:

- ORAUT-OTIB-0006, Rev. 03; ORAUT-OTIB-0024, Rev. 00; ORAUT-PROC-0060, Rev. 01; and ORAUT-PROC-OO61, Rev. 01

- A total of 1,628 documents contained in the NIOSH Site Research Database as pertaining to the FMPC site

- Fernald Historical Records

- Documentation and/or Affidavits provided by petitioners

Sections 5.0 and 6.0 of the ER provide summary descriptions of FMPC processes, FMPC monitoring practices, and available monitoring data. These data closely parallel information contained in the six TBDs that define the FMPC Site Profile and provide the technical basis for Section 7.0 of the ER.

While Sections 7.1, 7.2, and 7.3 of the ER address the generic feasibility of internal and external dose reconstruction for FMPC workers, Section 7.4 addresses specific issues and concerns identified in the SEC-00046 petition, as summarized below.

3.3 NIOSH'S RESPONSE TO MAJOR ISSUES RAISED IN SEC-00046

Response to Issue #1

NIOSH admits that beginning in 1961, recycled uranium was introduced at FMPC as feedstock (inclusive of POOS); however, no analyses for the presence of RU contaminants were conducted in behalf of urine or air sample analysis.

In an attempt to address these monitoring deficiencies, the ER merely states that:

> *Section 5.2.2 of Technical Basis Document for the Fernald Environmental Management Project (FEMP)-Occupational Internal Dose provides an approach to account for missed internal dose from unmonitored or undetected recycled uranium impurity activities. This approach determines the uranium intake, and then (for intakes occurring after 1961) adds a claimant-favorable ratio of recycled uranium impurity activities to that intake.*

Response to Issue #2

NIOSH's position is that for any individual who had the potential for thorium exposure, the default intakes will be assigned as described in Section 5.2.3 of the TBD. The default assumption assigns 1,050 MAC-hours per year for a radionuclide mixture defined in Table 5-16. (Note: The TBD contains two tables designated at 5-16; one on page 24 and the other on page 25.)

However, the default assignment of 1,050 MAC-hours per year will likely be applied only to **maximized** (i.e., **non**-compensable) dose reconstructions. The ER states that ". . . **in light of new data, a more precise approach is being developed**." [Emphasis added.]

NIOSH's **more precise approach** will assumedly apply to dose reconstructions that are based on **best estimates** and employ post-1968 MIVRML lung counting data and/or air monitoring data.

Response to Issue #3

NIOSH intends to **bound** worker exposures to Ra-226, Rn-222, and other radioactive daughter products contained in pitchblende ores by a **maximizing** approach that is applicable to K-65 silo operations. This **maximizing** approach is described on pages 24 through 28 of the TBD (ORAUT-TKBS-0017-5) and combines a limited amount of empirical data with various assumptions.

For non-K-65 Silo workers, other data may be used that includes radon breath analyses and the results of a FMPC radon study published in 2004.

Response to Issue #4

For assigning missed neutron doses to select worker groups, NIOSH intends to employ a neutron-to-photon ratio of 0.23, as described in Section 6.3.5.2 of the TBD. This value is described as the 95th percentile for a lognormal distribution involving paired sets of photon and neutron measurements on 56 individual drums of UF_4.

Response to Issue #5

For assigning estimates of internal exposures to **K-65 workers**, the ER states that ". . . the **maximizing** approach to bounding K-65 silo exposure does **not** take credit for respiratory protection (ORAUT-TKBS-0017-5)." [Emphasis added.]

Response to Issue #6

In spite of the fact that pre-1989 urinalysis employed a fluorophotometric method that only defined the elemental uranium content in urine in units of mg/liter, these data can be readily converted to activity values in behalf of depleted, natural, and low-enriched uranium, as dictated by **worker location/work processes**. Once converted to radiological units, both **urine** and **air sampling data** can be used to derive internal doses.

Response to Issue #7

The ER states that while fecal analysis may have been employed at FMPC as part of select incident investigations, the decision to exclude fecal analysis from routine use was based on the limited reliability of this bioassay technique.

Response to Issue #8

Documents contained in the petition (in the form of an affidavit and a report) imply that air sampling and effluent releases may have been manipulated and/or misrepresented. Upon review of these documents, NIOSH has concluded that:

> *. . . this practice was unlikely to have **routinely** occurred, and since NIOSH will **not** be relying on a single air sample result to estimate a worker's intake (but rather a distribution of or compilation of multiple air dust measurements), it is unlikely that this practice would have a significant affect on an individual's dose.* [Emphasis added.]

3.4 NIOSH CONCLUSIONS

The ER concluded that based on available information that includes monitoring records, process descriptions, and source term data, dose reconstruction is feasible for FMPC workers employed between January 1951 and December 1989 who may have been exposed internally and externally to the following sources:

- Internal
  - Uranium
  - Thorium
  - Other radionuclides (e.g., POOS nuclides, radon, thoron)

- External
  - Gamma
  - Beta
  - Neutron
  - Occupational medical

On a final note (and perhaps to support its conclusions), the ER states the following:

> *As of September 14, 2006, a total of 690 claims have been submitted to NIOSH for individuals who worked at FMPC during the years identified in the proposed class definition. Dose reconstructions have been completed for 619 individuals (90%).*

4.0 PRELIMINARY FINDINGS ASSOCIATED WITH THE ABILITY TO RECONSTRUCT INTERNAL AND EXTERNAL DOSES FOR FMPC WORKERS

This section of the SEC review process identifies discrete issues of concern that may adversely affect the ability to estimate FMPC worker exposures from internal and external sources. Findings presented below are grouped as follows:

- Section 4.1: Findings Associated with Urinalysis Data for Assessing Intake of Uranium
- Section 4.2: Findings Associated with Dose Assessments in Behalf of K-65 Wastes and Other Raffinate Wastes
- Section 4.3: Findings Associated with Approaches for Internal Thorium Dose Estimate
- Section 4.4: Limitations and Findings Associated with the Use of MIVRLM Data for Uranium and Thorium Dose Estimates
- Section 4.5: Findings Associated with External Exposure Monitoring at FMPC

4.1 FINDINGS ASSOCIATED WITH URINALYSIS DATA FOR ASSESSING INTAKE OF URANIUM

Finding 4.1-1: Limitations Associated with the Use of Fluorophotometric Urinalysis Data

Section 5.3.6 of FMPC TBD (as well as Section 6.1 of the SEC-00046 Evaluation Report) states the following:

> *. . the **fundamental** and **primary** bioassay for the first 35 years (1951 – 1986) of Fernald operational experience was urine analysis for **uranium metal, reported in milligrams per liter.*** [Emphasis added.]

Thus, it is NIOSH's intention to rely primarily on urinalysis data of **elemental uranium** to assess organ doses that may have resulted from the internalization of U-238, U-235, and U-234 of variable degrees of enrichment, which, moreover, existed in various chemical forms that include UF_4, UF_6, UO_2F_2, UO_2 $(NO_3)_2$, UO_3, UO_2, UO_4, U_3O_6, and U metal.

By design, the fluorophotometric urinalysis merely measures the total amount of elemental uranium without regard to the isotopic composition and radioactivity levels of the excreted uranium. Justification for this simplistic monitoring approach of FMPC workers was based solely on concerns for the **chemical** toxicity of uranium on kidney function, as opposed to radiological concerns.

Thus, the obvious difficulty with the conversion of urine data to organ-specific radiation dose(s) is the near absence of critical data. Unknown data include the relative isotopic composition(s) of U-238/U-235/U-234 of materials representing depleted, natural, recycled/enriched uranium as

well as the chemical form and solubility of uranium materials. Over even a modest employment period, select workers such as members of a **labor pool** or **roving maintenance** personnel must reasonably be expected to have been exposed to a wide variety of uranium materials.

Neither the FMPC TBD nor the SEC-000046 ER addresses the complexity of this problem or provides specific guidance for overcoming these deficiencies in the reconstruction of "best estimate" doses.

Finding 4.1-2: The Questionable Integrity of Fluorophotometirc Urinalysis Data

Aside from the intrinsic limitations that characterize the fluorophotometric urinalysis method discussed in Finding 4.1-1, there are reasons to also question the integrity/accuracy of the reported results. In addition to the near absence of formal records that define the analytical protocols, quality assurance/quality controls, instrument(s) performance standards (e.g., limits of detection), training and qualifications of laboratory personnel, etc., there is reason for concern about the integrity of reported results that reflect the **perceived** role of the urinalysis program by the Health and Safety personnel at FMPC.

In contrast to NIOSH, which at present views the urinalysis data as its primary tool for the reconstruction of dose from uranium exposure, FMPC personnel considered these data as having a limited, if not questionable, value as given in the following statements by FMPC personnel:

- Excerpts
  From: J.A. Quigley, MD, Director of Health and Safety
  To: _____ of the U.S. AEC
  Date: Nov. 1, 1963

  > *. . . Exposures to internal emitters is the more serious type of exposure at the feed materials center and probably also at the mills which prepare concentrates for the feed materials center . . .*
  >
  > *We use urinary uranium excretion information along with air survey information* ***to be sure*** *that we* ***are controlling*** *airborne exposures to amounts that will not be harmful. We* ***do not consider the urinary uranium excretion measurements as an accurate method of estimating either body burden or exposure.*** *We have assumed that the determination of internal exposure by* ***any*** *method or combination of methods is less precise the [sic] are estimations of exposure to* ***external*** *radiation . . . Our urinary uranium excretion records substantiate this opinion.* [Emphasis added.]

- Excerpts
  From: M.S. Nelson, Manager/FMPC
  To: U.S. AEC
  Date: March 6, 1972

  > *. . . As we have pointed out on previous occasions, we have* ***little confidence in the reliability*** *of any method for assessing dose to the lung from depleted,*

normal, or lightly enriched uranium at the expressed level of interest, 25% to 50% of the annual standard. We believe that ***uranium assay results are of no value*** *for this purpose.*

It must be assumed that ***anyone*** *who works in the production area has the potential for acquiring 25% of a permissible lung burden. At present there are 353 wage employees working in the production area. Also there are about 50 salaried employees who have the potential for acquiring 25% of a permissible lung burden.* [Emphasis added.]

- Excerpts
  From: S.F. Audia, Manager/FMPC
  To: U.S. DOE
  Date: Aug. 1, 1979

  . . . Uranium urinalysis results are ***not*** *used to evaluate radiation exposure at the FMPC. . . . Urinalysis results are only used as an* ***indication of the adequacy of basic exposure control.*** [Emphasis added.]

- Excerpts
  From: R.M. Spenceley, Manager/FMPC
  To: Battelle-Northwest Laboratory
  Subject: Answers to a Questionnaire on Radiation Recordkeeping
  Date: July 29, 1984

  Among various questions asked in the 1984 Questionnaire was Request #8, which asked FMPC to respond to the following:

  If you do not calculate radiation dose equivalents from internally deposited radionuclides please describe what data you record concerning internal exposure and the types of analyses which may be possible to perform on the data . . .

FMPC – Response to Request #8

(1) Amount of deposited nuclide determined from lung count is recorded and can be used to calculate lung burned.
(2) ***Excretion urinalysis data*** *recorded but this* ***cannot*** *be used for calculating internal dose.* [Emphasis added.]

When urine data for uranium exposure is either absent or incomplete, NIOSH intends to employ air monitoring data and/or in vivo lung count data. Findings in behalf of these two alternative approaches are discussed elsewhere in this report.

Finding 4.1-3: Failure to Monitor All Personnel with Potential Internal Exposure to Uranium

In Section 7.2.1.2 of the SEC-00046 Evaluation Report, NIOSH states the following:

> *Since **nearly all** FMPC workers were monitored for uranium in urine, **no co-worker** analysis has been deemed necessary for uranium intakes.* [Emphasis added.]

SC&A interprets NIOSH's position to imply that if a FMPC worker was not monitored for uranium intake, there is no justification or need for assigning internal dose(s) for uranium intake(s) other than "environmental intakes."

While records suggest the episodic monitoring of many **production workers**, there is evidence that ubiquitous fugitive emissions exposed **non**-production workers at other locations who were **not** monitored.

Attachment 4.1-3 identifies uranium results in behalf of four individuals even though they were not considered at risk and ". . . there were no apparent reasons for the high uranium results."

It should further be noted that FMPC had identified action levels regarding urine bioassay values. In a memorandum dated April 19, 1972, J.A. Quilgley, M.D., head of FMPC's Health and Safety Program, the following criteria were identified:

> ***Urine Results.*** *. . . Persistent results over 0.025 mg/l indicate moderate exposure and results over 0.040 mg/l are considered due to **excessive exposures** which require follow-up.* [Emphasis added.]

Thus, the "unexplainable" urine result of 0.543 mg/l in individual #3 is more than 13 times the value of 0.04 mg/l action level. Of concern to SC&A is the fact that this value was observed in an individual whose ". . . possibility of . . . getting an exposure of 0.543 mg U/l is **very remote**."

A reasonable interpretation of Attachment 4.1-3 is that these unexpected bioassay results may have involved "non-production workers" whose urine data were to have provided a baseline control value. If this interpretation can be substantiated, then it must be concluded that all workers (regardless of job-function/classification) were likely exposed internally to substantial amounts of uranium (as well as thorium), but may not have been monitored.

ATTACHMENT 4.1-3

F 2-1-3

May 13, 1955

URINARY URANIUM INVESTIGATIONS

R. C. Heatherton 2132431

W. S. Shurkin

The following urinary uranium results were investigated first because there were no apparent reasons for the high uranium results.

The investigations failed to show why these urinesamples were high in uranium.

Following are the results of the investigations:

(1) works for
as a She never goes into any area that would result in an exposure. There is no reason for the result of 0.072 mg U/l given by the analysis on 4/27/55.

(2) works for
, office where he is working to the present time. I could find no reason for the high uranium result of 0.466 mg U/l given by the urine sample of 4/29/55.

(3) worked as
Radiochemistry Lab, in the Laboratory Building. Her principle job was
Possibility of her getting an exposure which would result in 0.543 mg U/l is very remote.

(4) , is a
Her duties occasionally take her to the reproduction room in the Laboratory Building. I could find no reason for the urinary result of 0.053 mg U/l given by the sample of 5/2/55.

WSS:bg W. S. Shurkin

cc: J. A. Quigley
R. Hoover
W. S. Shurkin
Central Files

Finding 4.1-4: Use of Claimant-Unfavorable Assumptions and Default Values Regarding the Level Uranium Enrichment

The degree of U-235 enrichment of uranium feedstocks impacts the interpretation of uranium bioassay measurements, which are limited to fluorophotometric values defined in units of mg of elemental uranium per liter urine.

To account for the variability of uranium enrichment, Section 5.2.1.1 of the FMPC TBD provides the following:

> *During the following production years [after 1964], uranium was processed in a variety of enrichments ranging from depleted to as high as 20%. The quantities of enriched material* ***above 2%*** *was* ***not*** *documented but was qualitatively* ***reported*** *to be* ***small and/or insignificant*** *in total mass . . .*
>
> *In the absence of specific enrichment information . . . the default assumption for time periods after 1964 is 2% enrichment for bioassay data in milligram quantities of uranium. Prior to 1964 natural uranium should be used.* [Emphasis added.]

While SC&A concurs with the statement that ". . . quantities of enriched material above 2% was likely to be small/insignificant in total **mass**, the concluding default value of 2% enrichment is likely to significantly underestimate the interpretation of urine bioassay for select workers. Moreover, these workers cannot be separated from the rest because the bioassay was restricted to photofluorometry and the in-vivo counting made an across the board 1% enrichment assumption. Furthermore, enriched uranium was introduced into Fernald much earlier (SC&A 2006c).

Enclosed as Attachment 4.1-4A is a 1968 Health Protection Appraisal Report for NLO, which includes the following statements:

> *". . . action has been initiated for handling U-235 enrichments above* ***5%.*** *Current plans include the installation in Plant 1 of a geometrically safe continuous digester for enrichments to* ***10%.*** *It is expected that this facility will be operational by March 1969 . . .*
>
> *Projected and Anticipated U-235 Enrichment Processing*
>
> *Discussions with CAO and NLO personnel have indicated that Fernald will probably reprocess cold fuel from several reactor sites including Hallan, Bonus, EGCR, Piqua, and perhaps SRO.* ***Significant portions of the fuel will range from 3% to 7% U-235*** *enrichment. In this regard, a campaign is scheduled to begin in February 1969.* [Emphasis added.]

The above-cited statements suggest that for select years and FMPC facilities, some workers may have been exposed to uranium materials that are significantly higher than the 2% default value.

ATTACHMENT 4.1-4A

EXCERPTS FROM HEALTH PROTECTION APPRAISAL REPORT DATED SEPTEMBER 1968

Initial steps were being taken at the time of the appraisal to develop the NLO program of off-shift supervision and emergency planning. Meetings of the newly appointed NLO shift supervisor with the Y-12 Plant shift supervisor and emergency coordinator are planned. It is anticipated that the influence and impact of this planning at the higher levels of supervision at NLO will be felt in emergency training throughout the NLO organization.

5. Recommendation that corrective action should be taken to eliminate the refinery fume problem.

This problem has received a high priority at NLO, and conceptual engineering for correcting the problem appears to be adequate. Preliminary measures have been taken which have reduced the excessive fuming frequency somewhat; however, it was noted during the inspection tour that inattention to proper procedure continues to permit higher than desired fume concentrations, particularly at Digester D1-7.

B. Recommendation - September 1968 Appraisal

None.

IV. Findings

A. Nuclear Safety

1. Safe Digester

As noted in Part III-A.1 of this report, action has been initiated for handling U-235 enrichments above 5%. Current plans include the installation in Plant 1 of a geometrically safe continuous digester for enrichments to 10%. It is expected that this facility will be operational by March 1969. The installation of this equipment outside the Refinery is considered desirable and in keeping with recommendations of the NLO Health and Safety Division.

Attachment 4.1-4A (Continued)

2. Current Refinery and General Plant Operation with Enriched Materials

Production requirements are somewhat lower than that observed in previous appraisals. Currently, the Refinery is processing normal enrichment uranium while only a small production campaign of 2.1% U-235 metal is in progress in other plant areas. Inventories of pads and general storage areas are significantly reduced from that observed in former reviews. Hence, with the implementation of previous recommendations and the status of current operations, the criticality potential is considered lower than that observed in past appraisals.

3. Projected and Anticipated U-235 Enrichment Processing

Discussions with CAO and NLO personnel have indicated that Fernald will probably reprocess cold fuel from several reactor sites including Hallam, BONUS, EGCR, Piqua, and perhaps from SRO. Significant portions of the fuel will range from 3% to 7% U-235 enrichment. In this regard, a campaign is scheduled to begin in February 1969. To upgrade the safety and economy for processing these materials, studies are underway for equipment modification in Plant 4 and in the Refinery Denitration Area. With regard to the latter, the ORO, NLO, and CAO staffs have been working together in statistical studies and computational efforts for establishing an upper safe enrichment limit for operating the 500-gallon denitration units without batch restrictions. Since water must be excluded from the denitration pots to utilize the "nitrogen poison-moderation control" principle under consideration, further studies are underway regarding the use of scrubbers, water cooling systems, etc., which could become sources of water inleakage into the units. Detailed discussions and plant inspections with NLO engineering and operating personnel were held on these aspects during the appraisal.

Finding 4.1-5: There are several radionuclide contaminants in RU that are not adequately considered for internal dose estimates. Most relevant to this concern are impacts of these contaminants in RU raffinate waste streams.

The TBD focuses on Pu-239, Np-237, and Tc-99 in its evaluation of RU. Other radionuclides, such as americium-241 and thorium isotopes (228, 230, and 232) are mentioned, but no data are provided (see Section 5.2.2, Vol. 5, pp. 13–18). The omission of thorium isotopes, and in particular thorium-230, may be of considerable significance. Furthermore, when RU is processed for its uranium content, the raffinates tend to accumulate the plutonium and other trace contaminants, including thorium-230. The raffinate stream contains little uranium. Hence the problem of dose reconstruction for workers who handled the raffinates is analogous to that of the workers who handled the waste streams from pitchblende ore processing. This problem was recognized at Fernald at least by the mid-1980s. For instance, a 1988 evaluation stated the following:

> *The uranium feed would contain the trace of TRU impurity that was typical of recycle uranium. A portion of the TRU impurities would end up in the uranium product and a portion in the byproducts. The vast majority of uranium goes into the uranium product, but a small amount does end up in the byproduct. The end result is that the ratio of TRU to U is slightly lower in the product than it was in the feed, but that ratio is* ***much higher in the byproduct than it was in the feed.*** [Hinnefeld 1988, emphasis added].

This problem of concentration of trace radionuclides in the raffinate stream is also recognized in the TBD, which cited an expert evaluation done in 1989 (Bassett et al. 1989). In the case of magnesium fluoride feed, a note to Table 5-9 in the TBD states the following:

> *Though the results in the table are all reported in ppb U, this measure is meaningless in subgroups in which there is very little uranium, such as subgroup 8, in which the MgF_2 did accumulate some isotopes, but was low in uranium by design.* [Vol. 5, TBD, p. 15]

Despite the fact that the TBD states that trace contaminant values are "meaningless" when there is very little uranium present, the quantitative discussion in the TBD of RU dose estimation is focused primarily on the trace contaminant values of uranium feed material, rather than raffinates or magnesium fluoride.

Thorium-230 has also been recognized as a specific problem in this regard. For instance, the DOE-commissioned evaluation of radiation doses due to trace contaminants in RU for the Paducah plant indicates that thorium-230 doses were among the highest in some circumstances. In that case, the maximum bone surface dose estimated for "ash receivers" was estimated as 110 rem, about the same as that for Pu-239 and much higher than Np-237 (PACE/University of Utah 2000, Tables 7.10 and 7.11, pp. 76–77). As with the processing of ores, thorium-230 will tend to concentrate in the raffinate stream as well, exacerbating the problem.

A complete evaluation should also consider thorium-232, uranium-232, and uranium-236 as potential contaminants of RU. Specifically, U-232 is created as a neutron activation (decay) product of protactinium-231, and the DOE recommends that it be taken into consideration in RU assessments. This is both an internal and external dose issue, because U-232 decays into thorium-228 with a 70-year half-life. According to DOE-STD-1136-2004, the *Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities*, U-232 presents the greatest external dose hazard in RU:

> *The isotope in recycled uranium presenting the greatest potential radiological hazard from external sources is ^{232}U. ^{232}U is a daughter product of neutron activation of ^{231}Pa. The health hazards of ^{232}U are primarily due to the rapid buildup of gamma activity of its decay products, particularly from ^{228}Th. The gamma activity buildup is both time and process-dependent.* [DOE 2004, p. 2-15].

Given that the highest values of trace contamination with plutonium received at Fernald could be in the thousands of ppb, Table 5-9, which gives the values for plutonium in the various RU streams at Fernald, is incomplete and inadequate. The highest value of Pu-239 in this table, 412.177 ppb, corresponds to feed material (ash) from Paducah. There is no discussion in the TBD of the specific batches of RU and the waste streams arising from them. Such an analysis is necessary for individual internal dose reconstruction for at least some groups of Fernald workers.

Finding 4.1-6: The data on trace contaminants in RU in the Fernald TBD are incomplete and appear to be incorrect. Different official documents have very different values for various aspects of RU data, including production and contamination. The contradictions have not been sorted out in the TBD. (Note: This finding was previously identified in SC&A 2006c.)

The TBD cites considerable data on the contamination of RU with trace amounts of plutonium-239, neptunium-237, and technetium-99. However, these data are incomplete. The representation of maximum trace contamination is at variance with other official documents and appears to be incorrect.

Table 5-9 of the TBD (Vol. 5, pp.15–16) provides data on plutonium-239, neptunium-237, and technetium-99 contamination of various sources of RU received at Fernald. The data are given in parts per billion of the trace contaminant in uranium, written as "ppb U," which we will abbreviate here simply as ppb. The highest value of Pu-239 contamination, associated with uranium trioxide from tower ash from Paducah is given as 412.177 ppb (TBD, Vol. 5, Table 5-9 and p. 17). Several values of Pu-239 contamination are between 10 and 100 ppb, and the rest are below 10 ppb, which was the specification limit for Pu-239 contamination at Fernald.

However, other documents are at variance with the maximum value of 412.177 ppb. For instance, a 1985 compilation of RU feed materials above 3 ppb U received at Fernald, prepared by National Lead of Ohio (NLO), gives the highest total plutonium contamination in "ash" for 1980 as 1,122.553 ppb (Spenceley 1985). Plutonium isotopes other than Pu-239 would not contribute significantly to the ppb values; hence, it is safe to interpret the "Total plutonium ppb"

in Spenceley 1985 as approximately equivalent to a Pu-239 ppb value. This reference does not provide details of other radionuclides.

It is quite possible that both sources are incorrect. The TBD appears to be based on a DOE report on RU (DOE 2000). This DOE report states that the total uranium receipts at Fernald amounted to 362,581.8 metric tons (DOE 2000, p. ES-2). This appears to be inconsistent with materials accounting reports from Fernald. For instance, the cumulative receipts until the end of FY 1986 were stated by Westinghouse to be 606,931.9 metric tons (Bogar 1986, Table V). This materials account is consistent with others produced during the period of production and submitted to the AEC and the DOE. Hence, it is likely that the DOE 2000, which is the basis for the data on RU, is incorrect even for the basic value relating to uranium receipts at Fernald.

We note here that the TBD also appears to have an incorrect value for uranium production at Fernald. Volume 1 of the TBD estimates the shipments of uranium metal at 170,000 metric tons and intermediate products at 35,000 metric tons. The materials account cited above provides a value of 594,699 metric tons cumulative shipments to the end of FY 1986. Furthermore, the total shipments of 205,000 metric tons in Volume 1 of the TBD are less than the estimate of 246,683 metric tons of RU alone that the TBD states were received at Fernald (TBD Vol. 5, p. 13). The total amount of RU of 246,683 metric tons in DOE 2000 appears rather large. In contrast, the amount estimated in Spenceley 1985 is only 7,183.6 metric tons, cumulative through 1985. This is almost 30 times less than the value in DOE 2000. Finally, Volume 6 of the TBD contains an entirely different number for RU compared to Vol. 5. Citing a DOE 2003 report on RU, it states that the receipts of RU at Fernald amounted to 17,966 metric tons. This matter is further discussed in Chapter 7.

Since the last mentioned report (DOE 2003) was prepared in order to correct "some inconsistencies between quantities of RU shipped and the quantities received" (DOE 2003, p. v) in the DOE 2000 report, it is surprising that NIOSH did not employ the corrected report. The figures from this report are shown in Vol. 6 of the TBD (Table 6-2, p. 8); they indicate an overall average Pu contamination of the RU received at Fernald of 4.14 ppb. This is greater than all the average contamination values for enriched, natural, and depleted RU shown in Table 5-10, Vol. 5 of the TBD (3.5 ppb, <0.1 ppb and <0.1 ppb, respectively), where the basis for the RU dose reconstruction is developed. Volume 5 of the TBD gives the overall average Pu contamination of RU as 0.9 ppb, which is only about 22% of the value in DOE 2003.

The overall average values for Np-237 and Tc-99 in Table 5-10 are also at variance with DOE 2003 (Table A-9, p. 60, which is reproduced as Table 6-2 in Vol. 6 of the TBD). The concentrations of Np-237 and Tc-99 calculated from the DOE 2003 data are 319 ppb and 7510 ppb, respectively, compared to 104 ppb and 1,346 ppb given in Vol. 5 of the TBD.

Another contradiction emerges from the comparison of the values in Volume 5 of the TBD and DOE 2003. Since the overall value for RU receipts given in Volume 5 of the TBD is so much larger than that in DOE 2003 (246,683.1 metric tons versus 17,966 metric tons), the total contaminant content of RU estimated in Volume 5 of the TBD is much larger than that in DOE 2003. Table 4.1-1 shows the comparison.

Table 4.1-1. Comparison of Total Fernald RU Contamination, TBD, Vol. 5 vs. DOE 2003

	Total Pu, grams	Total Np-237, grams	Total Tc-99, grams
TBD Vol. 5, Table 5-10	217.7	25,742.1	331,998.1
DOE 2003, Table A-9	74.3	5,735	135,000
Ratio, TBD/DOE 2003	2.93	4.49	2.46

Volume 5 of the TBD is not only in contradiction to Vol. 6 of the TBD, but it is also at variance with what DOE claims is a more definitive DOE report on RU (DOE 2003), since that report was designed to correct earlier problems. SC&A has not done a review of the underlying data that led to the correction, since that would involve a major effort to review RU data across the complex. It is unclear at the present time how reliable the various figures for plutonium, neptunium, and technetium contamination (both as totals and in terms of concentrations) might be.

An evaluation by Bechtel of RU shipped to Fernald from Paducah provides yet another set of values for RU contamination for a specific batch that do not match the values in Volume 5 of the TBD. This document provides a range of values of Pu-239 in "Feed Plant Ash" shipped to Fernald in 1980 from Paducah as 37 to 3,118 ppb (Bechtel 2000, Table 4-2.2, p. 51). The various containers of Feed Plant Ash were not mixed at Paducah, because the reported values were "calculated from results of 16 hoppers analyzed by FMPC" (Bechtel 2000, footnote to Table 4.2-2, p. 51). Hence workers handling and measuring the hoppers would have been exposed to concentrations of trace radionuclides during some time periods when the concentrations were far higher than the largest value reported in the TBD, especially if they worked with raffinate streams. Finally, the same table in Bechtel 2000 notes that data for plutonium contamination are not available for "Filter Cake" shipped to Fernald. Three other items have only blanks in the column for plutonium contamination. The higher trace contamination levels may adversely affect some workers, who were mainly in contact with them due to their work assignments or periods of employment. For others, long-term exposure to RU may mean that the values suggested by NIOSH are claimant favorable (see below).

In summary, the contradictions and conflicting values in the RU data need to be investigated, before a reliable set of values for RU amounts and contamination can be established.

4.2 FINDINGS ASSOCIATED WITH DOSE ASSESSMENTS IN BEHALF OF K-65 WASTES AND OTHER RAFFINATE WASTES

Finding 4.2-1: The K-65 Default Model is Inappropriate

Section 7.4.1.3 of the ER addresses the petitioner's concern about worker dose assessment in behalf of K-65 processes involving Silos 1 and 2. For K-65 processes, NIOSH states that a maximized approach will be employed as described on page 27 of ORAUT-TKBS-0017-5.

SC&A has evaluated the proposed model and concludes that the model contains numerous **assumptions** that are inappropriate and consistently **non**-claimant favorable.

Key Elements of the K-65 Dose Model

Critical parameters that define NIOSH's K-65 Silo dose model include the following empirical data:

- Internal and external exposures were received by workers who transferred 13,000 drums of K-65 wastes into Silos 1 and 2 between July 1952 and September 1958.
- The isotopic composition of K-65 wastes in Silos 1 and 2 are given in Table 5-16 of the TBD and reflect a 1993 study of core samples.
- A single record dated 4-15-1953 identifies the transfer of an ". . . average about 80 drums/day."
- A small number of records/data sheets from 1952 and 1953 involve air samples with a wide range of activity levels defined in alpha activity per cubic meter of air. Values ranged from <1 MAC to 18,777 dpm/m of 268 MAC.
- Air sampling consisted of both general air (GA) and breathing zone (BZ) samples. The flow rate of air samples was consistently recorded at 0.02 m^3/min (or 20 liters/min) for both GA and BZ sampling with sampling times ranging from 1 to 30 minutes.

While these limited empirical data are helpful in the development of a bounding **internal** dose model, these data provide no concrete information regarding the amount of time a given worker was exposed to these air contaminants in any given year. To fill these gaps of information, NIOSH's dose model is based on the following **assumptions**:

(1) The transfer of 13,000 drums was an **around-the-clock** effort that involved three shifts of workers at 80 drums per day.

(2) A group of **external** dose data sheets (i.e., film badge records) for 22 K-65 workers were used as the basis for defining the **yearly** exposure duration to K-65 airborne contaminants and include the following:

- Of the 22 K-65 workers (identified in a small number of data sheets that spanned only a brief time period), NIOSH chose 13 workers with the highest doses ranging from 158 to 500 mrem average per week. Available records show that three of the 13 workers were assigned to K-65 for three weeks; and there were 10 workers with K-65 dosimetry data for 6 weeks. The highest recorded weekly external gamma dose among the 13 workers was 1,200 mrem.
- The collective **average** exposure for all 13 workers was calculated at 312 mrem/week.

This collective average **external** dose of 312 mrem/week for the 13 highest K-65 workers was used by the model to justify the yearly exposure time to K-65 airborne levels by means of the following assumptions:

- NIOSH assumed that for **1952** the **annual** external exposure limit for penetrating radiation was 5 rem.

- NIOSH further assumed that FMPC must have had a more restrictive **administrative dose limit of 4 rem/year**.

- By dividing the assumed administrative dose limit of 4 rem/year by 312 mrem/week, NIOSH concluded that K-65 workers would be restricted to a maximum of **3 months** after which the workers would have been shifted to a **non**-radiological work location.

- The above-derived **3 months per year** exposure duration was further reduced to **6 weeks**, as explained by the following statement on page 27 of the TBD:

  > *. . . From the information derived in the external dose data sheets and the air monitoring sample sheets, it appears that the transfer could have been limited to a period of 10 weeks per year with no individual working more than a period of 6 weeks in the year in order to control external dose within the regulatory limits.*

Thus, NIOSH's final reduction of the **yearly internal exposure time to 6 weeks** was based on the assumed administrative dose limit of 4 rem/yr and the highest recorded weekly dose of 1,200 mrem among the 13 highest externally exposed K-65 workers.

SC&A concludes that NIOSH's internal dose model for K-65 workers is based on **incorrect** and **unfounded** assumptions that are consistently **un**favorable, as explained below.

- Use of the 13 Highest Externally Exposed Workers. By using the **highest** externally exposed workers (and applying their exposure data to regulatory/administrative dose limits), NIOSH has employed a modeling approach that is not only irrelevant to **internal** exposure but is **non**-favorable to the claimant.

- Exposure Limits. During this 6-year period, the exposure limit employed by the **AEC** was 0.3 rem/week, 3.9 rem/13 weeks, and **15 rem/year**, which is three times higher than NIOSH's "assumed" value of 5 rem/year. It was not until 1958 that the 5 rem/year limit was introduced in combination with the lifetime limit defined by 5(*n*-18) (see Attachment 4.2-1A).

- Administrative Dose Limit. Review of available data provides **no** indication that FMPC imposed an administrative dose limit of 4 rem/yr. In fact, three separate data sheets identified as Attachments 4.2-1B, 4.2-1C, and 4.2-1D reference the AEC dose limit of 300 mrem/week. Attachment 4.2-1D identifies the maximum permissible monthly dose of 1,250 mrem (or 15 rem/yr) for whole-body gamma as late as 1959. Moreover, data

sheets/memos show that dose limits were routinely exceeded as well as **ignored** (Attachment 4.2-1D).

- Three-Shift Work Schedule. Support for the assumption of a three-shift work schedule for **all 6 years** of K-65 operation is based on a single data sheet dated October 16, 1952. This data sheet identifies the shift schedule and personnel at the "K-65 Dumping Station."

  It must be recalled that in addition to the 13,000 drums received from MCW, Silos 1 and 2 received raffinate wastes **produced at FMPC**, which were "transferred via pipes to Silos 1 and 2. It is unclear whether individuals cited in the October 16, 1952 data sheet were assigned to drum disposal activities or to assuring that FMPC-produced raffinates were properly disposed.

  The likelihood that these workers were assigned to FMPC-produced raffinate disposal on a three-shift basis is based on the fact that **processing of uranium ores** at FMPC was a 24-hour operation.

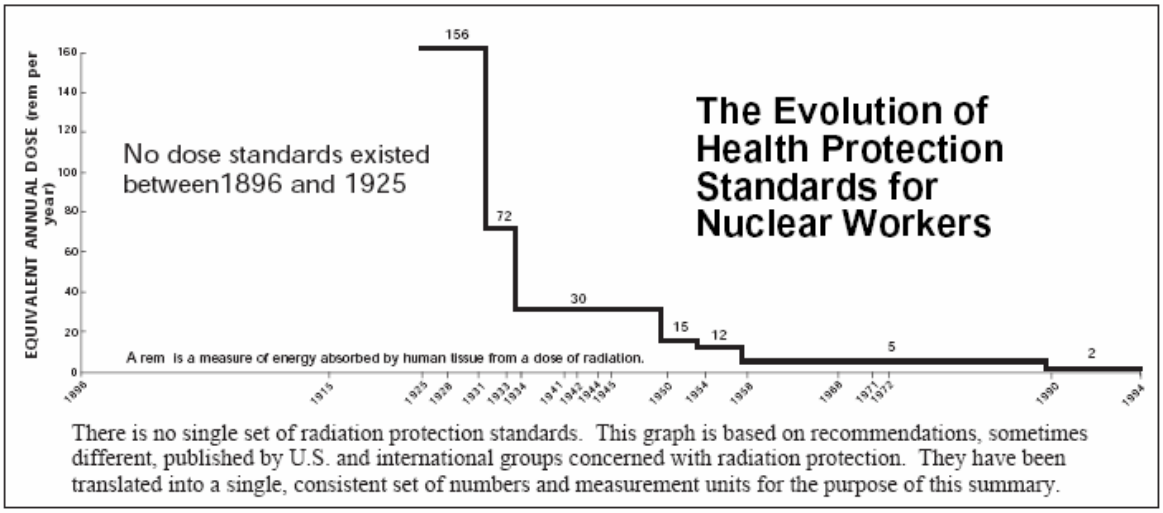
  It is also counter-intuitive to assume that the **manual removal** and disposal of **MCW-produced** raffinate waste would be performed during hours of darkness. Moreover, there is no logical basis to suggest an urgency to compress disposal into a 6-week period on a three-shift schedule, and then abandon this task for the balance of the year.

In concluding remarks, NIOSH describes that mode as one that is ". . . **based upon assumptions that are cumulative conservative, claimant favorable, and establishes an upper bound of intake for workers involved in the transfer operation of the 13,000 barrels of the stored MCW raffinates to the K-65 silos**." [Emphasis added.]

In contrast, SC&A regards NIOSH's dose model as one that is based on incorrect assumptions, unsupported assumptions, and counter-intuitive assumptions that are consistently claimant **un**favorable.

ATTACHMENT 4.2-1A

Closing the Circle on the Splitting of the Atom



There is no single set of radiation protection standards. This graph is based on recommendations, sometimes different, published by U.S. and international groups concerned with radiation protection. They have been translated into a single, consistent set of numbers and measurement units for the purpose of this summary.

1896 Henri Becquerel discovers radiation. First radiation injuries are reported, but no protection standards exist.

1915 Protection standards describing "safe practices" for handling radium and X-ray machines are published in Sweden and Germany. Radiologists are advised to stay as far away from their equipment as possible, to handle radium vials with tongs, and to work no more than 35 hours a week. The U.S. and Britain soon follow suit, but no dose limits are set because measurement techniques and units do not yet exist.

1925 Swedish and German scientists publish estimates of "tolerance doses," the amount of radiation a person is thought to absorb without harm. Based on the amount of radiation that would burn skin, the tolerance dose is initially estimated to be the equivalent of about 156 rem per year (over 45 times the current standard), although the estimates vary widely.

1928 The first internationally accepted X-ray protection standard, 1 one-hundredth of the amount that burns skin per month, is accepted at an international congress.

1931 The tolerance dose is standardized at 6 rem per month (72 rem per year).

1933 The genetic effects of radiation on fruit flies are studied by German scientist A. Mueller. He learned that radiation caused genetic mutations.

1934 First international radiation safety standards based on measurements of damage to human tissue are published in Zurich by the International Commission on X-Ray and Radium Protection. Workers are allowed up to 0.1 rem per day (30 rem per year).

1941 Recommended tolerance for ingested radium is initially set at 1 ten-millionth of a curie per person by the National Commission on Radiation Protection. This recommendation is based on studies of radium-watch-dial painters.

1942 The Manhattan Project begins. The 1934 radiation exposure standards of 30 rem per year are accepted by the University of Chicago's Metallurgical Laboratory after experimental verification. The "tolerance" concept is discarded in favor of the "maximum permissible exposure."

1944 The initial tolerance limit for plutonium inhalation is set at 5 millionths of a gram per person by the Manhattan Project's radiation protection laboratory.

1945 The first atomic bombs are produced, tested, and used. Weighting factors for the different types of radiation are introduced to account for their different health effects. The plutonium tolerance limit is lowered to 1 millionth of a gram per person.

1950 Scientists discard the idea of a "maximum permissible exposure," recognizing that any amount of radiation may be dangerous. Radiation protection scientists recommend that exposure be "as low as reasonably achievable." Concern over latent cancer, life shortening, and genetic damage also causes standards to be halved: 0.3 rem per week (15 rem per year).

1954 A quarterly limit of 3 rem per 13 weeks (12 rem per year) is introduced by the U.S. National Bureau of Standards to allow more flexibility in exposure patterns. Workers are still allowed 0.3 rem per week up to this limit.

1958 In response to a study by the National Academy of Sciences of the genetic effects of radiation, a new dose limit is introduced, using a formula that allows workers to receive 5 rem per year after the age of 18. Annual doses are allowed to exceed this level up to 3 rem per 13 weeks (12 rem per year). To protect the gene pool, a lower standard of 0.5 rem per year is set for the general public.

1968 The Federal Government updates its protection standard to the 5 rem per year recommended in 1958. This standard has not been changed since.

1971 Radiation protection standard is restated by the National Committee on Radiation Protection but not really changed: 3 rem per 13 weeks in the past, 5 rem per year in the future. By including exposure from internal radiation ("body burden"), the standard is effectively lowered by a significant amount.

1972 The National Academy of Sciences publishes its first study of the health effects of radiation since 1956. The report, Biological Effects of Ionizing Radiation I (BEIR I) becomes the first of a series.

1990 The National Academy of Sciences BEIR V report asserts that radiation is almost nine times as damaging as estimated in BEIR I. Annual doses may no longer exceed 5 rem per year. The International Commission on Radiation Protection recommends that an average dose of 1 or 2 rem per year not be exceeded.

38

ATTACHMENT 4.2-1B

2132117

CENTRAL FILES

November 25, 1952

Transfer of K-65 from Deteriorated to Solid Drums

W. Strattman

R. C. Heatherton

On Tuesday, November 25, I made an inspection of the subject operation on the Storage Pad. There were indications that people working on this operation are subject to very high radiation exposure and in all probability, exposure to radioactive dust in excess of the maximum allowable concentration. At the time of my inspection there were a total [redacted] operators.

a) Two (2) were handling drums with fork lifts.
b) Two (2) were removing lever locks and covers from old drums and placing the collar and new drum in position.
c) Two (2) were removing the old drums and placing covers and lever locks on new drums.

None of these operators were working behind shields, although shields were provided for Operators B, above.

Radiation exposures as measured with a pocket dosimeter on Monday indicate that the fork lift operators were receiving approximately 20 mr/hr. Other operators were receiving about 10 mr/hr when working behind shields. However, it is expected that their exposure is at least doubled when they are working as they were today. At this time we have no dosimeter data to confirm this, although we are accumulating more information.

Previously we have permitted exposures equal to or in excess of the maximum permissible dose in case of emergencies. However, the practice of considering each job as an emergency and permitting exposures at this level should not be continued. The maximum permissible exposure of 300 mr/wk is just what the term implies, the maximum permissible exposure. It is not an exposure which we would recommend be permitted on a continuous basis. It will be the policy in this plant to limit radiation exposure to a minimum. Where emergency requires that a person receive a certain amount of exposure the total during the emergency should be limited to no more than 150 mr if possible. This is on the assumption that a person may normally receive 150 mr in his other duties.

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ATTACHMENT 4.2-1C

NLO-2-LOT2

NATIONAL LEAD COMPANY OF OHIO

CENTRAL FILES

P. O. BOX 159
MT. HEALTHY STATION
CINCINNATI 31, OHIO

August 11, 1954

SUBJECT:

2132095

TO

D. Nelson

FROM

A. J. Stefanec

REFERENCE:

Recently we have noticed a sudden increase in the number of overexposures to radiation as indicated by the film badge. It seems that the bulk of these overexposures are to operators of the burnout area. We have investigated and have noted the following.

In the [redacted] section, the glass shield with arm ports is broken out allowing 100 mrep/hour of beta to irradiate the operator doing this work. In the crucible assemble section where the shield is usually raised there is emitted 20 mrep/hour to the operator.

Since our present limit of exposure is 300 mrep/week it can readily be seen why we have these overexposures to this particular group of men.

Having the above information it is therefore recommended that all shields be replaced and used properly.

Yours truly,

A. J. Stefanec

AJS:bg

cc: D. J. Blythe
W. Hill
J. A. Quigley, M. D.

090892

NOTICE: This document has been reviewed for Privacy Act information and has been edited accordingly.

NOTICE: This report is pre-decisional and has not been reviewed by the Advisory Board for factual accuracy or applicability within the requirements of 42 CFR 82.

ATTACHMENT 4.2-1D

HSM DEPARTMENT MONTHLY REPORT FOR JUNE, 1959
J. A. Quigley, M.D.
July 2, 1959

2. APD, Whole-body (gamma) - 417 mrem/mo. = 5 rem/yr (for life-time)
   a. Persons receiving APD or greater - 1
   b. Distribution: Thorium Warehouse - 1.

3. **MPD, Skin (beta plus gamma) - 2,500 mrem/mo. = 30 rem/yr
   a. Persons receiving MPD or greater - 14
   b. Distribution: Plant 5 - 12, Plant 6 - 1, Plant 9 - 1.
   c. Highest skin dose - 5,690 mrem - Plant 5

4. MPD, Whole-body (gamma) - 1,250 mrem/mo. = 15 rem/yr
   a. Persons receiving MPD - 0
   b. Highest whole-body dose - 450 mrem - Thorium Warehouse

*APD - Average Permissible Dose - Monthly fraction of average dose/year lifetime occupational (AEC Manual Chapter 0524)
**MPD - Maximum Permissible Dose - Monthly fraction of maximum dose/year (AEC Manual Chapter 0524)

Ground Contamination Survey

The weekly ground contamination survey conducted in the vicinity of each of the production plants is continuing, and it is thought with some success. The line supervisors are all cooperative to the extent of correcting undesirable conditions as they are brought to their attention. There are still a number of undesirable conditions existing, such as the major backlog of turnings in the east side of Plant 6 and a number of damaged drums on the storage pad. However, definite progress is being made considering the entire plant, and it is thought that this improvement will start reflecting in the lower effluent contamination. A few of the more serious spills during the month are as follows: trailer cake spills between Plant 5 and the waste pit continue, overloading of the trailer results in occasional spills of trailer cake along the roadway. Although these spills are cleaned up immediately upon notification by members of this department, definite steps should be taken to prevent the spills in the first place.

A sizable quantity (approximately 50 lbs) of black oxide was mistaken for dirt or soot in a metal container sent from the Pilot Plant to the Welding Shop for alterations before installing in Plant 6. This material was flushed onto the floor and pad at the Welding Shop and some washed into the storm sewer before inspection revealed the nature of the material. The remainder was then shoveled up and delivered to Plant 5 for recovery. Pilot Plant supervision was consulted and agreed that the equipment should have been cleaned first, then sent to the Decontamination Building.

A major release of liquid UNH occurred at Plant 3 on June 21, with some 300 gallons blowing out onto the pad and ground to the SE of the plant and as far away as Plant 7 shipping area. No notice was given this department, and the incident was discovered by chance late on June 22. The gravel was extensively covered with the uranium salt. Rains occurred the night of June 22 and the day of June 23. On June 24, a sample of

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NOTICE: This document has been reviewed for Privacy Act information and has been edited accordingly.

NOTICE: This report is pre-decisional and has not been reviewed by the Advisory Board for factual accuracy or applicability within the requirements of 42 CFR 82.

Attachment 4.2-1D (Continued)

IH&R DEPARTMENT MONTHLY REPORT FOR OCTOBER 1969 Page 2
J. A. Quigley, M. D.
November 11, 1969

additional work and some slight, but unnecessary, radiation exposure which could have been avoided by thorough communication. More explicit information on the purchase order would have helped.

Some preliminary investigation of the radiation exposure to the hands of various operators is being made. Wrist film dosimeters have been worn by the burnout and mold reconditioning operators in Plant 5. These dosimeters have not been processed yet.

Measurements of the gloves worn by the burnout operator for a full day showed inside radiation levels of 60 to 100 mr/hr. When the operator changed gloves after every third crucible the levels were less than 20 mr/hr. The mold reconditioning operator normally used three pairs of gloves per shift. Radiation levels in these gloves were 10 to 25 mr/hr.

Miscellaneous

A lighting survey was performed in the General Purpose Warehouse. As noted in an earlier survey, the illumination was less than the recommended levels for seeing tasks. A follow-up survey will be made to determine lighting improvement after the existing 200 watt light bulbs are replaced with 300 watt bulbs in each ceiling fixture.

This department witnessed a demonstration of an air powered drill in Plant 5 and found its performance favorable in not creating a dust problem. An air diffuser is used to control dusting that some other air powered tools do not have.

We observed a preliminary test to determine if precipitated thorium fluoride could be dewatered in a centrifuge. The Plant 9 chip centrifuge was lined with a filter cloth and used in this test. No industrial hygiene problems were seen if the filtrate, which contains hydrofluoric acid, can be removed to a vented tank. In the test it leaked to the floor and caused some eye irritation to the people present.

External Radiation

During September two film badges received beta and gamma radiation in excess of the MPD (2500 mrem per month for whole body skin). The badges were worn in Plant 5 by [redacted] and had received

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Attachment 4.2-1D (Continued)

exposures of 2550 and 3250 mrem. There were ten badges that exceeded one-half the MPD or APD. A breakdown of these exposures is as follows:

Plant 5 - [redacted] - Remelt Area Operators
Pilot Plant - [redacted] - Thorium Processing
Plant 9 - [redacted] - Remelt Area Operator

Ground Contamination

The amount of uranium lost via the Storm Sewer System for October was 294 pounds. No unusual spills of contaminating materials or losses to the Storm Sewer were found to have occurred.

Stack Losses

The estimated uranium loss from dust collectors during October totaled 62 pounds. No thorium loss was estimated.

Environmental Sampling

No NCG values were exceeded during October in the Miami River or Paddy's Run. The total suspended solids concentration in Manhole 175 effluent continues to average well below the NCG of 100 mg/l.

Our off-site sampling results for nitrogen dioxide and fluoride during October were all below NCG values.

Work Statistics

Samples Collected	155	Equipment Material Passes	29
Air Dust	114	Nuclear Safety Change-Over Inspections	16
Stack	14	Receipts Monitored	4
Water	11	Radiation Work Permits	8
Fluoride	6	Drawings Reviewed	3
Nitrate	8		

M. W. Boback

MWB/fb

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Finding 4.2-2: Neither monitoring data nor a default dose model exist for estimating internal dose from raffinate streams associated with high-grade ore processing in Plant 2/3. (Note: This finding was previously identified in SC&A 2006c.)

Fernald processed high-grade ores, including pitchblende, which was processed during the 1953 to 1955 period (TBD Vol. 5, p. 7). These ores, being very rich in uranium (up to two-thirds uranium oxide content), therefore also have high concentrations of Ra-226 and Th-230, which are decay products of U-238 generally present at levels close to equilibrium with U-238. Similarly, they have relatively high concentrations of protactinium-231 and actinium-227 (and its decay products, thorium-227 and radium-223), all of which are in the decay chain of uranium-235. Processing of high-grade ores gives rise to waste streams that are high in the decay products of U-238 and U-235, but relatively low in uranium, which is part of the product stream.

Essentially no personnel monitoring for the decay products of U-238 and U-235 was done in the period of production when ores were handled at Fernald. The TBD cites some air concentration data for Plant 2/3 (Vol. 2, pp. 21–22), but these are in production areas, not waste stream areas. Unlike production areas, where uranium bioassay data can provide at least a starting point for internal dose reconstruction, such data are not very useful in determining dose of decay products. Uranium is a minor constituent of the waste streams in terms of its fraction of the total radioactivity per gram of material. This is accentuated by the fact that the DCFs for most organs of the trace constituents are much larger than they are for any of the isotopes of uranium present in natural uranium.

The TBD has data on the isotopic composition of the waste streams as present in an aggregated form in the K-65 Silos, also called Silo 1 and Silo 2. These data can be used to estimate doses in the absence of personnel monitoring data, provided sufficient air concentration data are available. However, no such data are cited for the processing waste streams in Plant 2/3. The TBD cites the decay products that are the radionuclides of concern for Building 3E, where raffinates were processed. However, there are no data that would be useful for estimating doses due to these radionuclides in the TBD.

The problem of estimation of doses for production workers who worked at the filter presses and other locations where the waste streams were handled was dealt with by SC&A at length during consideration and review of the MCW SEC Petition (1949–1957 period). NIOSH also considered it in detail as part of that same process. The analyses and reviews can be found in SC&A 2005a and SC&A 2005b. The dose reconstruction procedures suggested by NIOSH, as well as illustrative examples, are in the attachments to SC&A 2005b. A review of those procedures can also be found in SC&A 2005b.

While some of the analysis in the MCW-related reports is specific to that site, given that residues sent to storage were brought back to the site and reprocessed for uranium extraction, the primary discussion relating to pitchblende waste streams applies here and will not be repeated. Suffice it to say that uranium bioassay data provide an uncertain basis for estimating internal dose, due to the trace constituents in pitchblende processing waste streams. For such data to be used at all, knowledge is needed of the fraction of uranium relative to the other radionuclides at various points in the waste stream. Furthermore, these data need to be rather reliable, because the dose

depends greatly on accurate (or upper-bound) knowledge of the ratio of trace radionuclide activity to uranium activity. No relevant data specific to Fernald are provided in the TBD, and SC&A has not come across any in the course of this review.

One alternative approach that NIOSH suggested in the context of Mallinckrodt was to use radon breath data. Such a dataset was available for a subset of Mallinckrodt workers. The Fernald TBD mentions that "a series of radon breath samples" were located in the context of a discussion of the composition of the K-65 silos (TBD Vol. 5, p. 26); however, the data are not provided, nor is it clear whether any of the workers who processed the waste streams in Plant 2/3 were covered by the sampling program.

As it stands, the TBD has no procedure in place and no data on which to base doses to workers involved with ore processing waste streams. It is to be noted in this context that one of the statements made by SC&A in the Mallinckrodt context was that using the general approach for estimating maximum plausible doses using ORAUT-OTIB-0002 may result in doses smaller than the ones actually experienced by some workers.

Finding 4.2-3: Incorrect Model Assumptions Pertaining to Radon Releases from K-65 Silos

MCW and FMPC raffinates disposed and stored in Silos 1 and 2 at FMPC contained large amounts of Ra-226 that served as source term for the Rn-222 emissions that would have exposed K-65 workers, all other FMPC workers, as well as members of the general public.

Radon exposures from Silos 1 and 2 are based on modeled data as described in a 1995 study (RAC 1995). Key information used in this study were the isotopic composition of Silos 1 and 2, as summarized in Table 5-16 of the TBD and restricted release rates through structural fissures that are the result of diurnal barometric pressure changes.

In Section 5.2.4 of the TBD, NIOSH states that:

> *. . . during the 1953 to 1978 period 5,000 to 6,000 Ci/year of ^{222}Rn were released from the silos (RAC 1995). Considering the expected large differences in release rates due to barometric pressure changes, the release rates would average up to 15 to 20 Ci/day after addition to the Silos were complete.*

NIOSH's ER of SEC-00046 further states the following:

> *. . . In addition to Section 5.2.4 of Technical Basis Document for the Fernald Environmental Management Project (FEMP) - Occupational Internal Dose, The Pinney study, which estimated exposure to all FMPC workers, may also be used to bound the doses to workers when sampling results are not available (Pinney, 2004).*

SC&A has reviewed key assumptions of the RAC 1995 model and concludes that these release rates are a factor of 10 to 20 too low. Our conclusion is based on the fact that the RAC exposure model is not based on empirical data, but represents a conceptual construct of restricted release

rates driven by diurnal variations in atmospheric pressure. While the model may be credible for a restricted time period that approximates the time periods of the 1995 study, the basic model assumption of a restricted release driven by diurnal barometric pressure is inappropriate for periods that predate 1986, as explained below.

A letter dated September 13, 2006, to one of the SEC-00046 petitioners provided the following information:

> *The K-65 Silos . . . were constructed in 1951 to 1952, and materials were added to the Silos from July, 1952 to September, 1958. The Silos had problems with deterioration almost since the time of construction. Significant cracking in the walls and seepage were noted from the 1950s. Because of these problems, periodic repairs and improvements to the Silos were implemented from the 1960s through the 1980s.*
>
> *. . . Placement of protective* ***dome covers*** *in 1970s, constructed of steel and plywood, blanketed the center of each silo. By themselves, the covers offered little if any barrier to the diffusion and ventilation of radon. Vents in these domes were sealed in 1979. In 1986, a waterproof protective membrane of liquid neoprene was added, and in 1987 a layer of polyurethane foam was placed on dome surface in an attempt to mitigate the migration of radon gas to the environmental. No routine environmental monitoring for radon was performed prior to 1980.* [Emphasis added.]

On the basis of these modifications to the silos, the model assumptions employed in the RAC 1995 study cannot be assumed applicable before 1986.

Prior to 1986, a more appropriate and claimant-favorable approach would assume an **unfiltered** release of radon that is unaccounted for in the isotopic composition, as defined in Table 5-16 of the TBD. For Silo 1, Table 5-16 identifies the following activity levels from which radon releases can be estimated by means of first principles:

Ra-226 – 477 nCi/g
Po-210 – 281 nCi/g
Pb-210 – 202 nCi/g

First principles dictate that if no radon escaped from the raffinate wastes, the activity concentration of Ra-226 would be in equilibrium and, therefore, equal to those of Po-210 and Pb-210. Conversely, the observed disequilibrium implies the release of radon. On the assumption that Silo 1 contained one-half of the 10,000 metric tons of raffinate, SC&A calculates a radon release of (1) 64,500 Ci/yr based on the disequilibrium between Ra-226 and Po-210; and (2) 92,000 Ci/yr based on the disequilibrium between Ra-226 and Pb-210.

These derived values are about 10 to 18 times higher than those estimated in RAC (1995). SC&A favors the higher value of 92,000 Ci/yr since Pb-210 has a 21-year half-life and is less affected by potential ingrowth than Po-210. (The improved dome cap modifications in the 1980s

may have increased retention of Rn-222, which in turn may have differentially increased the ingrowth of Po-210 above that of Pb-210.)

4.3 FINDINGS ASSOCIATED WITH INTERNAL DOSE ESTIMATES FOR THORIUM

NIOSH's Changing Position on Proposed Approach for Reconstructing Thorium Doses

At this time, there is considerable uncertainty with regard to the approach NIOSH intends to employ for estimating internal exposures to thorium for "maximized" and "best estimate" dose reconstructions.

Proposed Method in TBD Volume 5. Upon review of available monitoring data for thorium, NIOSH initially concluded the following, as stated in Section 5.3.1 of the FMPC TBD (ORAUT-TKBS-0017-5):

From pages 22 and 23:

> *A fundamental difficulty of dose reconstruction for thorium processing is that either 1) in vitro bioassays for thorium were not performed or 2) data is not available until after 1986. An additional consideration is that air sampling data was not used to calculate intake and dose until after 1986. Air monitoring was used only to control exposures to levels below the MAC. A number of internal memoranda identify those areas with concentrations at or above the MAC of 100 dpm m^3 (4.5 ×10-11 µCi cm^3) as areas requiring respiratory protection. However, recorded examples of exposure to multiple MAC levels without respirators indicate these violations of policy were not uncommon. In addition, the urine sampling was performed for uranium only. The only discovered record of thorium exposure has been in vivo lung count data sheets in a few claimant records and a single claimant record which indicates thorium urine results, counted for beta and at essentially no detectable results, from before 1986.* ***Thorium processing was completed in 1979, with exposure from that time being limited to repackaging and shipping operations.***
>
> ***After 1986*** *thorium air sampling was used to estimate internal exposure using continuous lapel air samples as* ***breathing zone (BZ) evaluations****. From that time until the present air monitoring is used to conservatively estimate internal intake even when the worker wore respiratory protection.*
>
> *Based upon the above information and assumptions, the recommended claimant-favorable default exposure approach to assign thorium intakes is to assume:*
>
> - *An intake for an exposure period of 100 hours per year at an assumed exposure of 10 MAC is judged adequate to account for the higher levels of exposure indicated by air sampling, since few samples above 10 MAC were reported and these primarily represented short term maximized sampling*

(based upon descriptions on the sample sheets). Also typical and more extensive uranium air sample data demonstrate that 10 MAC is a reasonable assumption of the higher level of exposure.

- *No respiratory protection factor, although not wearing respirators when air concentrations were above MAC represented procedural violations. This violation was known to have occurred and was not unusual.*

- *An intake for an exposure period of 500 hours per year at an average air activity of 0.1 MAC during normal operations*

Using these assumptions, the claimant-favorable assumption would be:

500 hr × 0.1 MAC + 100 hr x 10 MAC = 1050 MAC-hr exposure (5-1)

. . . ***This default intake rate applies to the most exposed craft personnel*** *(e.g., chemical operators, process maintenance personnel, safety personnel, and first line supervisors/ foremen) at the locations and during the periods noted below. For workers whose location cannot be determined the claimant favorable assumption is that they were exposed to thorium and daughter products when they were employed during the listed periods in Table 5-16. Exposures to casual workers who worked in the immediate vicinity of the plants should be evaluated in the Environmental Occupational Dose section.*

Thorium chest counts may indicate that lower exposures occurred. When available, the chest count data should be used to constrain an employee's intake. In other words if there are chest count results for an employee, the smaller of the default thorium intake or the chest count determined intake should be assigned for full dose reconstructions. [Emphasis added.]

Proposed Method in SEC-00046 Evaluation Report. In the SEC-00046 ER, issued October 25, 2006, NIOSH modified its position, as given in Section 7.2.1, by the following statements:

NIOSH reviewed available process information for the entire operational period of the proposed class. Air monitoring programs were in place during this entire time period. These programs covered all operational areas and emphasized sample collection in process areas with higher potential for airborne contamination. In addition to ***general area*** *airborne concentration levels, there are data available from job-specific* ***breathing zone air*** *sampling events.*

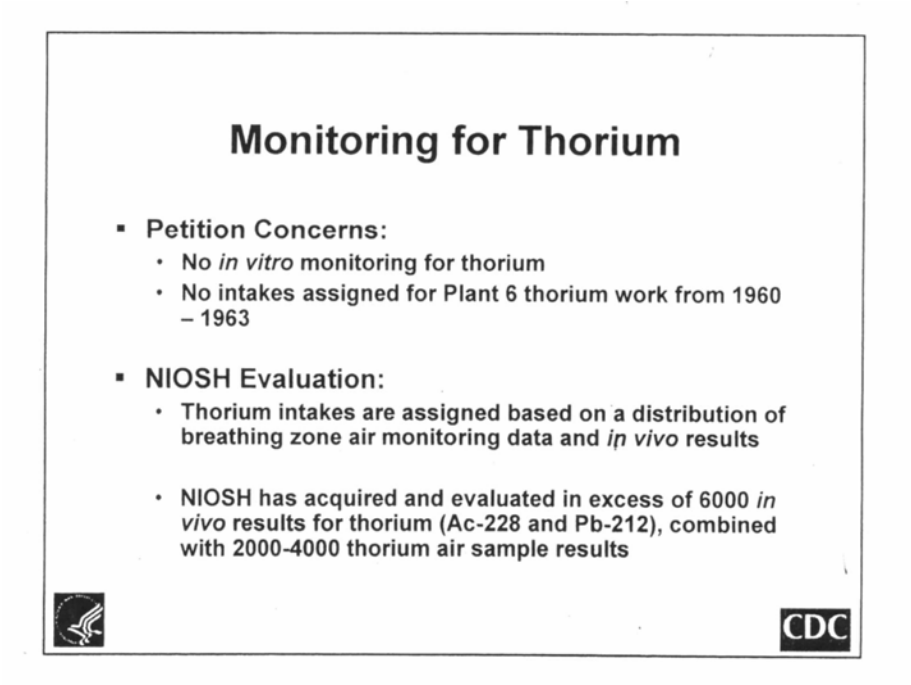
. . . Air monitoring specifically identified for thorium operations, coupled with an ***extensive lung count database during 11 years*** *of that period, provides a basis for default intakes for workers who worked with these materials during the recorded periods of operation.* [Emphasis added.]

In Section 7.2.3 of the ER, entitled *Internal Dose Reconstruction Feasibility Conclusion*, NIOSH states the following:

> *Recorded bioassay for uranium is extensive and sufficient for internal dose reconstruction.* ***Thorium*** *bioassay is* ***not*** *as well documented. However, with the addition of a database of in vivo bioassay (lung counting) and additional air sampling data currently being expanded, the air monitoring database is being strengthened through recent retrieval of additional field data, which will be used to ensure a claimant favorable dose reconstruction to represent maximum dose.* [Emphasis added.]

At a meeting of the Advisory Board held in Mason, Ohio, on February 8, 2007, NIOSH presented its evaluation of the SEC Petition-00046 and further refined its approach for assessing thorium exposures. Presented as Slide #10 and shown here as Exhibit 4.3-1 is NIOSH's most current proposed method for assessing thorium doses.

EXHIBIT 4.3-1



SC&A interprets Exhibit 4.3-1 to imply that NIOSH intends to develop a model that correlates breathing zone air sample data (taken at various FMPC locations over time) with worker-specific lung counts. SC&A also assumes that this thorium dose model will be used as follows for assigning intakes:

(1) A claimant will be identified by job function/FMPC work location.

(2) Based on job function/FMPC work location, NIOSH will assign a breathing zone air concentration for the duration(s) of thorium exposure work period(s).

(3) Based on NIOSH's correlation study of "6000 in vivo results for thorium (Ac-228 and Pb-212), with 2000 – 4000 thorium air sample results," NIOSH intends to assign a claimant-specific thorium intake that is linked to the claimants' job title, assigned work location, and employment period.

The credibility and feasibility for assigning thorium intakes by means of these approaches are the subject of Findings 4.3-1 through 4.3-10, as discussed below.

Finding 4.3-1: Generic Limitations and Uncertainties Associated with Air Sampling for Monitoring Worker Exposures

There are two basic kinds of air sampling strategies used to monitor worker exposure: fixed station, commonly called general area (GA) sampling, and breathing zone (BZ) sampling. Because sources of airborne contamination are highly localized, concurrent measurements by GA and BZ frequently differ by orders of magnitude.

In a 1967 study conducted at the Nuclear Materials and Equipment Corporation (NUMEC), BZ lapel air sampling measurements were compared to GA samples. Figure 4.3-1 illustrates the strong tendency of GA samples to underestimate the air concentrations to which a worker is exposed. Important to note is that this discrepancy increases with air concentrations and at the MPC level is on average about 70-fold too low (see Figure 4.3-2).

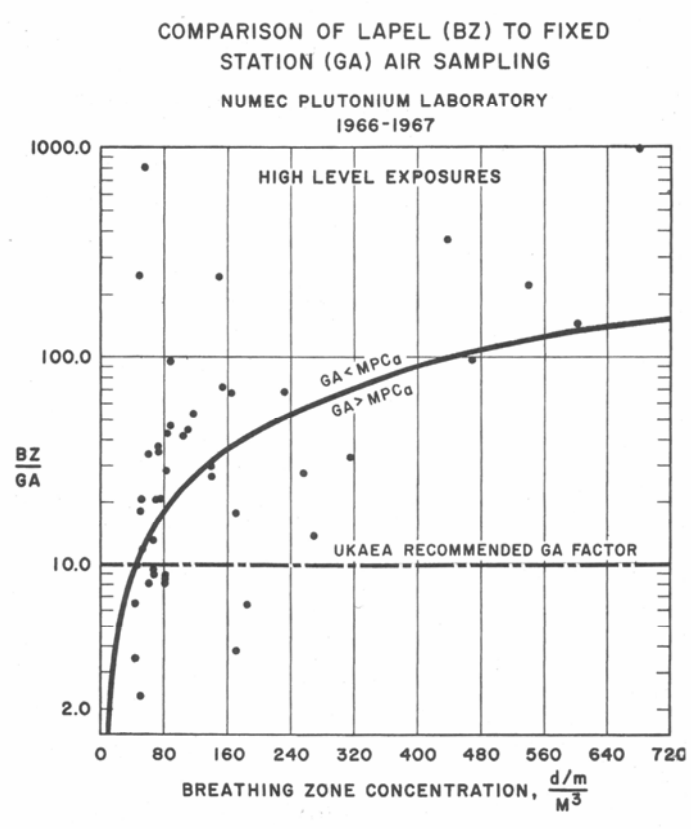


Figure 4.3-1. Comparison of Lapel to Fixed Station Air Sampling
(Source: Caldwell et al. 1967)

In spite of the intent by NIOSH to limit its use to **BZ air samples**, the high variability of BZ samples with time severely limit their use. To illustrate this variability for a **fixed location and a fixed job task**, BZ sampling data are presented in Attachments 4.3-1A to 4.3-1E that correspond to time differences of only minutes, weeks, and years between BZ air samples:

- Attachment 4.3-1A: Variability Over Short Time Intervals Taken on November 19, 1970

  Identified in Attachment 4.3-1A are three job descriptions. In turn, for each job task, three separate BZ samples were taken. For example, the first task involved an operator removing ThF_4 from drying pans with a metal scoop, etc. Of only **three** BZ air samples, which were assumedly taken over a relatively short time, air concentrations varied nearly 26-fold from a high of 4400 dpm/m^3 to a low of 170 dpm/m^3.

  For the second task, the operator who "takes full retort pans of ThF_4 from ventilated enclosures . . ., the air concentrations varied more than 33-fold (i.e., from 100,600 to 3,000 dpm/m^3); and for the third task that involved the ". . . operator sawing derbies, loading and unloading was . . ." the air concentration for three samples varied from 45,570 to 620 dpm/m^3 or more than 72-fold.

- Attachment 4.3-1B: Defines Air Concentrations for Eight Discrete Locations at 30-Minute Time Intervals

  For each of the eight locations, air sampling measurements were taken at **30-minute time intervals**. For example, at the "West Separation Booth Area," the air concentrations were as follows:

Time	Air Concentration (dpm/m^3)
9:05 a.m.	355
9:35 a.m.	140,012
9:50 a.m.	3463

- Attachment 4.3-1C: Variability in Air Concentrations Over a One-Week Period

  Attachment 4.3-1C cites variation in air concentrations over a one-week period. For example, for the 21 BZ air samples taken for workers "repairing inside furnace," air concentrations varied from 81,470 dpm/m^3 to 43 dpm/m^3 or nearly 1900-fold.

- Attachment 4.3-1D: Compares BZ Data for Select Operations/Locations

  For the years **1960, 1961, and 1962**, BZ air concentrations were compared for select operations and locations. For example, the task of "unplugging furnace discharge line" yielded an exposure of 417 MAC (or 29,190 dmp/m^3) in 1962, but the same operation in 1961 resulted in an exposure of 4 MAC (or 280 dmp/m^3).

While **spot** air samples (with sampling times of only minutes) can be expected to show a higher level of variability, a more consistent measure of air concentration is expected when air concentrations are defined as **daily weighted** air concentrations. However, even when concentrations were normalized and expressed as daily weighted air concentrations, this variability persisted as illustrated in Attachment 4.3-1E. Attachment 4.3-1E compares the **daily weighted thorium** air concentrations for two time periods in 1955: May 17–October 31 versus November 4–November 23). Job descriptions showing the highest variability included the following:

Job Description	Daily Weighted Air Concentration (x MAC)	
	May 7–Oct. 31	Nov. 4–Nov. 23
Wet Area Operators	215.1	2.7
Reduction Charge Helpers	233.7	3.5
Secondary Welder Helpers	685.6	122.1
Primary Arc Furnace Operators	473.0	23.3

In addition to data shown in Attachments 4.3-1A to 4.3-1E, SC&A reviewed a large body of BZ air sampling data, which showed variations that are wholly consistent with those of the enclosed Attachments. SC&A concludes that this high degree of variability of spot air samples is but one of several major deficiencies that severely limit their use for dose reconstruction.