5.10.4 Occupational Lumbar Spine X-rays

Finding 33: NIOSH has prematurely concluded that lumbar spine x-rays for laborers and construction workers were not conditions of employment. Based on the evidence provided, this assumption is not sufficiently documented and is not claimant favorable.

The TBD acknowledges that Fernald construction workers and laborers received lumbar spine x-rays (Vol. 3, p. 11), but NIOSH has ruled out the possibility that lumbar spine x-rays were used as a condition of employment at Fernald:

> *It also was noted in reviewing claimant files that lumbar spine X-rays were taken primarily for construction worker and laborers. In a telephone communication with Mr. Louis C. Bogar, the former Vice President of ES&H for FEMP, on October 28, 2003, he clearly stated that lumbar spine X-rays and any X-rays other than chest were not taken as occupational or pre-employment requirements.*

A contemporaneous interview is not a sufficient basis to rule out the possibility that the lumbar spine x-rays were taken as a condition of employment. Such x-rays could easily have been a condition of employment in the 1950s and 1960s. Fernald, after all, was a site where heavy labor was involved for many workers, including construction workers and laborers. The TBD provides no evidence from claimant files or other sources that the lumbar spine x-rays that were done were as a result of injuries or medical conditions unrelated to employment. Unless there is definitive evidence that lumbar spine x-rays were unrelated to employment or were the result of injuries, their presence should be assumed to be a condition of employment for construction workers, laborers, and any others who may have received them.

6.0 OBSERVATIONS

6.1.1 Internal Inconsistencies in the TBD

Observation 1: The TBD has not been checked for internal consistency and there are internal contradictions in it; some of the basic facts in it are incorrect.

Several examples of inconsistencies and factual problems have been discussed in the findings above. For instance, the estimate of production of 205,000 metric tons is less than the figure provided for RU receipts of over 246,000 metric tons. One of these numbers is wrong. There are two quite different estimates of RU receipts, one more that 200,000 metric tons less than the other.

Another important inconsistency relates to the decontamination factor due to the use of respirators. Volume 2 of the TBD provides intake estimates in certain jobs with the use of respirators. Volume 5 of the TBD provides guidelines that do not assume the use of respirators. Furthermore, SC&A notes that in Table 2-1a and subsequent tables, decontamination factors are cited, but this is done without reference to actual respirator efficiencies or the adequacy of any program of fit tests. This is not relevant to dose reconstruction if the decontamination factors are not used, but it would be helpful if the citation of specific performance characteristics that relate to intake could be accompanied by a reference.

A third example of incorrect statements relates to thorium air concentrations:

> *The same air sampling procedures were followed for thorium processing as for uranium processing. Some records have been recovered that indicate that basic air activity levels were recorded in fractional MAC (70 dpm m^{-3} prior to 1970 and 100 dpm m^{-3} thereafter) for thorium processing. The thorium air sampling results are similar to the uranium air sample results.* [TBD Vol. 5, p. 21]

As has been discussed in Chapter 5, there is a great deal of evidence of high thorium air concentrations at Fernald.

As a final example, the production estimates in the TBD are not only internally inconsistent, they appear to be at variance with the materials accounting documents generated during the production phase of Fernald.

SC&A discussed this issue of inconsistencies and factual problems with NIOSH/ORAU during the August 18, 2006, conference call. NIOSH and ORAU are cognizant of the problem and will correct them when a new revision of the TBD is published. It is currently under revision.

6.1.2 Intakes and Plant Production Capacity Utilization

Observation 2: Individual intakes should not be linked to plant production capacity utilization.

The TBD suggests that air concentrations of radioactivity for periods for which there are no data can be derived by reference to production capacity utilization:

> *The measured airborne radioactivity concentrations are adjusted for other years than the year in which the measurements are made, in accordance with the percentage of process system throughput capacity in one shift. In absence of specific throughput information, Appendix 2A is used as the default model for FEMP production rates for the derivation of the adjustment factors.* [Vol. 2, Table 2-3b footnote]

The same concept is applied in Table 2-1b. A similar concept is applied to estimating in-plant thorium concentrations, except here, atmospheric emission ratios are used. In Table 2-1c (Vol. 2, p. 14), in-plant thorium concentrations were obtained by multiplying the uranium concentration estimates for a particular year by the thorium/uranium emission ratio.

Air concentrations experienced by an individual worker would not be expected to vary with the throughput or capacity utilization, but rather with the working conditions, equipment, ventilation, and other industrial hygiene measures prevalent while the work is being done. It is quite possible for low throughput rates to have high workplace contamination and vice versa. There is no necessary relationship or even a tendency for throughput or capacity utilization to be related to air concentration. Similarly, in-plant air concentrations cannot be assumed to scale with emissions, as much depends on the details of the air flow patterns within the plant, the size distribution of the aerosol, the positions of the ventilation extraction ducts, and the degree of filtration imposed on the extraction. Such assumptions should not be used as a basis for intake estimation. The only factor related to production that can be usefully taken into account, if all other factors are known to be the same, is if plants were completely idle for entire shifts or longer. Note that this is not necessarily the same as partial capacity utilization. For instance, partial capacity utilization could still mean that some lathes or drills or reduction furnaces may be operating each day and the entire plant operated with fewer workers, creating similar exposure conditions to full capacity utilization, but for fewer workers. Hence, the time of exposure may be reduced only if there are data showing that there was no work during certain periods, all other things, such as industrial hygiene measures, being equal.

6.1.3 Bioassay Frequency and Incidents

Observation 3: NIOSH dose reconstruction procedures should ensure that the bioassay samples were frequent enough to capture incidents such as chip fires, or that the plant procedures themselves as carried out in practice ensured that samples would be taken after fires or blowouts.

Chip fires were common at Fernald. Sometimes these incidents could involve intense exposure to fumes, as occurred during in 1956:

> *Specifically, a drum of fines located under the chip crusher ignited. By the time the burning drum was removed from the building (approximately 2 to 3 minutes later), the machining bay air was heavily laden with smoke and fume. Personnel did not evacuate immediately but remained in the area 7 to 8 minutes after the fire started. No one was observed wearing a respirator until several minutes later and then only a few. When evacuation was made it was for a very short duration, perhaps 18 minutes, and when re-entry was made the room air was still visibly contaminated.* [Stefanac 1956]

There was considerable contamination even after visible dust had cleared. The incident was analyzed to try to set procedures for such chip fires, which were frequent (refer to interviews), perhaps even daily in some periods. TBD does not provide any procedure to check for bioassay frequency, as well as who was monitored using such data on incidents and air contamination as a check.

6.1.4 Uranium Isotopic Ratios

Observation 4: The uranium isotopic ratios in some of the data in the TBD are incorrect.

The isotopes present in uranium (U-238, U-235, and U-234) appear in certain ratios that are characteristic of the enrichment of the uranium. This implies certain mass ratios, which are also characteristic of the enrichment level. The ratios of U-238 to U-235 and U-238 to U-234 must be consistent with each other for a given enrichment of the sample. Some values in the TBD are incorrect, because they represent ratios that cannot arise in practice or are inconsistent.

For instance, the Waste Pit 2 uranium isotopic composition is incorrect. The U-238/U-234 ratio suggests slightly depleted uranium (close to natural uranium), but the mass ratio of U-235/U-238 suggests about 7% enriched uranium. Furthermore, U-235 is almost 20% of the radioactivity. This is impossible, since U-235 never represents more than 5% of the radioactivity at any enrichment of uranium. (At higher enrichments, U-234 dominates the specific activity. For DU, it is U-238.)

The same problem is present in the data for Waste Pit 6 (TBD Vol. 2, p. 65) where the U-234/U238 ratio suggests depleted uranium, but the U-235/U238 ratio suggests enriched uranium. SC&A has not tried to check all such basic problems, but it is important that isotopic compositions be physically plausible and consistent. NIOSH should examine whether there are errors in the underlying data as well.

6.1.5 Frequency of Events in Thorium Overpacking Operations

Observation 5: The number of "events" listed for thorium overpacking operations is very high, but the TBD provides no detail on the nature of most of the events, the data on which the estimates of event frequency and intakes were based, or how the intake estimates were derived.

Table 2-22 (Vol. 2, p. 51) gives the expected number of events during thorium overpacking operations. It lists three specific types of events—fork impact, fork drop, physical degradation of the drums—and miscellaneous. For the first three, the annual event frequencies are given as 17, 17, and 42, respectively. For miscellaneous, the event frequency is given as 1,358 per year, or almost 4 every day (assuming 365-day operation). The nature of these events is not specified; the method of estimating emissions is also not specified. This is an inordinately large frequency of events, whose implications for dose reconstruction need to be explored in greater detail.

6.1.6 MDLs for Beta Extremity Monitoring

Observation 6: The MDLs for beta extremity dosimeters should be provided for missed dose estimation.

The values for the MDLs for the extremity beta dosimeters should be provided. The exchange frequency of the extremity dosimeters is also required to calculate the missed extremity dose.

6.1.7 X-ray Unit Survey Data

Observation 7: NIOSH should review the calculated data for the Bennet x-ray unit and the Keleket unit survey to determine if the dose estimates in Table 3-13 are appropriate.

The TBD states that the earliest recorded survey of x-ray equipment (Keleket) occurred in November 1961. Review of available historical memos suggests the purpose of this survey was to ascertain exposures to film badges, if badges were inadvertently worn during annual chest x-rays given to workers. Difficulties encountered included not being able to operate the x-ray unit in the full diagnostic range, and the Victoreen R-meters were not being read on the same day as exposures. Consequently, many assumptions were applied as being derived from NCRP guidelines, such as the half-value layer (HVL) of 2.5 mm Al. It appears the intent of the survey was to determine any undue contribution of "Grenz" radiation to skin dose, as measured on the film badge. NIOSH should re-evaluate the assumptions being applied; this could lead to substantial changes in Table 3-13 (*Organ Dose Estimates to FEMP Chest Radiographs from 1951–1977*) of the TBD.

The TBD does not detail or provide substantial evidence that equipment survey data reported for the period March 1977 to February 1988, as evidenced in Tables 3-10 and 3-14, are related to an actual survey of the output of the Bennett 300 unit, which was put into service in March 1977. During the August 18 conference call, NIOSH/ORAU clarified that the data for this unit are calculated from a Hanford unit. SC&A has requested a copy of the survey of that unit.

6.1.8 Miscellaneous Observations

- In Table 5-6 (Vol. 5, p. 12), it is unclear why the radiation exposure limit for the 2% enriched soluble form is more than an order of magnitude lower than the limit for the natural form, whereas for the insoluble form, the limits for the natural and 2% enriched forms are identical at 3.0E-10. The basis of these figures should be clarified.
- Table 5-8 (Vol. 5, p. 15) reports derived air concentrations from 1989; however, the table lists results in terms of inhalation Type S, which was not introduced by the ICRP until 1994. A clear statement of how the original results were derived and how they subsequently have been interpreted would be helpful. This is of importance, as Type S does not correspond exactly in biokinetics to the Class Y that was formerly used.
- In Figure 5.1 (Vol. 5, p. 19), should 'Th-23' at the top of the figure read 'Th-228'?
- In Table 5-14 (Vol. 5, p. 20), the entries for oxalate are associated with the chemical formula for nitrate.
- On page 28, it is misleading to state that urine samples were provided after a 2-day break to allow elimination of uranium cleared rapidly via the GI tract. Urinalysis only evaluates uranium that has been taken up and subsequently excreted. What a 2-day interval does is ensure that the early kinetics of uptake and retention, which can be very variable, do not unduly influence the results obtained.
- At the end of Section 5.3.4 on page 31 (Vol. 5), it is stated that uranium results that are within a factor of 10 of the Decision Level (DL) should be adjusted for full dose reconstructions. What does 'adjusted' mean in this context? Furthermore, it seems inequitable to assign a DL for Fernald at 5 times that for INEL (0.8 vs. 0.16 micrograms/L).
- As lung counting began in 1968, why does Table 5-24 (Vol. 5) show only data from 1974 onward? In the paragraph following that table, it appears that the reference to percent body burden should be to percent lung burden?
- On page 36, it is noted that no system performance characteristics of the Mobile In Vivo Radiation Monitoring Laboratory (MIVRML) have been found to date. As this was the Y-12 instrument, these characteristics should be in the various papers published by Cofield. Only one journal and one 'grey literature' publication are cited in the reference list. A more thorough search is indicated.
- In Vol. 2 on page 24 in the second line of Section 2.2.4.2, 'UF_6' should read 'UF_4.'
- Table 5-5, Vol. 5, does not contain any rating for Plant 6, where machining of U was done. This should be rated as high.
- In Vol. 5 in Table 5-6, the heading of the second column ("mg intake = approx. 0.337 mg kidney – toxicity limit") needs explanation and a better connection to the values listed in the column.
- The energy given on page 6 of the TBD (Vol. 6) should be written as 0.300 ± 0.005 MeV.

- On page 7 of the TBD (Vol. 6), the text “Figures 6-1 and 6-2” should be changed to “Figures 6-3 and 6-4.”
- On page 24 of the TBD (Vol. 6) the calculation of the total missed photon dose should be 400 + 30 × 3 × 0.5 = 445 mrem and not 449 mrem as given.
- Page 15 of Vol. 4 refers twice to a RAC 1988 report that does not exist. The document RAC 1998 that is in the reference list does not contain the information about particle sizes in Appendix E
- In Table 6-7, Vol. 6, the values of Hp(10) and Hp(0.07) for Sr-90/Y-90 have been interchanged. It is probable that this also happened to these values for the other DOELAP energies. The table shows the “angular response,” not the “annular response.” Furthermore, the 9 values between the energies of M30 ± 60 V and M150± 40 H are given twice in the table.

ATTACHMENT 1: SC&A QUESTIONS ON THE FERNALD TBD SENT TO NIOSH

QUESTIONS FOR NIOSH REGARDING THE TECHNICAL BASIS DOCUMENT FOR THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT (FEED MATERIALS PRODUCTION CENTER)

A. GENERAL QUESTIONS AND QUESTIONS RELATING TO VOLUMES 1 AND 2 OF THE TBD

1. Could NIOSH provide SC&A with the notes of its interviews with site experts?

2. NIOSH states that there were a “relatively small number of production workers” at Fernald (TBD, Vol. 1, p. 8). What is the documentary basis for this statement? In the same paragraph, the TBD states that “it seems likely that few workers routinely exceeded established exposure limits.” What is the documentary basis for this statement?

3. The TBD provides cumulative production figures of nearly 170,000 metric tons of uranium metal and 35,000 metric tons of intermediate products (Vol. 1, p. 5). Please provide the reference(s) for these figures.

4. Was the ore processing flowsheet similar to that used at Mallinckrodt with the various stages of filtering and concentration of Ra-226, Th-230, Pa-231 and Ac-227?

5. Would the ratios of radionuclides in the K-65 Silo 1 or Silo 2 be applicable to specific waste streams, or do they represent mixtures of actual waste streams that were all discharged into the silos? The question relates only to Fernald waste streams and not the Mallinckrodt materials in the silos.

6. What is the scientific justification for using the ratio of Th-232 to U atmospheric emissions to determine in-Plant thorium contamination?

B. QUESTIONS RELATING TO MEDICAL DOSE (VOL. 3)

1. On page 11 of Vol. 3, NIOSH cites a number of telephone communications on the basis of which the possible use of PFG at Fernald was ruled out. Could NIOSH provide SC&A with the records of these communications?

2. The TBD does not detail the evidence that equipment survey data reported for the period March 1977 to February 1988, as shown in Tables 3-10 and 3-14, are related to an actual survey of the output of the Bennett 300 unit, which was put into service in March 1977. Could NIOSH clarify whether the data are from an actual survey?

3. Section 3.1.4 of the TBD concludes that, based upon a survey of selected radiographs from 1952–1980, it was determined that collimation was always used from the

inception of x-ray use at the site. This conclusion is based upon the observation of a dark line at the bottom of the selected radiographs. Since collimators are made of very dense materials (e.g., lead, etc.), their use should appear as a lightened or unexposed area on the film. Also, any evidence of collimation should occur on all sides of the film, not just the bottom. Did NIOSH examine other explanations for the black line at the bottom of the radiographs?

4. Are doses from x-rays taken after workplace accidents going to be included in dose reconstructions?

5. The TBD in Section 3.2 states that a review of claimant files showed that 15% of the claimants reported that retakes occurred. Could NIOSH provide SC&A with the data compilation used to determine the retake rate?

C. QUESTIONS RELATING TO ENVIRONMENTAL DOSE (VOL. 4)

1. Why did the TBD use the source term developed by Boback 1987 and the 1988 supplement for uranium, rather than the source term developed for the Radiological Assessments Corporation by the CDC, which is much higher (about 310,000 kilograms compared to about 175,000 kilograms used by NIOSH)? Did NIOSH take into account the consideration that the RAC source term has been shown to be in accordance with soil data in Appendix C (RAC, 1998)?[16]

2. Why did the TBD use the thorium source term from Boback 1987 and the 1988 supplement rather than the RAC 1995 source term?

3. Table 4-4 lists annual airborne thorium emissions at Plants 8 and 9 and the Pilot Plant. This estimate is claimed to be conservative because of the assumptions used for scrubber and dust collector efficiency. What were the values of efficiency used? Did the procedure take into account documentation indicating that scrubber efficiency, notably in Plant 8, was sometimes far below the manufacturer-specified range?

4. According to a tabulation by NLO,[17] a significant fraction of the uranium releases from Fernald were of an episodic or accidental nature, influencing the environmental doses. How is NIOSH going to account for episodic releases in estimating environmental internal dose for individual dose reconstructions?

5. Tables 4-2 and 4-3 (TBD, Vol. 4) summarize annual fugitive uranium and thorium emissions. Please provide methodological details as to how the numbers were derived.

6. Could information be provided that demonstrates that the trace radionuclide-to-uranium ratios observed in 1985 apply to the earlier years? Specifically, what about the

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[16] RAC (Radiological Assessments Corporation), 1998, *The Fernald Dosimetry Reconstruction Project, Task 6 Radiation Doses and Risk to Residents from FMPC Operations from 1951-1988*, RAC Report No. 1-CDC-Fernald-1998-FINAL Vols. I and II.

[17] Adams W.J. (1985), letter to Vincent Fayne, Oak Ridge Operations, Cincinnati, March 21, 1985.

radionuclide ratios for (a) ore processing, including pitchblende processing, and (b) waste stream handling, processing, and dumping?

7. In developing the radionuclide-to-uranium ratios, the TBD used average observed values. Has NIOSH considered using the 95th percent confidence level of the mean, as opposed to the true mean, as a more claimant-favorable strategy?

8. Are there time periods when a given facility may have experienced radionuclide-to-uranium ratios that were chronically at the high end of the distributions?

9. Given that Tables 1 and 2 of the Boback report cited in the TBD reveal that the release heights were comparable to the heights of the nearby buildings, what is the basis for taking credit for an elevated release of 10 m when deriving atmospheric dispersion factors? How were building wake effects taken into consideration?

10. For the purpose of deriving the radon and radon progeny releases from the silos, the TBD used the median values derived in the RAC 1995 report. Wouldn't this approach be considered claimant-neutral as opposed to claimant-favorable?

11. Page 17 of the TBD states that atmospheric dispersion factors (X/Q values) were derived assuming a wind speed of 3.2 m/sec and stability class F. Once the X/Q values were derived for a given distance between the release point and receptor (using the σ_y and sigma σ_z values in Figures 4-3 and 4-4 of the TBD), an adjustment factor is applied to account for the frequency the wind blows toward a given receptor from a given source. Why didn't NIOSH employ the conventional joint frequency approach to deriving average annual atmospheric dispersion factors? Furthermore, the selected wind speed of 3.2 m/s does not appear to be claimant favorable. Please provide a justification as to why NIOSH is using this value for wind speed.

12. Table 4-8 contains the estimated distances for receptors from contributing emission sources. For EA-6, the distance from the K-65 silos is given as 250 m, even though the geographic center of EA-6 appears to be at a distance of about 100 m. The distance from the K-65 silos to EA-9 is given as 2,000 m, even though the most distant point in EA-9 appears to be about 1,500 m away from the K-65 silos. The distance to Plant 7 to EA-3 and EA-8 is 250 m in both cases, even though Plant 7 is located inside EA-7. Please explain the basis for the assumptions.

13. The TBD states on page 16 that the respirable fraction (<10 µm) of uranium particles was determined to be 65% on the basis of RAC (1995), Table E-1. It appears that for this calculation, the simple arithmetic average of data from 15 dust collector stacks was used. Table E-1 does not provide data on particle sizes from scrubber emissions (Plant 2/3 and Plant 8). Table E-8 of RAC (1995) indicates that the composite of U_3O_8 releases indicate that more than 75% of the emissions in the outlet had a particle size of less than 10µm. Please explain how the fraction of 65% respirable particles is representative for the total of all uranium emissions.

14. Has NIOSH considered the contribution to the internal dose associated with the resuspension and inhalation of deposited Pb-210?

15. Has NIOSH attempted to compare the pre-1989 derived atmospheric dispersion factors with the actual empirically determined atmospheric dispersion factors obtained using the actual monitored emissions and airborne radionuclide concentrations at monitored locations?

16. The footnote to Table 4-7 on page 19 suggests that the dispersion coefficients were multiplied by a factor of 0.5 for U and Th particulate aerosols, presumably to account for plume depletion, as explained in the paragraph below equation 4-3 on page 17. For most distances, plume depletion will be less than 50%. Please explain how it can be claimant favorable to apply a uniform plume depletion factor of 50% for all releases of particulates.

17. Equation 4-5 on page 35 of the TBD presents the method used to estimate the external radiation dose rates at each of the 11 grid locations. The basic approach was to use the actual measured dose rate at the locations where measurements were made, and then derive the dose rate at the grid locations, based on adjustments that take into consideration the distance from the source and the distance to the grid location using the inverse square law. One concern with this approach is that it only applies to point sources. Has NIOSH evaluated the degree to which this approach works for sources whose dimensions are large relative to the distance to the measurement location and/or the grid location?

18. For the purpose of deriving the external environmental exposure pre-1976, when there were no measurements, the doses were derived by comparing the uranium throughput in those years with the years for which there were external environmental dose measurements. What is the relevance of uranium production to external environmental dose in outdoor areas? Why did NIOSH not use uranium emissions instead, for instance? Were uranium isotopes the main external environmental dose problem throughout the Fernald site? Has NIOSH evaluated the degree to which the controlling factors remained unchanged over the years?

19. The TBD does not discuss the methods used to derive pre-1976 external environmental doses from the silos. How does NIOSH plan to reconstruct these doses?

20. How does NIOSH propose to reconstruct doses for the K-65 workers involved in handling Mallinckrodt K-65 residues, including the unloading of these residues and their loading into Silo 1?

D. QUESTIONS RELATING TO INTERNAL DOSE (VOL. 5)

1. What is the reference for the decontamination factor of 50 used for some Th-232 production activities?

2. Table 2-1a assumes respirator-based decontamination by a factor of 50 for some operations (Vol. 2, pp. 12–13). But in Vol. 5, "at least a factor of 10" is given for decontamination, and it is said that respirator use was not consistent and a decontamination factor cannot be assumed (Vol. 5. pp. 22–23). Is a decontamination factor being assumed for uranium when air concentrations are used for intake estimation? If so, for which jobs and periods? And what is the value being used?

3. Has NIOSH taken into account the dose reconstruction implications of the finding that respirators were judged at one point (1953) to be the "epitome of filth?"[18] Specifically, if respirators were stored in places or were worn so that they were susceptible to contamination on the inside, the intake could possibly be even higher than for those who did not wear respirators. Has NIOSH done interviews regarding jobs and periods during which respirators were worn and on the condition of the respirators? If so, SC&A requests the records of these interviews. Has NIOSH determined whether a central service (recommended in the memo quoted in the footnote) was implemented, and if so, when?

4. On page 11 (TBD, Vol. 2), it is not clear why thoria gel production for 1964 and 1965 was estimated based on a linear extrapolation of the quantity produced in 1966 through 1970. Can some justification for this assumption be provided?

5. Could NIOSH provide the flowchart of thorium processing? Was it similar to the Ames Laboratory flowchart?

6. How has NIOSH taken into account localized high concentrations of uranium dust in areas such as dust collector baghouses?

7. Is NIOSH developing an internal dose co-worker model? If so, what periods would this apply to, and what data are being used?

8. Has NIOSH compiled internal dose data into a database? If so, could it be made accessible on the Advisory Board's section of the O Drive?

9. How is NIOSH going to reconstruct internal dose prior to 1953, since there do not appear to be data before 1953, as implied by the sentence, "A urinalysis program was administered at FEMP starting in 1953 or possibly before" (p. 30 of Vol. 5). The table on the same page states that there are uranium bioassay data for 1952. Are there data for 1952?

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[18] Dr. Quigley to Charles Dees, "Industrial Case Study," October 12, 1953, p. 3, on which Dr. J. W. Durkin appears to be quoted. The full quote, which has the name of one person (perhaps two) deleted from the document is as follows: "The other problem that became apparent in this situation is the poor care being given to the dust respirators. The ones observed by [blank] and myself near the Chip Burner were the epitome of filth. Apart from this, it would have been a perfect fomite [?] for the transfer of respiratory infection between employees. This simply corroborates the reiteration of [blank] that something should be done about the respirator situation – either the men must take better care of them, or central service must be provided." An earlier part of the document notes that "there were two Dust-Foe respirators hanging on hooks" in the "shack-type office in the [Chip Burner] area."

10. Since no bioassay data for thorium are available prior to 1990 – that is for the entire production period – how is NIOSH going to validate the dose estimates for thorium-232, as well as for its decay products, notably radium-224?

11. Since much of the thorium data is lost and many documents have apparently been destroyed (p. 18, Vol. 5), and since there are hardly any bioassay data or other data specific to thorium in the workplace, how is NIOSH going to ensure that the dose reconstructions are claimant favorable? How is NIOSH going to ensure that all plants where thorium was processed are included in its list? Could NIOSH provide all the interviews on which its analysis of thorium production and related issues is based?

12. Given that thorium-232 DCFs are orders of magnitude larger than uranium for some organs, how is NIOSH going to address doses to uranium workers in the plants listed for thorium production (Plants 8 and 9, the Pilot Plant, and possibly Plant 4) (a) during thorium production periods, and (b) due to resuspension of thorium dust during non-thorium production periods?

13. Could NIOSH provide the records that have been recovered in relation to thorium described at the bottom of page 21, Vol. 5?

14. On page 22, Vol. 5, NIOSH states that "Therefore, the three Plants mentioned [Plants 8 and 9, and the Pilot Plant] should be considered the primary processing sites, although there is some evidence that a few isolated thorium operations occurred in other locations." There seems to be no guidance for dose reconstruction at these other locations (such as Plant 4), and how the periods or workers who were exposed would be determined. How is NIOSH addressing the issue of thorium work in Plants other than Plant 8, Plant 9, and the Pilot Plant?

15. On page 22, NIOSH states that it is using BZ samples from lapel samplers to conservatively estimate thorium exposures. How is NIOSH taking into account the Y-12 study indicating that this is not a reliable way to make intake estimates, and that BZ-estimated intakes could be significant underestimates when compared with bioassay estimated intakes?

16. Since enrichments of uranium-235 up to 20% were processed at Fernald, how does NIOSH justify the use of 2% enrichment as the default value after 1964? Given the large difference in specific activities and the fact that the fluorometric method was used for determining uranium content of urine, this would appear to be an assumption that would not be claimant favorable for some groups of workers at some times. Would it be possible to use a range of enrichments with a suitable distribution (or distributions for different time periods) instead?

17. In Table 5-11, RU contaminant concentrations are given for plutonium-239, neptunium-237 and technetium-99. Although plutonium-239 is likely to have dominated the plutonium component of the contamination in mass terms, plutonium-238 could have been more important in activity terms. Has NIOSH given

consideration to the possibility of specifying a default mass concentration for plutonium, together with a default partitioning between plutonium-238, plutonium-239, and plutonium-240, to allow intakes of activity by radionuclide to be assigned?

18. In Table 5-16, is there any explanation why Pb-210 and Po-210 activity concentrations in Silo 1 measured in 1993 are substantially less than would be expected based on the secular equilibrium concentrations that would be supported by the Ra-226 present? It is noted that this effect is much less marked in Silo 2.

19. How can the Rn-222 concentration of 2.3 WL given on page 27 of Volume 5 be justified as claimant favorable when it is based on the higher of only two samples from a single radon sample data sheet?

E. QUESTIONS RELATING TO EXTERNAL DOSE (VOL. 6)

1. Is NIOSH developing an external dose co-worker model? If so, what periods would this apply to and what data are being used?

2. Page 23 of the external dose volume mentions the use of co-worker data for missed doses? What criteria are being used to choose the co-workers for the missed doses?

3. Page 23 also mentions lost dosimeter results. What proportion of the data has been lost?

4. Has NIOSH compiled external dose data into a database? If so, could it be made accessible on the Advisory Board's section of the O Drive?

5. The TBD discusses adjustments to dosimeter readings. In regard to radioactive dust settling on the dosimeter, the TBD states that dosimeters were in plastic bags "at times" (p. 11, Vol. 6).[19] However, Volume 4 of the set of transition reports in the handover from NLO to Westinghouse discusses the application of adjustment factors to TLDs for a period between 1983 and October 1985. The use of this correction factor sometimes resulted in negative radiation dose estimates. The correction factors resulted in changes (according to the calculations shown in the datasheets) of 6% to 663%. In the examples given in the report, the largest magnitude correction of 1,652 millirem was applied to a dose of 1,291 millirem, resulting in a net negative estimated dose equal to -361 mrem.[20] The practice was used from 1983 (when TLDs were introduced) to October 1985, when its regular use was discontinued. However, it appears to have been continued in an

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[19] "An additional radiological concern at several locations at FEMP occurred when workers were subjected to high levels of radioactive material-bearing dust. This widespread source of contamination was a concern for personal dosimeters, so at times the dosimeters were enclosed in plastic bags for protection against dust contamination. The manner in which these contaminated dosimeters were handled was not identified; however, this should not be an issue in dose reconstruction because the dosimeters were calibrated in plastic bags and no adjustments were made to the dosimeter results for either Hs(0.07) or Hp(10)." (TBD, Vol. 6, p. 11)

[20] Feed Materials Production Center, Final Phase-in Report, Vol. 4 of 15, Environment, Safety and Health, Westinghouse Company of Ohio, January 17, 1986. See Attachment 3 for the datasheets.

ad hoc fashion after that date.[21] While doses with high percentage corrections (more than 50%, therefore including negative dose estimates) were not automatically entered into the dose record, it is unclear what exactly was done. The TBD does not discuss this problem, although it indicates some difficulties in the initial period of TLD testing due to a problem in the algorithm, notably for shallow dose (p. 12, Vol. 6). Has NIOSH investigated this problem and how the resultant doses might be interpreted? Since the TBD acknowledges that plastic bags were used only "at times," has NIOSH investigated the periods when this was not the practice? Were correction factors applied during such periods? Does NIOSH have documentation indicating the periods when dosimeters were in plastic bags? Section 6.5 on adjustments to dose does not discuss the use of the correction factors described above. How is NIOSH going to take them into account?

6. Vol. 6 of the TBD discusses correction factors for geometry. Has NIOSH taken adequate account of some jobs where the badge readings were unlikely to have any systematic relationship to the organ dose? One such job, stamping numbers on ingots, was photographed by Robert del Tredici in 1987. The photograph shows the worker sitting astride an ingot stamping an ID number on its flat face; it can be provided upon request. His film badge is dangling from his coverall pocket parallel to the face of the ingot. His body shields the radiation from behind. The use of wrist badges is evident. The angular response correction factors (Table 6-7) do not address this problem.

7. On page 22 of Vol. 6, NIOSH states that "Corrections to the FEMP-reported dose are required, due to uncertainties in the recorded data and lack of significant data, especially prior to 1980." How much pre-1980 data is missing? What happened to the individual external dose records for the pre-1980 period that caused a significant amount of data to be missing?

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[21] Ibid. p. 15.

ATTACHMENT 2: ANSWERS TO SC&A QUESTIONS ON FERNALD SITE PROFILE

FINAL ORAUT DRAFT
08/16/2006

A. GENERAL QUESTIONS AND QUESTIONS RELATING TO VOLUMES 1 AND 2 OF THE TBD

1. Could NIOSH provide SC&A with the notes of its interviews with site experts?

   The Site Profile development team only interviewed four former Fernald workers. Unfortunately, there were no comments from interviewees that related directly to issues or assumptions in the TBDs, so documentation of these interviews was not retained.

2. NIOSH states that there were a "relatively small number of production workers" at Fernald (TBD, Vol. 1, p. 8). What is the documentary basis for this statement? In the same paragraph, the TBD states that "it seems likely that few workers routinely exceeded established exposure limits." What is the documentary basis for this statement?

   ASI (Advanced Sciences Inc.) prepared a document (date unknown) for Westinghouse Materials Company of Ohio (Fernald, Ohio) which states that there were almost 2900 employees, some of whom were production workers. This is relatively small when compared to other AEC sites such as Hanford and SRP.

   The basis for stating that it seems likely that few workers routinely exceeded established exposure limits is the many letters and notes [Dugan (1981) and Noyes (1968)], as well as lists of individual exposure results in the early production years.

3. The TBD provides cumulative production figures of nearly 170,000 metric tons of uranium metal and 35,000 metric tons of intermediate products (Vol. 1, p. 5). Please provide the reference(s) for these figures.

   The original figures were calculated and extrapolated from available data. Other data was received from mass balance reports. The site descriptions and other TDB sections will be revised to reflect updated information, which will include references for the information.

4. Was the ore processing flowsheet similar to that used at Mallinckrodt with the various stages of filtering and concentration of Ra-226, Th-230, Pa-231 and Ac-227?

   The two facilities' flow sheets have not been reviewed together. We currently understand that there were similarities with the Mallinckrodt Destrehan process, but the process adopted at Fernald would have included modifications and upgrades.

5. Would the ratios of radionuclides in the K-65 Silo 1 or Silo 2 be applicable to specific waste streams, or do they represent mixtures of actual waste streams that were all discharged into the silos? The question relates only to Fernald waste streams and not the Mallinckrodt materials in the silos.

The isotopic ratios were determined in the early 90s by taking core sample of the accumulated sludge. Thus the analyses represent results of mixtures of actual waste streams that were discharged to the silos, including the Mallinckrodt waste.

6. What is the scientific justification for using the ratio of Th-232 to U atmospheric emissions to determine in-Plant thorium contamination?

   The footnote to Table 2-1c indicates that the basis for the ratios would be found in Appendix 2B, but it appears that there is a typographical error somewhere. We will either provide the basis for these numbers or delete them, as they are superseded by information in the internal dose TBD.

B. QUESTIONS RELATING TO MEDICAL DOSE (VOL. 3)

1. On page 11 of Vol. 3, NIOSH cites a number of telephone communications on the basis of which the possible use of PFG at Fernald was ruled out. Could NIOSH provide SC&A with the records of these communications?

   No other information regarding telephone conversations beyond that included in the TBD, is available.

2. The TBD does not detail the evidence that equipment survey data reported for the period March 1977 to February 1988, as shown in Tables 3-10 and 3-14, are related to an actual survey of the output of the Bennett 300 unit, which was put into service in March 1977. Could NIOSH clarify whether the data are from an actual survey?

   It appears the data for the Bennett unit were calculated, not measured. The exposure data reported in a memo dated February 24, 1977, presumably associated with the Bennett X-ray machine, were not measurement data. Instead they represented calculations of exposure for various projections based on the nominal technique (including tube potential and mAs) in use at Fernald at that time and nominal dose factors extracted from a graph on page 159 of the Radiological Health Handbook. The dose factors, in units of mR per mAs, were selected to match the tube potential and Source to Skin Distance for the projection of interest. The footnote below Table 3-10 which refers to the "the measured *data from 02/77" [emphasis added] is an error, and will be changed in the next revision.*

3. Section 3.1.4 of the TBD concludes that, based upon a survey of selected radiographs from 1952–1980, it was determined that collimation was always used from the inception of x-ray use at the site. This conclusion is based upon the observation of a dark line at the bottom of the selected radiographs. Since collimators are made of very dense materials (e.g., lead, etc.), their use should appear as a lightened or unexposed area on the film. Also, any evidence of collimation should occur on all sides of the film, not just the bottom. Did NIOSH examine other explanations for the black line at the bottom of the radiographs?

   No other information is available other than that presented. The fact that evidence of visible collimation is not seen on all edges of the film does not mean that collimation is not applied. Preparing to expose a radiograph includes an attempt to "cut the four corners" and precisely align the film and x-ray beam boundary. See SRDB Ref ID 22720 for a documented communication with a Brookhaven National Laboratory X-ray technician who used that technique. However, the ORAUT will attempt to look at actual radiographs from Fernald again to resolve the question about the "black line".

4. Are doses from x-rays taken after workplace accidents going to be included in dose reconstructions?

   In accordance with 42CFR 81 and 82, only medical exposures that were performed for medical screening and required as a condition of employment are included in the occupational medical dose. Diagnostic and therapeutic procedures not required for medical screening are not included." X-rays taken after workplace accidents are diagnostic and so are not included in dose reconstruction.

5. The TBD in Section 3.2 states that a review of claimant files showed that 15% of the claimants reported that retakes occurred. Could NIOSH provide SC&A with the data compilation used to determine the retake rate?

   No other information regarding X-ray retake rate, beyond that included in the TBD, is available.

C. QUESTIONS RELATING TO ENVIRONMENTAL DOSE (VOL. 4)

1. Why did the TBD use the source term developed by Boback 1987 and the 1988 supplement for uranium, rather than the source term developed for the Radiological Assessments Corporation by the CDC, which is much higher (about 310,000 kg compared to about 175,000 kg used by NIOSH)? Did NIOSH take into account the consideration that the RAC source term has been shown to be in accordance with soil data in Appendix C (RAC, 1998)?

   The original revision of the Fernald Occupational Environmental Dosimetry Technical Basis Document (OEDTBD) used the Boback data to estimate exposure to site releases because it was believed that its use would be sufficiently conservative and the resulting exposures would represent exposure estimates that would be favorable to the claimant. Use of the release data compiled by RAC (1995) would simply add to the existing conservative estimate.

2. Why did the TBD use the Th source term from Boback 1987 and the 1988 supplement rather than the RAC 1995 source term?

   See response to C.1 above.

3. Table 4-4 lists annual airborne Th emissions at Plant 8 and 9 and the Pilot Plant. This estimate is claimed to be conservative because of the assumptions used for scrubber and dust collector efficiency. What were the values of efficiency used? Did the procedure take into account documentation indicating that scrubber efficiency, notable in Plant 8, was sometimes far below the manufacturer-specified range?

   For the Th emission calculations, the efficiency assumed for the scrubber was 85% and the efficiency assumed for the dust collector was 95% (Dolan and Hill 1988), and although Dolan and Hill were aware that efficiencies varied, they thought their chosen values compared reasonably to the NRC's 95% estimate for a venturi-type scrubber and the typical rating of 99%+ for dust collectors, as well as made allowances for "operational upset."

   The RAC 1995 document provides a description of the scrubber efficiencies at both Plants 2/3 and 8 that differs from the Dolan and Hill (1988) assumptions. Updates to the TBD are warranted based on the differences in the efficiency estimates.

4. According to a tabulation by NLO, a significant fraction of the U releases from Fernald were of an episodic or accidental nature, influencing the environmental doses. How is NIOSH going to account for episodic releases in estimating environmental internal dose for individual dose reconstructions?

   Episodic (and operational) stack releases are included as annual integrated emissions within the tables in the TBD. Over extended periods of time, these integrated emissions provide means of estimating internal exposures for individuals who were not monitored and who would not have required monitoring because of their low potential for exposure during their employment. In accordance with program guidance given in ORAUT-PROC-0031, the derived maximum site-wide annual median intakes via inhalation and ingestion will be used to estimate doses for these unmonitored individuals when other dose-estimating information is not available.

5. Tables 4-2 and 4-3 (TBD, Vol. 4) summarize annual fugitive U and Th emissions. Please provide methodological details as to how the numbers were derived.

   For fugitive emissions, EPA guidelines were used to calculate emissions from the waste storage and production areas. Reference: Method for Estimating Fugitive Particulate Emissions From Hazardous Waste Sites. U. S. Environmental Protection Agency, Cincinnati, Ohio, August 1987. EP/600/2-87/066 PB87-232203.

6. Could information be provided that demonstrates that the trace radionuclide-to-U ratios observed in 1985 apply to the earlier years? Specifically, what about the radionuclide ratios for (a) ore processing, including pitchblende processing, and (b) waste stream handling, processing, and dumping?

   Yes. The values represent the earlier years. These values are also given within the Fernald Internal Dosimetry Technical Basis Document.

7. In developing the radionuclide-to-U ratios, the TBD used average observed values. Has NIOSH considered using the 95^{th} percent confidence level of the mean, as opposed to the true mean, as a more claimant –favorable strategy?

   Use of the mean values is reasonable for estimates of exposures to unmonitored workers, unless there is additional information that indicates that other values should be used. The mean ratios are to be applied to the maximum annual median uranium values, so they would tend to be favorable to claimants.

8. Are there time periods when a given facility may have experienced radionuclide-to-U ratios that were chronically at the high end of the distributions?

   Ratios of uranium to other radioactive contaminants varied among plants and even among areas within plants due to operational conditions and/or chemical processes being conducted. It would be expected that the non-uranium radionuclide to uranium ratios would be much larger in plants 1, 2/3, and 4; but becoming more weighted to uranium after initial reduction of UF_4 into metal within the Plant 5 "A" area.

9. Given that Tables 1 and 2 of the Boback report cited in the TBD reveal that the release heights were comparable to the heights of the nearby buildings, what is the basis for taking credit for an elevated release of 10 m when deriving atmospheric dispersion factors? How were building wake effects taken into consideration?

Many of the stack heights given in Table 1 indicate that they are only a few feet above the roof peak heights provided in Table 2 of Boback et al (1987), however the previous calculations need to be reviewed and consideration will be given to issues including stack heights and effective stack heights. No building wake effects were taken into account in estimating downwind concentrations from Fernald releases.

10. For the purpose of deriving the Rn and Rn progeny releases from the silos, the TBD used the median values derived in the RAC 1995 report. Wouldn't this approach be considered claimant-neutral as opposed to claimant-favorable?

    Best estimates (neither giving favor to the claimant, but not denying the benefit of doubt) are the preferred method of dose reconstruction. Regarding releases of Rn and associated progeny, a recent University of Cincinnati study has become available and the values in the TBD will be reconsidered in light of the new information.

11. Page 17 of the TBD states that atmospheric dispersion factors (X/Q values) were derived assuming a wind speed of 3.2 m/sec and stability class F. Once the X/Q values were derived for a given distance between the release point and receptor (using the σ_y and σ_z values in Figures 4-3 and 4-4 of the TBD), an adjustment factor is applied to account for the frequency the wind blows toward a given receptor from a given source. Why didn't NIOSH employ the conventional joint frequency approach to deriving average annual atmospheric dispersion factors? Furthermore, the selected wind speed of 3.2 m/s does not appear to be claimant favorable. Please provide a justification as to why NIOSH is using this value for wind speed.

    The wind speed of 3.2 m/s is from the environmental report and the choice of stability class "F" came from the Safety Analysis report for the thorium overpack operation.

12. Table 4-8 contains the estimated distances for receptors from contributing emission sources. For EA-6, the distance from the K-65 silos is given as 250 m, even though the geographic center of EA-6 appears to be at a distance of about 100 m. The distance from the K-65 silos to EA-9 is given as 2,000 m, even though the most distant point in EA-9 appears to be about 1,500 m away from the K-65 silos. The distance to Plant 7 to EA-3 and EA-8 is 250 m in both cases, even though Plant 7 is located inside EA-7. Please explain the basis for the assumptions.

    The estimated downwind distances will be reviewed and revised or justified as necessary.

13. The TBD states on page 16 that the respirable fraction (<10 μm) of U particles was determined to be 65% on the basis of RAC (1995), Table E-1. It appears that for this calculation, the simple arithmetic average of data from 15 dust collector stacks was used. Table E-1 does not provide data on particle sizes from scrubber emissions (Plant 2/3 and Plant 8). Table E-8 of RAC (1995) indicates that the composite of U_3O_8 releases indicate that more than 75% of the emissions in the outlet had a particle size of less than 10 μm. Please explain how the fraction of 65% respirable particles is representative for the total of all U emissions.

    Upon review, we believe that the higher fraction of respirable particles should be considered in determining the total respirable uranium particulate from at least Plants 2/3 and 8. The TBD will be revised accordingly.

14. Has NIOSH considered the contribution to the internal dose associated with the resuspension and inhalation of deposited Pb-210?

No, at this time NIOSH has not considered emissions of Pb-210 separately from the emissions of radon, because it is likely that assumed Rn intakes and the associated assumed equilibrium ratio of progeny are sufficiently large to account for intakes and associated doses from Pb-210 environmental releases.

15. Has NIOSH attempted to compare the pre-1989 derived atmospheric dispersion factors with the actual empirically determined atmospheric dispersion factors obtained using the actual monitored emissions and airborne radionuclide concentrations at monitored locations?

    The atmospheric dispersion factors have not been compared, but since the TBD was originally written, additional data have been received and comparisons are now possible.

16. The footnote to Table 4-7 on page 19 suggests that the dispersion coefficients were multiplied by a factor of 0.5 for U and Th particulate aerosols, presumably to account for plume depletion, as explained in the paragraph below equation 4-3 on page 17. For most distance, plume depletion will be less than 50%. Please explain how it can be claimant favorable to apply a uniform plume depletion factor of 50% for all releases of particulates.

    Although the Pasquill-Gifford Equation used for gases in Equation 4-2 should be divided by two for application to particulate, and thus results in Equation 4-3, the footnote to Table 4-7 appears to indicate that it's possible the numbers were divided in half again. The calculations will be checked and the numbers in Table 4-7 of the TBD will be updated if needed to reflect the appropriate values..

17. Equation 4-5 on page 35 of the TBD presents the method used to estimate the external radiation dose rates at each of the 11 grid locations. The basic approach was to use the actual measured dose rates at each of the locations where measurements were made, and then derive the dose rate at the grid locations, based on adjustments that take into consideration the distance from the source and the distance to the grid location using the inverse square law. One concern with this approach is that it only applies to point sources. Has NIOSH evaluated the degree to which this approach works for sources whose dimensions are large relative to the distance to the measurement location and/or the grid location?

    For most locations the distances compared to the source sizes are sufficiently large that a point source methodology is reasonable. For the few sources that might not be best approximated as point sources (e.g., the pits), the results are sufficiently close to actual measured results using these equations that the method appears reasonable.

18. The purpose of deriving the external environmental exposure pre-1976, when there were no measurements, the doses were derived by comparing the U throughput in those years with the years for which there were external environmental dose measurements. What is the relevance of U production to external environmental dose in outdoor areas? Why did NIOSH not use U emissions instead, for instance? Were U isotopes the main external environmental dose problem throughout the Fernald site? Has NIOSH evaluated the degree to which the controlling factors remained unchanged over the years?

    The environmental occupational exposures were ratioed to the U production rates. The primary environmental external exposure would have been due to the radium-bearing material (Ra-226) in the K-65 silos and the thorium (Th-232) stored within several warehouses on the Fernald site. Uranium's short-lived progeny, Pa-234m, contributes to the non-penetrating dose. This exposure *would have represented a baseline external exposure and would have incrementally increased based upon the throughput of uranium being processed within the process area.*

19. The TBD does not discuss the methods used to derive pre-1976 external environmental doses from the silos. How does NIOSH plan to reconstruct these doses?

    The method for extrapolating doses back to the pre-1976 periods is described in the TBD beginning with the last paragraph on p. 35. The method includes the dose from the silos, although the silo dose rates are not specifically called out in Table B-1 for pre-1976 periods. This is easiest to see by comparing the 1971–1975 and 1976 values in Table B-1, because the production rates were the same during these periods.

20. How does NIOSH propose to reconstruct doses for the K-65 workers involved in handling Mallinckrodt K-65 residues, including the unloading of these residues and their loading into Silo 1?

    This is not considered environmental exposure that would be used to address unmonitored worker doses, rather it is part of the exposure in a radiologically controlled workplace and so is covered in Section 5.2.4 of the Fernald Internal Dosimetry Technical Basis Document.

D. QUESTIONS RELATING TO INTERNAL DOSE (VOL. 5)

1. What is the reference for the decontamination factor of 50 used for some Th-232 production activities?

    A review of this TBD resulted in no locating of a decontamination factor of 50 in the document. Please clarify this question.

2. Table 2-1a assumes respirator-based decontamination by a factor of 50 for some operations (Vol. 2, pp. 12–13). But in Vol. 5, "at least a factor of 10" is given for decontamination, and it is said that respirator use was not consistent and a decontamination factor cannot be assumed (Vol. 5. pp. 22–23). Is a decontamination factor being assumed for uranium when air concentrations are used for intake estimation? If so, for which jobs and periods? And what is the value being used?

    To date, we are unaware of respiratory protection factors being used for Fernald dose reconstructions, and currently have no plans to apply these factors. (It's conceivable that in the future on a case by case basis, where there are no bioassay that can be used to estimate intakes and it can be shown that the worker was included in a respirator fit test program and was wearing a respirator that such factors might be applied). Table 2-1a applies (inappropriately) a respiratory protection factor only to some operations or locations. The last column in Table 2-1a and its associated footnote b., and other similar columns and footnotes in the Site Description TBD tables (e.g., 2-2b) will be deleted.

3. Has NIOSH taken into account the dose reconstruction implications of the finding that respirators were judged at one point (1953) to be the "epitome of filth?"[22] Specifically, if respirators were stored in places or were worn so that they were susceptible to contamination on the inside, the intake could possibly be even higher than for those who did not wear respirators. Has NIOSH done interviews regarding jobs and periods during which respirators were worn and on the condition of the respirators? If so, SC&A requests the records of these interviews. Has NIOSH determined whether a central service (recommended in the memo quoted in the footnote) was implemented, and if so, when?

   The TBD recommends that no credit be taken for respirator usage despite a documented program for respiratory supply and maintenance. Intakes derived from urinalysis results, which are likely to be available for those who handled respirators, would account for intakes that occurred directly from respirators. Ingestion intakes will be added for thorium operational intakes, which currently are based on intakes calculated from air concentrations. CATIs include some information regarding respirator usage, but other specific interviews regarding respirators, their care and their usage have not been assembled, and would unlikely affect exposure assumptions.

4. On page 11 (TBD, Vol. 2), it is not clear why thoria gel production for 1964 and 1965 was estimated based on a linear extrapolation of the quantity produced in 1966 through 1970. Can some justification for this assumption be provided?

   This question belongs in the section for Vol. 2 – the Site Description. Air monitoring and/or effluent release calculations are used to derive internal intakes and so this assumption does not affect dose reconstruction.

5. Could NIOSH provide the flowchart of thorium processing? Was it similar to the Ames Laboratory flowchart?

   Simplified flow sheets are included in the Dolan and Hill (1988 report) report. We are not familiar with the mentioned Ames Laboratory flowcharts. Is a more complete reference to these documents available, so we can review them?

6. How has NIOSH taken into account localized high concentrations of uranium dust in areas such as dust collector baghouses?

   Internal dose reconstruction is performed using uranium bioassay data, even if the intake occurred as a result of working in the high dust levels in the dust collector baghouses.

7. Is NIOSH developing an internal dose co-worker model? If so, what periods would this apply to, and what data are being used?

   So far, there has not been a need to develop a FEMP coworker model for internal dose.

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[22] Dr. Quigley to Charles Dees, "Industrial Case Study," October 12, 1953, p. 3, on which Dr. J. W. Durkin appears to be quoted. The full quote, which has the name of one person (perhaps two) deleted from the document is as follows: "The other problem that became apparent in this situation is the poor care being given to the dust respirators. The ones observed by [blank] and myself near the Chip Burner were the epitome of filth. Apart from this, it would have been a perfect fomite [?] for the transfer of respiratory infection between employees. This simply corroborates the reiteration of [blank] that something should be done about the respirator situation – either the men must take better care of them, or central service must be provided." An earlier part of the document notes that "there were two Dust-Foe respirators hanging on hooks" in the "shack-type office in the [Chip Burner] area."

8. Has NIOSH compiled internal dose data into a database? If so, could it be made accessible on the Advisory Board's section of the O Drive?

   At this point a NIOSH internal dose database is not available. There is a CEDR database, and if the Board Members have filed the appropriate paperwork for viewing CEDR data, access could be made available via the O drive).

9. How is NIOSH going to reconstruct internal dose prior to 1953, since there do not appear to be data before 1953, as implied by the sentence, "A urinalysis program was administered at FEMP starting in 1953 or possibly before" (p. 30 of Vol. 5). The table on the same page states that there are uranium bioassay data for 1952. Are there data for 1952?

   FEMP started to process radiological materials at the Pilot Plant in October 1951.The available data are adequate to estimate intakes from the beginning of radiological operations. In a quick review of the CEDR database for Fernald and some Fernald claims with employment prior to 1953, some uranium urinalysis results from 1952 were observed.

10. Since no bioassay data for thorium are available prior to 1990 – that is for the entire production period – how is NIOSH going to validate the dose estimates for thorium-232, as well as for its decay products, notably radium-224?

    Dose estimates are based on an understanding of the process, some air sampling measurements and default maximum credible intakes, derived from maximum air sample data. If a more comprehensive air monitoring database becomes available, its use will be considered. The concern is not clear about Ra-224, the alpha-emitting, short-lived progeny of Th-228, whose dose appears to be adequately accounted for in the assumption that the alpha activity measured in air only comes from the larger dose contributors Th-232 and Th-228.

11. Since much of the thorium data is lost and many documents have apparently been destroyed (p. 18, Vol. 5), and since there are hardly any bioassay data or other data specific to thorium in the workplace, how is NIOSH going to ensure that the dose reconstructions are claimant favorable? How is NIOSH going to ensure that all plants where thorium was processed are included in its list? Could NIOSH provide all the interviews on which its analysis of thorium production and related issues is based?

    The TBD referred to interviews performed by Dolan and Hill (1988) and that reference is available in the Site Research Database. The dose reconstruction for thorium exposures includes a default assumption that is claimant favorable to the extreme and should address any credible exposure. The TBD recognizes that a few scattered operations with thorium were conducted in plant 4. Any suggestion in the interviews that a claimant could have been involved with thorium operations will have the conservative defaults applied. However, the documented data for the few operations outside the pilot plant, Plant 8 and 9 are few and some additional information search may clarify how to address this question.

12. Given that thorium-232 DCFs are orders of magnitude larger than uranium for some organs, how is NIOSH going to address doses to uranium workers in the plants listed for thorium production (Plants 8 and 9, the Pilot Plant, and possibly Plant 4) (a) during thorium production periods, and (b) due to resuspension of thorium dust during nonthorium production periods?

    The question of addressing possible residual thorium contamination from discontinued thorium operations is under consideration.

13. Could NIOSH provide the records that have been recovered in relation to thorium described at the bottom of page 21, Vol. 5?

    The thorium air sampling records that have been recovered can be found in the SRDB and can be provided.

14. On page 22, Vol. 5, NIOSH states that "Therefore, the three Plants mentioned [Plants 8 and 9, and the Pilot Plant] should be considered the primary processing sites, although there is some evidence that a few isolated thorium operations occurred in other locations." There seems to be no guidance for dose reconstruction at these other locations (such as Plant 4), and how the periods or workers who were exposed would be determined. How is NIOSH addressing the issue of thorium work in Plants other than Plant 8, Plant 9, and the Pilot Plant?

    Perhaps a clarification should be emphasized that dose reconstructions for claims that include evidence of thorium exposure should include thorium internal dose based on the default values in the TBD. This question will receive additional consideration.

15. On page 22, NIOSH states that it is using BZ samples from lapel samplers to conservatively estimate thorium exposures. How is NIOSH taking into account the Y-12 study indicating that this is not a reliable way to make intake estimates, and that BZ-estimated intakes could be significant underestimates when compared with bioassay estimated intakes?

    The TBD statement on page 22 describes the current (modern) methods of controlling and assigning internal intakes – conservatively. If the questioner's Y-12 reference is the Y-12 Uranium Exposure Study (Eckerman and Kerr 1999 [Ref ID 11600]), it is clear that the intake estimation method proposed in the TBD is reasonable; in the Y-12 study the ratios of air concentration to bioassay derived intakes range from 0.11 to 1.38 with an average of 0.49 in Table 11 of the Y-12 study, indicating that if bioassay is the gold standard, Y-12 intakes derived from bioassay might be low in some cases by up to a factor of 9. However, the intakes in the Y-12 study were reduced to account for respiratory protection factors ranging from 1 (no respirator) to 50, but typically in the 25 to 50 range. For FEMP claims there is no proposal to apply a respiratory protection factor to the FEMP BZA derived intakes. In addition, currently the more claimant-favorable missed intakes from bioassay rather than air concentration derived intakes have been used to estimate FEMP doses. Assigning intakes based upon breathing zone air sampling data collected in current day programs with appropriate collection and measurement techniques is recognized as a reasonable way to estimate intakes.

16. Since enrichments of uranium-235 up to 20% were processed at Fernald, how does NIOSH justify the use of 2% enrichment as the default value after 1964? Given the large difference in specific activities and the fact that the fluorometric method was used for determining uranium content of urine, this would appear to be an assumption that would not be claimant favorable for some groups of workers at some times. Would it be possible to use a range of enrichments with a suitable distribution (or distributions for different time periods) instead?

    The amount of U of enrichments above 2% at FEMP was trivial (a few 55 gal drums compared to MTU). Also the exposures to these enrichments were less due to increased value, small amounts, need for additional criticality controls, etc.

17. In Table 5-11, RU contaminant concentrations are given for plutonium-239, neptunium-237 and technetium-99. Although plutonium-239 is likely to have dominated the plutonium component of the contamination in mass terms, plutonium-238 could have been more important in activity terms. Has

NIOSH given consideration to the possibility of specifying a default mass concentration for plutonium, together with a default partitioning between plutonium-238, plutonium-239, and plutonium-240, to allow intakes of activity by radionuclide to be assigned?

The Pu-238 was not a significant internal dose factor, as a result of processing primarily DU and low LEU. The method used to account for the dose from recycle uranium contaminants tends to be claimant favorable and uses the larger mass ratios to estimate intakes and it is likely that this worst-case method is sufficiently bounding to account for a small fraction of the higher specific activity Pu-238 in the mixture.

18. In Table 5-16, is there any explanation why Pb-210 and Po-210 activity concentrations in Silo 1 measured in 1993 are substantially less than would be expected based on the secular equilibrium concentrations that would be supported by the Ra-226 present? It is noted that this effect is much less marked in Silo 2.

There are a number of possible explanations for the less-than-equilibrium ratios, but the most likely one is that at some point during the ore processing much of the Pb-210 (21 year half-life) was separated from the Ra-226. Much (if not all) of the K-65 residue in Silo 1 came from Mallinckrodt's Destrehan facility, and some of the residues had been reprocessed in 1949 to extract additional uranium, which could have removed more lead. Silo 2 contained K-65 from Fernald beginning in 1952 and from Mallinckrodt in 1953 to 1956, when Mallinckrodt was no longer processing pitchblende. One would guess that there was less emphasis in "getting the lead out" by the time Silo 2 came into use (or perhaps there was more emphasis in controlling lead waste or releases to the environment). It is not clear how this would affect dose reconstruction, because it seems reasonable to use the measured ratios.

19. How can the Rn-222 concentration of 2.3 WL given on page 27 of Volume 5 be justified as claimant favorable when it is based on the higher of only two samples from a single radon sample data sheet?

Based on reviews of radon concentrations at sites that processed African as well as domestic ore and handled or stored its residues, such as Mallinckrodt and Linde Ceramics, the value of 2.3 WL appears favorable to the claimant. More information on radon at Fernald has become available and will be reviewed and incorporated into the site profile as necessary.

E. QUESTIONS RELATING TO EXTERNAL DOSE (VOL. 6)

1. Is NIOSH developing an external dose co-worker model? If so, what periods would this apply to and what data is being used?

No external dose "co-worker model" is currently under development.

2. Page 23 of the external dose volume mentions the use of co-worker data for missed doses? What criteria are being used to choose the co-workers for the missed doses?

The term "co-worker" as used in the TBD referred to someone who worked "side-by side" or did exactly the same job as the worker who either lost his dosimeter or whose dosimeter results were lost or was not monitored for some unknown reason for that exchange period. It was not intended to imply anything other than that.

3. Page 23 also mentions lost dosimeter results. What proportion of the data has been lost?

Dosimeter results have not been tabulated to estimate the proportion(s) of unavailable (because of dosimeter loss, record unavailability, etc.) results. The current sense is that the proportions are not likely to be large.

4. Has NIOSH compiled external dose data into a database? If so, could it be made accessible on the Advisory Board's section of the O Drive?

   Fernald external dose results were not compiled by ORAUT. To our knowledge the only databases that may be available are DOE's REMS database and ORAU's CEDR database. If the Board Members have filed the appropriate paperwork for viewing CEDR data, access could be made available via the O drive. Summary data from REMS are in the Site Research Database.

5. The TBD discusses adjustments to dosimeter readings. In regard to radioactive dust settling on the dosimeter, the TBD states that dosimeters were in plastic bags "at times" (p. 11, Vol. 6).[23] However, Volume 4 of the set of transition reports in the handover from NLO to Westinghouse discusses the application of adjustment factors to TLDs for a period between 1983 and October 1985. The use of this correction factor sometimes resulted in negative radiation dose estimates. The correction factors resulted in changes (according to the calculations shown in the datasheets) of 6% to 663%. In the examples given in the report, the largest magnitude correction of 1,652 millirem was applied to a dose of 1,291 millirem, resulting in a net negative estimated dose equal to -361 mrem.[24] The practice was used from 1983 (when TLDs were introduced) to October 1985, when its regular use was discontinued. However, it appears to have been continued in an *ad hoc* fashion after that date.[25] While doses with high percentage corrections (more than 50%, therefore including negative dose estimates) were not automatically entered into the dose record, it is unclear what exactly was done. The TBD does not discuss this problem, although it indicates some difficulties in the initial period of TLD testing due to a problem in the algorithm, notably for shallow dose (p. 12, Vol. 6). Has NIOSH investigated this problem and how the resultant doses might be interpreted? Since the TBD acknowledges that plastic bags were used only "at times," has NIOSH investigated the periods when this was not the practice? Were correction factors applied during such periods? Does NIOSH have documentation indicating the periods when dosimeters were in plastic bags? Section 6.5 on adjustments to dose does not discuss the use of the correction factors described above. How is NIOSH going to take them into account?

   The dose of record during the period in question, 1983–1985, was from the same film dosimeter in use from 1954–1985 and not from the bagged TLDs (see Table 6-12, pg.22). The TLD model in question was one under development and was not the dosimeter of record. The TLD model that was finally put into service in 1985 was the first to be DOELAP certified. As for correction factors, none were needed because plastic bags did not cover the dosimeter of record prior to the 1985 service date and no data was found that indicated the use of plastic bags after this date. However in discussions with ex-Fernald employees involved with the dosimetry program the use of plastic bags did occur and the same calibration practices prevailed.

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[23] "An additional radiological concern at several locations at FEMP occurred when workers were subjected to high levels of radioactive material-bearing dust. This widespread source of contamination was a concern for personal dosimeters, so at times the dosimeters were enclosed in plastic bags for protection against dust contamination. The manner in which these contaminated dosimeters were handled was not identified; however, this should not be an issue in dose reconstruction because the dosimeters were calibrated in plastic bags and no adjustments were made to the dosimeter results for either Hs(0.07) or Hp(10)." (TBD, Vol. 6, p. 11)

[24] Feed Materials Production Center, Final Phase-in Report, Vol. 4 of 15, Environment, Safety and Health, Westinghouse Company of Ohio, January 17, 1986. See Attachment 3 for the datasheets.

[25] Ibid. p. 15.

6. Vol. 6 of the TBD discusses correction factors for geometry. Has NIOSH taken adequate account of some jobs where the badge readings were unlikely to have any systematic relationship to the organ dose? One such job, stamping numbers on ingots, was photographed by Robert del Tredici in 1987. The photograph shows the worker sitting astride an ingot stamping an ID number on its flat face; it can be provided upon request. His film badge is dangling from his coverall pocket parallel to the face of the ingot. His body shields the radiation from behind. The use of wrist badges is evident. The angular response correction factors (Table 6-7) do not address this problem.

   The stated situation, while against all company rules, regulations and procedures, happened frequently. Instructions were given describing how dosimeters were to be worn so that they would measure the highest exposure to the body. The time spent in conducting this activity, e.g. stamping an ID number on an ingot, is a very small fraction of the individual's total working time and therefore of the individuals total exposure. Any individual claim involving a situation as depicted by the photo will be evaluated on a case-by-case basis. No generic correction factor is available or thought necessary for this particular situation.

7. On page 22 of Vol. 6, NIOSH states that "Corrections to the FEMP-reported dose are required, due to uncertainties in the recorded data and lack of significant data, especially prior to 1980." How much pre-1980 data is missing? What happened to the individual external dose records for the pre-1980 period that caused a significant amount of data to be missing?

   The "lack of significant data" referred to the information provided thereafter in the TBD regarding external dosimeter response-related details, and was not meant to imply that individual external dose records were missing. The corrections to pre-1985 data are due to the responses of the dosimeters and their inability to measure the contribution to the total dose from those photon radiations of less than several hundred keV and in particular the L-x-rays of both U and Th. The standard error for film dosimeters of this period and for these low energies is estimated to be+/- 30%, a value given in several TBD's, (Y-12, Hanford, IAAP). Since a portion of the total doses lie in these lower energy ranges, a correction is suggested in order to maintain a "favorable to claimants" position.

ATTACHMENT 3: SUMMARY OF THE CONFERENCE CALL OF AUGUST 18, 2006, ON THE FERNALD SITE PROFILE REGARDING SC&A QUESTIONS SENT TO NIOSH

For NIOSH and ORAUT: Mark Rolfes, Mel Chew, Cindy Bloom, Bryce Rich, Liz Brackett, Bob Morris, Elyse Thomas, Tom LaBone, Jack Fix, Karen Kent, Mutty Sharfi, Kenny Fleming

For SC&A: John Mauro, Harry Pettengill, Arjun Makhijani

These notes are a complement to the written answers provided by NIOSH to SC&A, which are reproduced in Attachment 2. Those answers are not repeated here, unless necessary to provide context for the notes of the discussion. The questions submitted by SC&A to NIOSH are shown in Attachment 1. Only those questions on which there was substantive discussion beyond the written replies provided by NIOSH are summarized here. NIOSH written responses reproduced here from Attachment 2 are indented and italicized. Furthermore, a full list of NIOSH actions to revise the TBD has been extracted from the Attachments in this review and provided in the text of the review in Section 5.0. The conversational style is retained to provide a flavor of the nature of the technical exchanges. This summary is not verbatim.

A. GENERAL QUESTIONS AND QUESTIONS RELATING TO VOLUMES 1 AND 2 OF THE TBD

1. Could NIOSH provide SC&A with the notes of its interviews with site experts?

> *The Site Profile development team only interviewed four former Fernald workers. Unfortunately, there were no comments from interviewees that related directly to issues or assumptions in the TBDs, so documentation of these interviews was not retained.*

SC&A: Are there any e-mail exchanges of the interviews?

ORAUT/NIOSH: There were e-mails, but the interviews were casual in nature. They focused on thorium. They were done in the context of preparation of the Dolan report (1988). We do not have any thing more than the reference to the interviews in the Dolan report, nor do we know if those interviews were documented.

SC&A: Did the interviews play a role in the thorium section, and if so, could NIOSH ask Dolan whether the documentation is available?

ORAUT/NIOSH: Yes, the interviews did play a role. Much more documentation is becoming available on thorium. When we did the TBD, information on thorium was limited, but we have received and are expecting more thorium information, which will be considered and incorporated in a revision of the TBD.

SC&A: Are you revising the TBD, and what is the schedule – is it within the next 30 days?

ORAUT/NIOSH: We are going through the bi-annual TBD review and revising it. We are behind schedule. We are not going to publish the revised TBD in the next month. We could respond to your TBD review as part of the revision.

SC&A: Are the new documents, especially regarding thorium, on the O Drive?

ORAUT/NIOSH: We are placing the documents on the Site Research database. Reference numbers will be sequential, so you can find the latest documents easily.

ORAUT/NIOSH action: Place thorium documents on the Site Research database as they become available. NIOSH will also prepare a brief summary of where ORAUT/NIOSH is in the TBD revision process as soon as possible, so it can be reflected in the SC&A TBD review. SC&A will make a list of the major revisions that are now planned or being produced.

2. How many workers were there at Fernald?

ORAUT/NIOSH: The TBD reflects at specified times the size of the workforce and SC&A was considering the total number of workers over time. Both are smaller than at some large DOE sites, hence the use of the term "relatively small."

SC&A: Yes, that seems right; we agree.

3. Regarding cumulative production.

SC&A: The production numbers in the TBD seem low. There are shipment and receipt data that indicate production of uranium (all types) of around half a million metric tons.

ORAUT/NIOSH research was centered on some material balance reports and the recycle uranium work. The mass balance mainly for RU is in OTIB-53 in final review.

SC&A action: Arjun will send data and/or references to Mark Rolfes.

4. Are the uranium ore processing flowsheets similar to that developed by NIOSH for Mallinckrodt showing the various stages of filtering and concentrations of Ra-226, Th-230, Pa-231 and Ac-227?

ORAUT/NIOSH: The Fernald flow sheet was similar to Mallinckrodt, but would have incorporated better designs. There were some differences. There is a text that talks about the differences.

ORAUT/NIOSH action: Look at flowsheet for Fernald and compare to Mallinckrodt. At Fernald, the waste that went into Silo 2 is the main concern, since that was the waste from processing of relatively high-grade ores at Fernald. The first step would be to create the Fernald flowsheet and try to benchmark that with MCW.

5. Would the ratios of radionuclides in the K-65 Silo 1 or Silo 2 be applicable to specific waste streams, or do they represent mixtures of actual waste streams that were all discharged into the silos? The question relates only to Fernald waste streams and not the Mallinckrodt materials in the silos.

ORAUT/NIOSH: Comprehensive radionuclide-specific analyses for Silo 2, like those reported in the 1990s, have not been located at this time.

6. What is the scientific justification for using the ratio of Th-232 to U atmospheric emissions to determine in-plant thorium contamination?

ORAUT/NIOSH: Those ratios are not being used in dose reconstruction. The internal dosimetry part of the TBD specifies how thorium doses are estimated. The uranium-to-thorium ratio was used as a sanity check. The TBD is being revised to reflect the extensive data on thorium that is becoming available, including more results from thorium air samples and thorium lung count data.

SC&A: The assumptions in the Site Description are not the same as those in the environmental and internal dose sections of the TBD. This is confusing.

ORAUT/NIOSH: Vol. 2 was developed early on. It will be made consistent with Volumes 4 and 5, the environmental and internal dose sections.

SC&A: This would be useful and clear up this confusion by making the needed changes.

B. QUESTIONS RELATING TO MEDICAL DOSE (VOL. 3)

1. This question was about records of telephone communications as the basis for which the possible use of a PFG unit at Fernald was ruled out.

    No other information regarding telephone conversations beyond that included in the TBD is available.

SC&A: Are we to take the response to mean that no record of these conversations is available? Specifically, we are looking for documented information as to why the use of a PFG unit is ruled out. The only person who worked in the period of interest and who was interviewed was Nurse Smith, so validating that conversation is central to this issue. Relying on people who joined in the 1980s may not be viewed as reliable for determining whether there were PFG units in use in the 1950s.

ORAUT/NIOSH: There are no formal records of those conversations. They were just documented in the TBD and that is all there is.

SC&A: Who helped determine and therefore rule out PFG use as concluded in the TBD?

Mel Chew: I helped with this. I don't remember the specific conversation about the PFG unit. It came up, but I just don't recall it.

SC&A: If you look at the [NIOSH] guidelines, especially OTIB-0006, there is an appreciation of the need to consider the use of PFG units as a fast and efficient screening tool for the high employee volume being hired at new DOE facilities built during the 1940s and 1950s. PFG was in common use at most DOE facilities in the 1950s, so you should not default to x-rays as opposed to PFG units without validation.

SC&A: In my review of the TBD medical section, I don't recollect any discussion of film size. If you find smaller than 14" by 17" film, that is usually a dead giveaway that there was use of a PFG unit. I don't recall that there was anything stated about the size of the x-ray film in the TBD.

SC&A: Also of concern is whether there is any indication that x-rays of employees may have been taken offsite or outside the Fernald medical clinic.

ORAUT/NIOSH: We have no reason to think that that was the case. How would we look at that?

SC&A: If you look a number of x-ray films, you can see if you have different levels of definition (contrast, etc.), film sizes, and such. Specifically, any PFG film will be smaller in size. So you can infer whether they were made in one location or more, and whether a PFG unit was used.

NIOSH/ORAUT action: Elyse will go to the Fernald records center, look at the some of archived records, including films, and try to resolve some of these questions.

SC&A: If there are the actual films to review and not just the medical interpretation, it will be easy to check if PFG was used.

2. Were data for Bennett unit calculated or measured?

ORAUT/NIOSH: The data were calculated. There were also data from Hanford. The calculated values were higher than the measured Hanford values, so this appears to be claimant favorable.

SC&A: We suspected that early survey information [Tables 3-10 and 3-14] was calculated. In our records search, we were unable to find an actual survey attributable to the Bennett unit. I understand that has been done. How about the Keleket unit? Have you looked at that again? They assumed a half-value layer of 2.5 mm of Al.

ORAUT/NIOSH: We're not yet ready to answer the question about the Keleket unit. Can you clarify the question you want answered?

SC&A: The TBD states that the Keleket unit was surveyed in 1961 and the results of that survey help to validate the dose calculations for that unit. Our review shows the purpose of the survey was to establish whether unwarranted external doses resulted from workers inadvertently wearing their dosimeter during annual x-ray exams. There were problems also with the unit not operating in the full diagnostic range and the use of 2.5 mm of Al as added filtration, which appears to be assumed rather than measured. Can NIOSH demonstrate with actual survey data that the HVL of Keleket was empirically measured and output was later measured in the full diagnostic range of the unit?

Follow-up post-discussion question from Harry for NIOSH: "Can NIOSH provide SC&A with a copy of the actual Bennett unit survey that clearly identifies the date and unit number?"

3. Did NIOSH examine other explanations for the black line at the bottom of the radiographs, other than assuming that collimation was always used at Fernald from the earliest days?

SC&A: This assumption is not defensible without an actual examination of the film by a technician to determine the reason for the black line at the bottom of the film. Such a single line at the bottom of the film alone is unlikely to be due to collimation.

ORAUT/NIOSH action: NIOSH will review this issue again, and look at the actual films in the record center during a forthcoming visit and will report back to SC&A its findings.

Supplementary post-discussion question from Harry for NIOSH: NIOSH, in Section 3.1.4 of the TBD, concludes that from 1952–1980, collimations were always utilized. Can NIOSH show by actual documentation that the Keleket and Bennett units had collimators installed, and do any studies exist to show they were routinely checked for alignment error or leakage of the collimators?

4. Are doses from x-rays taken after workplace accidents going to be included in dose reconstructions?

> *In accordance with 42 CFR 81 and 82, only medical exposures that were performed for medical screening and required as a condition of employment are included in the occupational medical dose. Diagnostic and therapeutic procedures not required for medical screening are not included." X-rays taken after workplace accidents are diagnostic and so are not included in dose reconstruction.*

SC&A: The rationale for this question was not so much intended to cover whether a person was rolled in for x-ray because he had a workplace injury. Perhaps a clarification is in order. The question should state: Were some of the prescribed and often repetitive screening x-rays, which occurred outside the routine physical exam schedule also considered as a "condition of employment?" So far it has not been stated in the TBD that they were.

ORAUT/NIOSH: Pelvic and lumbar spine exams were also required [in the DOE complex] and those would be covered. They were typically given on an annual basis or more often for periods in the 1940s and in the 1950s. However, we asked about these x-rays for Fernald and were told that they did not do them there.

SC&A: My understanding is this resulted from a conversation you had with a manager in 2003. So the question remains whether there is documentation to establish whether screening exams of all types were included if they occurred. Is there a basis for knowing what happened in the 1950s?

Elyse: Usually what we tried to do was to determine whether x-rays were screening or not, whether they were performed on a large number of people who were asymptomatic, or, for instance, for tuberculosis screening. The clue usually is in the data submitted by the DOE site. If you see an exam just on a few people, then it is likely that this was not a screening. But if there were a large number of lumbar spines, for instance, then there is a good chance that was a screening method. Sometimes we have the [x-ray] records, but not the protocol for taking the x-rays. For Fernald, we may have seen lumbar spines in just one of the claimant files. But I am not sure of that right now. For an individual dose reconstruction, they count up the number of x-rays in the file and decide whether the file is complete. If it seems that there were routine annual x-rays, then they assign that, even if records for some years are missing. We usually have a list of x-rays taken for the individual employee. Some sites use forms that make it clear if an exam was for screening. But at most sites, at least in the early years, this was not clear.

SC&A: Was there a numerical criterion for how many people had to be x-rayed before one would conclude that it was screening that would be considered as a condition of employment?

ORAUT/NOISH: No. You get a feel for it as you go through the claimant cases; there is no hard and fast rule.

SC&A: Fernald was a uranium metal foundry from its earliest days. So it seems reasonable that it would have been important to establish whether new workers had a pre-existing back injury. Can NIOSH further validate that routine screening exams for respirator users, asbestosis workers, food handlers, etc., were included in medical dose estimates, even when they occurred at different times than when routine physical exams occurred?

ORAUT/NIOSH action: Elyse will look for evidence of lumbar spine x-rays and other screening exams that might have been a requirement for employment, and if it appears that these exams were performed at Fernald, she will look for the period of applicability. She will also look for information to address the Fernald PFG issue.

5. The TBD states that a review of claimant files showed that 15% of the claimants reported that retakes occurred. Could NIOSH provide SC&A with the data compilation used to determine the retake rate?

    No other information regarding X-ray retake rate, beyond that included in the TBD, is available.

SC&A: But what is the 15% rate based on? Was it a default value?

ORAUT/NIOSH: As best as I recall, it came from Ron Kathren, and was taken from OTIB–0006. We don't know whether it was a default value. If it was, then we will correct the language and say so.

SC&A: Retakes happen if the technicians decide they have a poor picture, or they may be ordered by the doctor to do it again, if he wants more detailed information. One is a retake and the other is really a new exam. Actual retakes hardly ever end up in the medical record. As such, it is very hard to estimate retakes unless you do a facility-specific study. Overall, an assumed 15% retake rate for Fernald—given the equipment and timeframe—might be borderline or low.

ORAUT/NIOSH: A 30% uncertainty is applied to the organ dose. It is from OTIB-0006 and presumably includes consideration of retakes.

SC&A: The 30% uncertainty does not have to do with retakes and does not include them, as the 30% uncertainty only covers systematic or measurement error. The retake rates would vary a lot. The reason it stood out to us was that the TBD indicated the 15% came from a "review of claimant files."

ORAUT/NIOSH action: Is it a Fernald statement or a generic statement? Clarify where the assumption of a 15% retake rate comes from.

C. QUESTIONS RELATING TO ENVIRONMENTAL DOSE (VOL. 4)

1. Why did the TBD use the source term developed by Fernald and not by the Radiological Assessments Corporation by the CDC, which is much higher (about 310,000 kg compared to about 175,000 kg used by NIOSH)?

   The original revision of the Fernald Occupational Environmental Dosimetry Technical Basis Document (OEDTBD) used the Boback data to estimate exposure to site releases because it was believed that its use would be sufficiently conservative and the resulting exposures would represent exposure estimates that would be favorable to the claimant. Use of the release data compiled by RAC (1995) would simply add to the existing conservative estimate.

SC&A: The RAC source term is not a conservative one; it is their median estimate. The Fernald 1987 and 1988 source terms were flawed, for instance, because they did not take into account that scrubber efficiencies in Plant 8 were very low sometimes; far below the lowest manufacturer-specified efficiency of 70%. CDC spent $6 million on the RAC study, whose source term is more scientifically sound than the Dolan and Hill source terms.

ORAUT/NIOSH: We felt that the values documented in the Boback report were conservative and claimant favorable. We can change it. It would be claimant favorable to use a higher RAC number.

SC&A: The use of RAC is not about what is claimant favorable. We believe that the RAC source term is much more technically defensible, and it specifies uncertainties. Note that the 5th percentile value of the RAC source term is about the same as the upper bound of the Westinghouse source term. So there are non-trivial differences here.

ORAUT/NIOSH action: NIOSH will look at this issue again.

2. Why did the TBD use the Th source term from Boback 1987 and the 1988 supplement, rather than the RAC 1995 source term?

   See response to C.1 above.

SC&A: This question was in error. The RAC study does not have a thorium source term.

ORAUT/NIOSH: The RAC Report indicates in Table L-13 relative concentrations of Th to U based upon liquid waste discharges. The Boback report also provides airborne Th release data. Both information sources will be assessed, and the TBD revised as necessary.

3. Table 4-4 on thorium emissions may not be conservative as stated in the TBD, for instance, due to low scrubber efficiency.

   The RAC 1995 document provides a description of the scrubber efficiencies at both Plants 2/3 and 8 that differs from the Dolan and Hill (1988) assumptions. Updates to the TBD are warranted based on the differences in the efficiency estimates.

ORAUT/NIOSH action: Both the RAC and Boback Reports provide information sources concerning airborne thorium emissions that will be assessed and the TBD revised as necessary.

4. According to a tabulation by NLO, a significant fraction of the U releases from Fernald were of an episodic or accidental nature, influencing the environmental doses. How is NIOSH going to account for episodic releases in estimating environmental internal dose for individual dose reconstructions?

   Episodic (and operational) stack releases are included as annual integrated emissions within the tables in the TBD. Over extended periods of time, these integrated emissions provide means of estimating internal exposures for individuals who were not monitored and who would not have required monitoring because of their low potential for exposure during their employment. In accordance with program guidance given in ORAUT-PROC-0031, the derived maximum site-wide annual median intakes via inhalation and ingestion will be used to estimate doses for these unmonitored individuals when other dose-estimating information is not available.

SC&A: There are really three issues in regard to estimating internal environmental doses that could affect the use of the annual average Gaussian plume model; episodic releases, ground level vs. elevated releases, and building wake effects. The NIOSH approach is claimant favorable for using stability Class F, but it is not for the other assumptions. For example, the building wake problem is important onsite for the radon emissions from the silos.

ORAUT/NIOSH: We did not have a lot of data when the TBD was prepared, so this was one of the approaches to use. If there were a large number of episodic releases, then they can be treated in an annual average release model.

SC&A: We agree with that. NIOSH has drawn upon the work of RAC, which was for offsite dose estimation for onsite purposes. This is not appropriate. This is a problem we have found across the board.

ORAUT: Are you suggesting another model?

SC&A: You used puff advection at Hanford. There should be some guideline as to when an annual average Gaussian approach can be used and when the more complex approaches should be used. If releases are frequent and random, then you can use annual average, but for large releases every few months, you want to use puff advection. It could make a lot of difference in that case.

(This discussion also covers questions 9, 11, 12, and 15, which are omitted from this summary.)

SC&A action item: SC&A will communicate some preliminary work to NIOSH, and at the same time, finish its site profile review.

5. How were fugitive U and Th emissions calculated?

> *For fugitive emissions, EPA guidelines were used to calculate emissions from the waste storage and production areas. Reference: Method for Estimating Fugitive Particulate Emissions from Hazardous Waste Sites. U. S. Environmental Protection Agency, Cincinnati, Ohio, August 1987. EP/600/2-87/066 PB87-232203.*

SC&A: This generic estimate does not seem appropriate. There are Fernald data from the 1950s or earlier where fugitive emissions were estimated. The fugitive emissions from some practices appear to have been substantial. For example, there were leaks in outdoor equipment, dust escaping from doors and windows opened during blowouts, and dust being blown about from keeping thorium trays in doorways. These data should be used. Also the EPA equations give very low values for dust loadings compared to empirical values for dust loadings. The EPA approach gives 1 to 2 micrograms per cubic meter; empirical data show that this is low by 2 or 3 orders of magnitude.

Mel Chew: We should review this as a generic approach. This was an early approach, and it should be reviewed generically. Is that what you are asking?

SC&A: SC&A will look at the dust loading, but it may not be the most important environmental source term. The other items we've mentioned above may be more important.

SC&A action: Arjun will try to dig up documents on fugitive emissions and send them to NIOSH for use in revising the site profile.

7. In developing the radionuclide-to-U ratios, the TBD used average observed values. Has NIOSH considered using the 95th percent confidence level of the mean, as opposed to the true mean, as a more claimant-favorable strategy?

ORAUT/NIOSH: Remember that environmental doses are for unmonitored workers. For other workers, the approach is specified in Vol. 5 of the TBD. Coverage of Fernald workers in terms of monitoring for both external and internal dose was quite thorough. NIOSH experience with claims shows that this was the case.

10. For the purpose of deriving the Rn and Rn progeny releases from the silos, the TBD used the median values derived in the RAC 1995 report. Wouldn't this approach be considered claimant-neutral, as opposed to claimant-favorable?

    Best estimates (neither giving favor to the claimant, but not denying the benefit of doubt) are the preferred method of dose reconstruction. Regarding releases of Rn and associated progeny, a recent University of Cincinnati study has become available and the values in the TBD will be reconsidered in light of the new information.

ORAUT/NIOSH: Again, the environmental dose TBD is for unmonitored workers. A separate protocol is used for monitored workers, as specified in Vol. 5. For these workers, the dose assignment is higher. We are re-evaluating all this in light of new information. Specifically, NIOSH has new information from the University of Cincinnati.

14. How about resuspension of Pb-210 that has built up in the soil from deposition?

ORAUT/NIOSH: This will be minor, since lead-210 has a long half-life relative to radon. The radon blows offsite to a large extent, and most of the lead-210 build-up will be there. Also, the lead-210 component of resuspension dose would be much smaller than the other components like uranium, due to high environmental releases.

SC&A: But there is a disequilibrium for lead-210 in the silos, indicating that there is a deficit, which must be somewhere.

ORAUT/NIOSH: We don't expect to see lead-210 in equilibrium, because the K-65 residues were reprocessed at Mallinckrodt in 1949 before being shipped to Fernald. The lead-210 may have been stripped at Mallinckrodt in the barium sulfate process.

SC&A: In that case, it would be perhaps two half-lives of lead-210, and that may be part of the explanation for the Silo 1 measurements.

SC&A action: SC&A will do a sample calculation of Pb-210 deposition to estimate build-up and see if this is an issue.

17. What about the validity of the inverse square law for external radiation for areal sources?

    For most locations the distances compared to the source sizes are sufficiently large that a point source methodology is reasonable. For the few sources that might not be best approximated as point sources (e.g., the pits), the results are sufficiently close to actual measured results using these equations that the method appears reasonable.

SC&A: What measurements were used?

ORAUT/NIOSH: The external dose values were from aerial survey data.

SC&A: This appears appropriate.

18. For pre-1976 period, there are no external dose environmental data. Why did NIOSH use production rather than emissions as the key variable for estimates?

SC&A: The external dose factors are not mainly production-dependent, since we know that emissions per unit of production emissions were bigger in the 1950s than later on. Hence, production should not be used to back-extrapolate any dose parameter.

ORAUT/NIOSH: This is unmonitored for workers.

SC&A: Why not scale it according to emissions? SC&A indicated they will revisit this issue and see if they still have a question.

20. How does NIOSH propose to reconstruct doses for the K-65 workers involved in handling Mallinckrodt K-65 residues, including the unloading of these residues and their loading into Silo 1?

ORAUT/NIOSH: This is really an internal dose issue and is addressed in Section 5.2.4 of the Internal Dose TBD, which includes information for allocating intakes from associate radionuclides. This question is not an environmental dose issue.

D. QUESTIONS RELATING TO INTERNAL DOSE (VOL. 5)

1. What is the reference for the decontamination factor of 50 used for some Th-232 production activities?

    A review of this TBD resulted in no locating of a decontamination factor of 50 in the document. Please clarify this question.

SC&A: There are many references to such a decontamination factor in Vol. 2, for instance in the footnotes to Tables 2-1a, 2-2a, 2-3a, etc.—about 10 instances in all.

ORAUT/NIOSH: This is actually a respirator protection factor used in Vol. 2 and is not being used in dose reconstruction. We will fix Vol. 2, so it is compatible with Vol. 5. Fernald was an early TBD and needs revision. This also clears up question 2 in this section.

2. Vol. 2 and Vol. 5 are not consistent in regard to respirator decontamination factors. Explain.

See answer to question 1 in this section. Assuming no respirator was used takes care of question 3 as well.

7. Is NIOSH developing an internal dose co-worker model? If so, what periods would this apply to, and what data are being used?

> *So far, there has not been a need to develop a FEMP coworker model for internal dose.*

ORAUT/NIOSH: The reason that a co-worker model is not needed is that essentially everyone was monitored.

8. Has NIOSH compiled internal dose data into a database?

> *At this point a NIOSH internal dose database is not available. There is a CEDR database, and if the Board Members have filed the appropriate paperwork for viewing CEDR data, access could be made available via the O drive).*

ORAUT/NIOSH: At the time of TBD, the data was in two archives. Now data are available. Bioassay data are the primary data, and there is really no need to go back and do this, since everyone essentially was monitored.

9. How will internal doses before 1953 be calculated, given that there might be no bioassay data?

ORAUT/NIOSH: Don't know how many claims include only exposures in late 1951 through 1952, but for claims that include later bioassay, chronic intakes can start on the day of employment. There are also some 1952 bioassay records.

10. How will pre-1990 thorium doses be estimated? And how about radium-224?

ORAUT/NIOSH: Ra-224 dose is small relative to the other radionuclides.

SC&A: We agree regarding Ra-224. But the TBD is not on the mark regarding thorium. The suggested method would be an underestimate, at least for the early years. Also, processing was done in more plants than indicated in the TBD.

ORAUT/NIOSH: We are getting more information. We have been able to get lung counting data for thorium. There are thorium chest counts from the late 1960s and early 1970s. The data are being developed, but they do not have them at this point; the DOE has them. Thorium chest counts were done on everyone who had uranium counts. They reported only thorium-232 and thorium-228. [Thorium-230 was not included.] The current default assumption typically results in a determination that a chest count would be positive, but the claims processed to date indicate that the default assumption typically results in an overestimate of intake. There is a box of records for everyone who was monitored at Fernald.

SC&A: How do you know if the people who worked on thorium in the 1950s and 1960s were monitored? You have to be careful to back-extrapolate both, because it may not be the same people who were exposed. We did not see that maximum air concentration data were cited or used in the TBD. Rather, there is the 1050-MAC recommendation for thorium intake that seems rather arbitrary.

ORAUT/NIOSH: We believe it is claimant favorable, but we are re-evaluating the thorium exposures. Thorium records will continue to be added to the Site Research database as they become available.

11. What is NIOSH doing to ensure that all periods and plants where thorium was processed are covered, since much of the thorium data is lost and many documents have apparently been destroyed (Vol. 5, p. 18)?

SC&A: There are data showing it was processed in Plant 6, for instance.

ORAUT/NIOSH: We are looking at where it was processed again.

12. Question about thorium resuspension doses to uranium workers during thorium production and after it.

    The question of addressing possible residual thorium contamination from discontinued thorium operations is under consideration.

SC&A: How about thorium exposure in the 1980s?

ORAUT/NIOSH: We are looking at residual contamination in general. This is a program-level issue, for which we are trying to develop generic approaches for these estimates. There may also be data available to address this.

SC&A: Since the residual contamination was a mixture of uranium and thorium contamination, the model suggested for Bethlehem Steel may be useful.

SC&A action: Arjun will send Bethlehem Steel reference to Mark Rolfes for Cindy.

13. Could NIOSH provide the records that have been recovered in relation to thorium described at the bottom of page 21, Vol. 5?

    The thorium air sampling records that have been recovered can be found in the SRDB and can be provided.

ORAUT/NIOSH: NIOSH is uploading newly found documents as they go along.

15. On page 22, NIOSH states that it is using BZ samples from lapel samplers to conservatively estimate thorium exposures. How is NIOSH taking into account the Y-12 study indicating that this is not a reliable way to make intake estimates, and that BZ-estimated intakes could be significant underestimates when compared with bioassay estimated intakes?

The TBD statement on page 22 describes the current (modern) methods of controlling and assigning internal intakes – conservatively. If the questioner's Y-12 reference is the Y-12 Uranium Exposure Study (Eckerman and Kerr 1999 [Ref ID 11600]), it is clear that the intake estimation method proposed in the TBD is reasonable; in the Y-12 study the ratios of air concentration to bioassay derived intakes range from 0.11 to 1.38 with an average of 0.49 in Table 11 of the Y-12 study, indicating that if bioassay is the gold standard, Y-12 intakes derived from bioassay [sic, the original response is miswritten and the word "bioassay" should be replaced with "air concentration."] might be low in some cases by up to a factor of 9. However, the intakes in the Y-12 study were reduced to account for respiratory protection factors ranging from 1 (no respirator) to 50, but typically in the 25 to 50 range. For FEMP claims there is no proposal to apply a respiratory protection factor to the FEMP BZA derived intakes. In addition, currently the more claimant favorable missed intakes from bioassay rather than air concentration derived intakes have been used to estimate FEMP doses. Assigning intakes based upon breathing zone air sampling data collected in current day programs with appropriate collection and measurement techniques is recognized as a reasonable way to estimate intakes.

SC&A: The Eckerman and Kerr study indicates the reverse. Air concentration-derived intakes were lower by up to a factor of 9.

ORAUT/NIOSH: That is because a respiratory protection factor for inhalation intakes was used. Without that, the air intakes are higher.

SC&A action: Revisit the Eckerman and Kerr study.

ORAUT/NIOSH: Post-discussion, it was noted that the ORAUT response erroneously referred to bioassay when air concentration was meant. A correction has now been added in square brackets within the response.

16. Since enrichments of uranium-235 up to 20% were processed at Fernald, how does NIOSH justify the use of 2% enrichment as the default value after 1964?

The amount of U of enrichments above 2% at FEMP was trivial (a few 55 gal drums compared to MTU). Also the exposures to these enrichments were less due to increased value, small amounts, need for additional criticality controls, etc.

SC&A: Some quantitative justification of "trivial" would be useful. It would provide some assurance that this is not a problem assumption for some workers. It would be desirable to document and give some quantitative expression to the term "trivial." We are surprised that there is not a careful materials account for uranium enriched to more than 2%, given that other sites seem to track even natural thorium down to kilogram quantities.

ORAUT/NIOSH: We are sure that it was small. It was not a requirement to do materials accounts for uranium enriched to less than 20%. Other sites did materials accounts for lower enrichments and thorium for their own purposes. It was not headquarters telling them to do it.

18. In Table 5-16, is there any explanation why Pb-210 and Po-210 activity concentrations in Silo 1 measured in 1993 are substantially less than would be expected based on the secular equilibrium concentrations that would be supported by the Ra-226 present? It is noted that this effect is much less marked in Silo 2.

    There are a number of possible explanations for the less-than-equilibrium ratios, but the most likely one is that at some point during the ore processing much of the Pb-210 (21 year half-life) was separated from the Ra-226. Much (if not all) of the K-65 residue in Silo 1 came from Mallinckrodt's Destrehan facility, and some of the residues had been reprocessed in 1949 to extract additional uranium, which could have removed more lead. Silo 2 contained K-65 from Fernald beginning in 1952 and from Mallinckrodt in 1953 to 1956, when Mallinckrodt was no longer processing pitchblende. One would guess that there was less emphasis in "getting the lead out" by the time Silo 2 came into use (or perhaps there was more emphasis in controlling lead waste or releases to the environment). It is not clear how this would affect dose reconstruction, because it seems reasonable to use the measured ratios.

NIOSH provided SC&A with a reference where measurements of radon in the head space of the K-65 silos are published. Waste management proceedings WM-4383, Eger, Jacob Engineering, Langner, Grand Junction Field office.

If there is good agreement between head space concentration of radon as estimated by RAC and Langner measurements in the Fernald head space, that would settle this issue.

SC&A action: Check this publication to see if there an issue here (in terms of a discrepancy between measured and calculated radon concentrations).

19. Rn-222 intake assumption of 2.3 WL is the higher of only two samples from a single radon sample data sheet.

ORAUT/NIOSH: Data from other sites show 2.3 WL is claimant favorable. And there are more data available now that are being analyzed.

SC&A: A comparative table for Fernald compared to other sites would be useful.

E. QUESTIONS RELATING TO EXTERNAL DOSE (VOL. 6)

3. Page 23 also mentions lost dosimeter results. What proportion of the data has been lost?

   Dosimeter results have not been tabulated to estimate the proportion(s) of unavailable (because of dosimeter loss, record unavailability, etc.) results. The current sense is that the proportions are not likely to be large.

SC&A: Is there some notion of what "not likely to be large" means?

NIOSH: The individual dose records are pretty complete. The missing or lost data would be well under 5% based on experience. There is no real gap here.

4. Has NIOSH compiled external dose data into a database? If so, could it be made accessible on the Advisory Board's section of the O Drive?

ORAUT/NIOSH: No action is planned. NIOSH will confirm with the Board.

5. The TBD discusses adjustments to dosimeter readings. In regard to radioactive dust settling on the dosimeter, the TBD states that dosimeters were in plastic bags "at times" (p. 11, Vol. 6).[26] However, Volume 4 of the set of transition reports in the handover from NLO to Westinghouse discusses the application of adjustment factors to TLDs for a period between 1983 and October 1985. The use of this correction factor sometimes resulted in negative radiation dose estimates. The correction factors resulted in changes (according to the calculations shown in the datasheets) of 6% to 663%. In the examples given in the report, the largest magnitude correction of 1,652 millirem was applied to a dose of 1,291 millirem, resulting in a net negative estimated dose equal to -361 mrem.[27] The practice was used from 1983 (when TLDs were introduced) to October 1985, when its regular use was discontinued. However, it appears to have been continued in an ad hoc fashion after that date.[28] While doses with high percentage corrections (more than 50%, therefore including negative dose estimates) were not automatically entered into the dose record, it is unclear what exactly was done. The TBD does not discuss this problem, although it indicates some difficulties in the initial period of TLD testing due to a problem in the algorithm, notably for shallow dose (p. 12, Vol. 6). Has NIOSH investigated this problem and how the resultant doses might be interpreted? Since the TBD acknowledges that plastic bags were used only "at times," has NIOSH investigated the periods when this was not the practice? Were correction factors applied during such periods? Does NIOSH have documentation indicating the periods when

[26] "An additional radiological concern at several locations at FEMP occurred when workers were subjected to high levels of radioactive material-bearing dust. This widespread source of contamination was a concern for personal dosimeters, so at times the dosimeters were enclosed in plastic bags for protection against dust contamination. The manner in which these contaminated dosimeters were handled was not identified; however, this should not be an issue in dose reconstruction because the dosimeters were calibrated in plastic bags and no adjustments were made to the dosimeter results for either Hs(0.07) or Hp(10)." (TBD, Vol. 6, p. 11)

[27] Feed Materials Production Center, Final Phase-in Report, Vol. 4 of 15, Environment, Safety and Health, Westinghouse Company of Ohio, January 17, 1986. See Attachment 3 for the datasheets.

[28] Ibid. p. 15.

dosimeters were in plastic bags? Section 6.5 on adjustments to dose does not discuss the use of the correction factors described above. How is NIOSH going to take them into account?

The dose of record during the period in question, 1983–1985, was from the same film dosimeter in use from 1954–1985 and not from the bagged TLDs (see Table 6-12, pg.22). The TLD model in question was one under development and was not the dosimeter of record. The TLD model that was finally put into service in 1985 was the first to be DOELAP certified. As for correction factors, none were needed because plastic bags did not cover the dosimeter of record prior to the 1985 service date and no data was found that indicated the use of plastic bags after this date. However in discussions with ex-Fernald employees involved with the dosimetry program the use of plastic bags did occur and the same calibration practices prevailed.

SC&A: We cannot accept this statement at face value. The datasheet reproduced in the Westinghouse transition report has badge numbers on it and implies that it is part of the workers' records. Some cross-walking of the data in the transition report with individual dose records is essential before it can be assumed that none of these calculated doses were in worker dose records.

SC&A action: Arjun will find Ref. 5 and send it to Mark, since it is not on the NIOSH database.

ORAUT/NIOSH action: ORAUT/NIOSH will review this issue.

6. Question of organ dose versus dose recorded on the badge due to location of the source relative to badge and organ. Example of a worker sitting on an ingot to stamp an ID number on it shown in a photograph taken by Robert del Tredici in 1987.

The stated situation, while against all company rules, regulations and procedures, happened frequently. Instructions were given describing how dosimeters were to be worn so that they would measure the highest exposure to the body. The time spent in conducting this activity, e.g., stamping an ID number on an ingot, is a very small fraction of the individual's total working time and therefore of the individual's total exposure. Any individual claim involving a situation as depicted by the photo will be evaluated on a case-by-case basis. No generic correction factor is available or thought necessary for this particular situation.

SC&A: Given the huge number of ingots made, it seems unlikely that it was a "very small fraction of the time." Furthermore, if you look at the fact that the badge is perpendicular to the floor and more or less to the source, the dose to the gonads is likely to be far greater than the recorded dose, even when some shielding is taken into account. Hence, even if the amount of time is small, the dose to the gonads is likely to be much greater than that recorded on the badge.

ORAUT/NIOSH: This issue may be addressed adequately in OCAS-TIB-013.

SC&A: A modeling of this problem using the ATTILA model that NIOSH used for Mallinckrodt would be useful and should be done for this job.

SC&A Action: Send the Mallinckrodt review reference to Mark.

ORAUT/NIOSH action: ORAUT/NIOSH will assess the geometry issue.

7. On page 22 of Vol. 6, NIOSH states that "Corrections to the FEMP-reported dose are required, due to uncertainties in the recorded data and lack of significant data, especially prior to 1980." How much pre-1980 data is missing? What happened to the individual external dose records for the pre-1980 period that caused a significant amount of data to be missing?

ORAUT/NIOSH: This is not about individual missing data, but about dosimeter response data, for which a correction is suggested.

SC&A: We seem to have misinterpreted the TBD statement as missing individual data.

ATTACHMENT 4: SITE EXPERT INTERVIEWS

Interviews were conducted with 48 former Fernald Environmental Management Project (FEMP), Department of Energy Ohio Field Office oversight personnel, and other individuals having knowledge of site operations. Years represented by those interviewed range from 1952-present. The interviews were conducted by Ed Sensintaffer and Kathryn Robertson-DeMers, members of the SC&A Fernald review team. The purpose of these interviews was to receive first-hand accounts of past radiological control and personnel monitoring practices at Fernald, and better understand how operations were conducted. Interviews were held in person from February 13–17, 2006. Interviewees were selected to represent a reasonable cross-section of production areas and job categories. Interviewees were originally obtained with the assistance of the DOE, the labor union, National Institute for Occupational Safety and Health (NIOSH) worker outreach meeting minutes, worker outreach groups and retiree organizations, and former health physics staff.

Workers were briefed on the purpose of the interviews and the FEMP Site Profile. They were asked to provide their names, in case there were follow-up questions. Participants were reminded that they would be provided the opportunity to review the interview summaries prior to inclusion into this report. Interviewees were told that there were aspects of operations that were classified and that this information could not be divulged. To ensure classified information has not been included in the interview notes, the notes were reviewed by a classification officer prior to release.

Former and current FEMP employees, and subcontractors interviewed worked in various operations throughout the site. Some of the facilities associated with their work included the Pilot Plant, Plant 2/3, Plant 4, Plant 5, Plant 7, Plant 8, Plant 9, the pit area, and the silos. Some individuals had access to all areas of the plant. The job categories represented included the following:

- Bioassay Laboratory Manager
- Carpenter
- Chemical Operator
- Construction Maintenance
- Construction Laborer
- Electrician
- Health and Safety Division Management
- Health Physicist
- Heavy Equipment Operator
- Inspector
- Laborer
- Laundry
- Machinist
- Millwright
- Pipefitter
- Production

- Radiation Monitor/Radiological Control Technician
- Radiological Engineer
- Security
- Shipping and Receiving
- Staff Engineer Environmental Monitoring
- Transportation
- Welder

The information the workers provided to SC&A has been invaluable in providing a working knowledge of the site operations and the safety program. All interviews have been documented and summarized below. This is not a verbatim discussion, but a summary of information from multiple interviews with many individuals. The information provided by the interviewees was based entirely on their personal experience with Fernald. It is recognized that site expert and former Fernald workers' recollections and statements may need to be further substantiated, however, they stand as critical operational feedback and reality reference checks. These interview summaries are provided in that context. FEMP site expert input is similarly reflected in our discussion. With the preceding qualifications in mind, this summary has contributed to our findings and observations.

General Information

The plant was divided into what was referred to as the Metal Area and the Chemical Area. The movement of the work force was dependent on the job responsibilities. There were individuals who worked throughout the site, as well as individuals who were assigned to a particular plant. At first, maintenance was assigned to cover a particular area. There was a maintenance pool located in Building 12. Eventually, maintenance personnel were used throughout the site. Transportation was deployed throughout the site. Chemical Operators tended to stay in an area, although they could bid on jobs in other areas to get reassigned to another plant. Operation-specific workers were more prone to stay in a single plant in the early years of operations.

Females were not originally allowed to work in the production areas, because Fernald did not have a fertile-female policy. In 1978 or 1979, a woman started work with the Transportation Department. In 1984, another woman went to work in waste treatment. The number of women in production areas increased through the 1980s. When a woman became aware of being pregnant, she advised Medical and was then sent to work on the "clean site."

Workers from Fernald were sent to other sites on occasion. For example, a contingent of six Fernald workers was sent to the Niagara Falls site to retrieve thorium. The thorium drums were not suitable for shipment, so the material had to be repacked (about 150–200 drums of material). Workers involved noticed differences between the RadCon program at FEMP and that at Niagara Falls, with Niagara Falls having the safer program. In addition, Fernald workers were sent to an area near the South Carolina and Georgia border to drum thorium packed material and ship it to Fernald. Two groups of six workers were sent to the area for about 3 weeks. There was a collaborative effort between Reactive Metals, Inc. (RMI), in Ashtabula, Ohio, and Fernald for a period of time. RMI extruded uranium metal billets for Fernald. Security personnel were sent to other DOE sites for training.

There was an abundant amount of overtime for employees that wished to work it. It was determined in accordance with company policy of the time. When an individual accepted overtime, he was required to work an additional 8 hours. Overtime was not broken into increments smaller than 8 hours for the hourly workers. During Uranyl Nitrate Hexahydrate (UNH) operations, work continued 12 hours per day during the week and 8 hours per day on Saturday and Sunday. The guidelines adopted by the union in the mid-1980s allowed an individual to work 2 shifts back to back and up to 84 hours in a week. The company violated this guideline at times. Prior to the 1980s, average overtime ranged from 15–25 hours per week. There was a slowdown in overtime during the 1980s; however, it picked up again during the cleanup, especially at the silos project. The salaried workers interviewed did not report working much overtime.

Operations personnel were under pressure to meet specific quotas. For example, site experts indicated that in the production area, they were required to make 100 derbies per shift. Once an individual met his quota, the individual could work at a more relaxed pace.

Security

National Lead Company of Ohio, Inc. (NLO), maintained tight security control during the production years. When NLO ran Fernald, Security worked under the prime contractor in support of the Atomic Energy Commission and later the Department of Energy. During the production years at Fernald, Security had a great deal of authority. In general, the rule was “Don’t Ask” related to processes and types of radioactive material, especially during the years of tight security.

When Fernald first started, there was a fence around each of the individual plants. Employees were required to have authorization to enter a particular plant. In 1961, there was a fence added and the area around the laboratory building became a controlled area. Access was allowed only to those individuals with a need to know. This was about the same time Fernald started to receive recycled uranium. Entrance could only be gained through a manned gate guarded by Security between the Pilot Plant and the Laboratory. The Chemical Warehouse and all production buildings had a 2-person rule. This stopped being enforced during the accelerated cleanup.

There were walking tours within the security fences, and driving tours of the perimeter. The guard would go to the guardhouse and pick up the clock key. For the east clock run, they were required to visit the garage (warehouse), Plant 4, Plant 6, Plant 9, the warehouse near Plant 9, the maintenance building, the service building, and finally the Administrative Building. Many of the plants had multiple Detex clocks that had to be punched. The west clock run covered the remainder of the Fernald site. During these tours, they were looking for evidence of access to unauthorized areas. Dust deposited on their uniforms as they completed their tours. Guards spent up to 5 days in the production areas per week. The off-shift worked the production area.

Security personnel were responsible for providing escorts for visitors and construction employees. The escortee had to be within sight of the Security Guard at all times. As an escort, they could go to any of the areas onsite. At times, escorting would be their only assignment for a week. When the plant first started, there was a requirement for two guards to escort personnel.

There were times during escorting when there were respirators used by production personnel; however, security was not required to wear it. They were not provided with escape respirators.

Security was involved in escorting trucks with incoming and outgoing materials. The truck was escorted onto the site to the building receiving the material. Security was required to verify the seals on the trucks as they came on and went off the Fernald site. They also verified that the paperwork was appropriate. There were a few incidents where the Bill of Lading did not match the material shipped. At times when transport vehicles were onsite, checking the vehicle was a part of their tour. Trucks delivering material came from all over the country. For shipments arriving by train, Security was required to meet the train at the gate, inspect the train cars, and ride the train onto the plant site. Security was not responsible for inventorying the material shipped to and from the site. In 1989, production was shut down and the emphasis at the site turned to remediation. Security no longer had to escort material onsite.

Security would report to the Security Building to obtain their assignment for the day. They then went to the locker room and changed into their uniform. Dosimeters were stored at the Security Building. They were required to wear their uniforms in the production area during their tours. They did not change into coveralls like other employees. The dosimeter was the only difference in their dress between the clean area and the production area. When they went into the production area, they wore a uniform plus a dosimeter. These same uniforms were also worn into clean areas of the plant. Whereas other plant staff had two pairs of shoes (one for the hot side and one for the cold side), security used a single pair of shoes for all areas of the site. They were not provided with shoe covers. Employees had a single locker to store their uniform in. When they were on duty, this is where they stored their personal clothing.

Security logbooks containing job assignments, information on material escorted, and information on events were maintained. Reports were issued for security infractions providing the details of the occurrence. These reports were maintained in a log by the lieutenant or sergeant.

All classified material had to be locked in a safe over night. If Security found a classified document not properly stored, Security Headquarters was notified and the document was confiscated. There were a lot of occurrences at first until the employees learned the consequences. Individuals were required to clean out their records on an annual basis. Classified documents that were no longer needed were put through a shredder. Confidential records and above were burned. Numbered classified documents had to be sent to Central Records when no longer needed. Once the stringent security controls on the site were lifted, there were only limited amounts of material destroyed.

Production Process

Belgium and African ore were received at Fernald starting in the 1950s. Production was responsible for receiving the raw material, which was transported in via railcar or truck. The material shipped by the railcars primarily came in drums. The cars were unloaded and empty containers were reloaded onto the cars. Some of the cars came in loaded with lime and decolite.

The Pilot Plant was used for numerous evaluations and experimental tests. Evaluations included areas such as refinery operations, hexafluoride reduction, derby pickling, and ingot casting. This plant also housed equipment used for other purposes. This plant was used to produce derbies prior to Plant 5 being constructed. Derbies were produced by reducing UF_4 green salt with finely granulated magnesium metal. Most green salt was produced by the refining process versus by UF_6 reduction. The UF_6 reduction process occurred at Fernald until it was taken over by other DOE sites. It involved vaporization of solid UF_6 to produce gaseous UF_6, and reduction of UF_6 to UF_4. Thorium production activities started in the Pilot Plant in 1964 and continued until 1980.

Ore was conveyed to Plant 2/3. This plant was responsible for conversion of uranium material to uranium trioxide, UO_3, or orange oxide. Material was dissolved in nitric acid to produce UNH. UNH was purified and separated from impurities (i.e., raffinate). The UNH was stored for further processing. The solution was boiled down to a concentrate and under went denitrification, converting the material to orange oxide. The orange oxide was removed with a manual suction process known as gulping. The operators did not like to participate in gulping, because it involved heavy labor, work in elevated temperatures, and exposure to fumes. They reported that respirators were not commonly used during this process. Scraps and residues created by the process included metal oxides and radium-bearing sludge.

The orange oxide was transported to Plant 4 using mobile hoppers. At times, Fernald received orange oxide from offsite. UO_3 was converted to uranium tetrafluoride, UF_4, or green salt by reduction and hydrofluorination. The green salt came out in a hopper and was packaged in 100–250 lb cans to be sent to Plant 5. The processes used in Plant 4 involved very high temperatures.

Plant 5 reduced UF_4 to high purity derbies through a process called reduction. Green salt was blended with magnesium metal granules and the charge put into a magnesium fluoride-lined reactor vessel (the charge was also referred to as a bomb). The lining process was referred to as "jolting." The bomb was capped and the lid was bolted on. It was then placed in a Rockwell Furnace and heated to 1400° for approximately 1.5 hours. The bomb remained in the furnace until it had fired. The operators could observe this on a watt meter. The material was allowed to cool. The contents of the bomb were dumped out, and the derby was separated from the MgF_2 and byproducts using manual and mechanical processes. The MgF_2 would have to be chipped off the derby with chisels and hammers, or cleaned with wire brushes. The slag was fed into chutes and recycled. Once separated, the derby was weighed, labeled, and stored on skids until needed. The derbies and scrap metal were melted in crucibles and cast into ingots for shipment to Plant 6.

Difficulties the operators encountered in the Plant 5 process included frequent blow-outs, where a hole would develop in the lid or bottom of the bomb during the firing. The blow-outs resulted in evacuation of the area and sometimes occurred as often as two to three times per shift. Also, during the removal of the derbies, the slag chutes would become plugged. To unplug these chutes, operations would have to use jackhammers and/or manually remove the material.

Plant 6 was responsible for the production of slugs from ingots. The uranium ingots were passed through a blooming mill to produce billets and sheared. The billets were reduced to the final rod dimensions, depending on where the rod was to be used. Some of the machines used in this area included shears, straighteners, automatic screw machines, centerless grinders, lathes, J-L machines, chaffers, cross machines, and rapid boring machines. Initially, the J-L machine was the only self-contained machine in the foundry area. The cast uranium ingots were treated in a neutral salt (NuSal) bath to harden the material. The NuSal bath contained potassium carbonate and lithium carbonate, and were heated to approximately 1300° F. The metal was pickled, and machining chips and tailings compressed into briquettes. If not adequately covered with water and solvents, the chips and sometimes chunks of uranium would catch on fire. The product was then sent to the Inspection Department, where it was inspected for pits, seams, dimensions, and handling defects. Ultrasound testing was used to check for flaws under the surface. If the slug was good, it was packaged for shipment. These machines required a lot of preventive maintenance internal to the units.

Plant 7 operated from 1954–1956 and was shut down in 1956. The plant was responsible for converting UF_6 into UF_4, which was used at Plant 5. There was a high demand for uranium metal during this period. The UF_6 was provided to Fernald by the gaseous diffusion plant at Paducah. This process supplemented the production of UF_4. Other Fernald plants were modified to increase production of UF_4, so Plant 7 was no longer needed. After shutdown, the area was used to store enriched uranium and as a maintenance shop.

Plant 8 received the bomb reduction liner material from Plant 5 in hoppers. It was emptied at an unloading station and moved to a surge hopper through a jaw crusher. The material was fed into an oxidation furnace where the metallic uranium was converted to black oxide (U_3O_8). The material was further ground and fed into digestion tanks, where it was dissolved in hydrochloric acid. The undissolved solids were filtered out and sent to the scrap dump. The uranium filtrate was sent to a precipitation tank, where it was converted to uranyl ammonium phosphate (UAP). The UAP was dried and sent to the refinery. The recovery process was eventually changed to produce ammonium di-uranate.

Plant 9 produced derbies, ingots, slugs, and washers of various enrichments. With the exception of the washer production, the operations were similar to those in Plant 5 and Plant 6. The plant also had a process for chemically decladding unirradiated fabricated fuel elements. In about 1955, Plant 9 was involved in making thorium metal. The thorium started as crystals and created high quality thorium oxide. This was shipped to Hanford and Bettis. The west side of Plant 9 was considered the thorium or chemical processing area. The east side was where the machining operations took place. There was a large incinerator outside to the southwest used to burn chips and tailings.

The raffinate was sent to the Hot Raffinate Building, where it went through a process to separate the Ra-226 and uranium. Hot barium sulfate was used as a precipitate. Portions containing radium and uranium were drummed and sent out. Some of the filter cake slurry was pumped out to Silos 1 and 2.

Remediation/Waste

The U.S. government obtained ore from the Belgium Congo for use at Fernald. The ore belonged to Belgium, who had planned to extract radium and precious metals from the waste stream. An agreement was eventually made between the Belgium and U.S. governments for Fernald to take on the responsibility for the waste.

Operable Unit 3 (OU3) was the Environmental Protection Agency's designation for the former production area at Fernald. Chips and paint were the primary samples collected from OU3 structures for characterization. The general approach to sampling remedial action sites is to survey and find the highest amount of activity. The sample was taken from this area. The raffinate stream was characterized in the mid-1980s. Analyses included evaluation of transuranics. The raffinate was pumped from the process area into Pit 5 for disposal. These waste pits were also characterized.

The site maintained six engineered pits. Pits 1–3 were really one pit. Materials were either pumped to the pits or transported by truck out to the pits and dumped in. All sorts of material, including slurries, solid waste, depleted uranium, etc., were added to the pits. During the remediation of the pits, derbies, ingots, graphite molds, and other radioactive materials were found. The uranium chips would periodically catch on fire.

Remediation of the pits involved pulling the water off, removing the contents to a predetermined depth, and performing soil sample analysis. If the soil samples did not meet the cleanup criteria, additional digging was required. During remediation, there were general assumptions made about what each pit contained. Pits 1–4 and Pit 6 contained U-238, debris, small pieces of metal, crucibles, cold traps, drums, building material, bags of asbestos, and other garbage from the production areas. Some of the radioactive material found in the pits was in pure form. Pit 5 contained raffinates. There was a Burn Pit at Fernald, which was used to burn just about anything. Residue still remained in the pit until it was remediated. A berm was built from the west side of Pit 3 to the Burn Pit, but the berms were not well defined.

The Clear Well Pit was used to decant water from the waste pits and other areas of the site. It was essentially used as a settling pond. This pit contained any radionuclide found onsite. Water was processed out and eventually released. During remediation, 30 feet of sludge was found in this pit. On the east side of the site, radium ash that had settled out from the Sewage Treatment Center was found.

There were areas of the site that were expected to be clean that were found contaminated during remediation. For example, during excavation in the former Administration area of the site, air sample results showed up 850,000 times the permissible limit. There was a holdup of radioactive material in the piping and ductwork, including thorium in the process piping at the Pilot Plant, black oxide in ducts at Plant 5, radioactive material in the duct work in the Administrative Building, radioactive material in the ventilation ducts and the dishwasher vent stack in the cafeteria area, and dried UNH in pipe alley.

The Plant 1 Storage Pads, located outside, held about 125,000–180,000 drums in 1989. The outdoor environment would sometimes cause the drums to rot. At times, the bottom would fall out of the drums. Many drums required overpacking. Other plants also had storage areas.

Construction Trades

Several of the construction trade personnel were temporarily assigned by their company to Fernald. Many of them left and returned several times. They provided construction and demolition support for the Fernald contract, as defined under the Davis-Bacon Agreement.

Maintenance and similar support services were provided by onsite employees. The construction trades were involved in activities site wide. Some of the construction trade jobs included the following:

(1) Removal and installation of asbestos and insulation from buildings

(2) Construction of railroad tracks to support K-65-related work

(3) Building demolition, including removal of hoods, flooring, walls, dust collectors, ductwork, tanks, furnaces, etc. (Plant 1, Plant 2/3, Plant 5, Plant 6, Plant 8, the Administration Building, the Production Laboratory, etc.)

(4) Transfer Tank Area (TTA) Remediation

(5) Pouring concrete

(6) Removal of brick and piping in pipe alley

(7) Equipment setup and take down (e.g., scaffolding)

(8) Removal of the Old Tank Farms

(9) Building the airlock for the thorium overpacking project

(10) Soil remediation throughout the site, including remediation of Silos 1 and 2

(11) Waste pit drudging and other related work

(12) Labor support

(13) Installation or renovation of areas within production buildings

(14) Installation of the Bentonite on the silos

Construction trades workers moved from site to site as work became available. Some of the other DOE and Atomic Weapons Employers facilities that site experts worked at included Portsmouth Gaseous Diffusion Plant (Piketon), the Mound Plant, and the General Electric Evendale Plant. As subcontractors moved around the complex, they noticed the differences in radiological control implementation at the various sites. For example, Piketon implemented Personnel Contamination Monitors (PCMs) prior to Fernald.

Tools used at the facility were surveyed by Fire and Safety and sometimes confiscated, due to contamination. This was especially true of wood-handled tools.

Radiological Hazards

The radiological hazards associated with the plants are summarized below.

Plant or Building	Concerns for Field Radiological Control
Plant 1 (Ore Assay and Milling)	All uranium isotopes, Ra-226, beryllium
Pilot Plant (Ore Silos)	Th-230-contaminated material, enriched uranium, handled Paducah material
Pilot Plant Annex	U-238
Plant 2/3	Uranium ore, Ra-226, and Th-230 in the raffinate stream
East End Plant 2/3	U-238
Plant 4	Natural uranium, depleted uranium, and enriched uranium, UF_4
Plant 5 (Metals Production Plant)	NU and DU, beryllium
Plant 6	Uranium and thorium-contaminated material and furnaces
Plant 8 (Recycle Plant)	Uranium (all isotopes) and Th-230
Plant 9 (Special Projects Plant)	EU metal, thorium metal, beryllium
Building 54A	U-238, depleted uranium
Building 13A	U-238, U-235, Th-230, Th-232, trace contaminants of Pu-238, Pu-239, Pu-241
Building 64	Thorium storage
Building 65	Thorium storage
Building 61 (Quonset Hut 2)	ThO_2
Quonset Hut 1 (Q-1)	Thorium storage after overpack
Building 67	Thorium storage
Building 68	Thorium storage
Building 69	Decontamination Facility - Uranium, Th-230
Silo 1	Rn, Th-230, Ra-226 (full list is on EDESK)
Silo 3	Th-230 + D, Ra-226 + D
Pits including Burn Pit and Clean Well	U-238, derbies, small pieces of metal
Pit 5	Raffinates; Th-230

Fernald had real-time radiography devices. There was a Co-60 source kept in a vault in the south warehouse of the Pilot Plant. This system was complete with interlocks. In the 1980s, additional soil had to be dumped and distributed around a portion of the building to increase shielding. The source had been in place long before this was done. There were also Phillips Constant Potential X-ray Units used for drum inspections. These units were used in an interlocked area. The integrity of welds was routinely checked with dyes or by visual inspection. When x-rays of welds were required, the objects were sent to the drum inspection booth in the Plant 1 Chemical Warehouse.

Red drums and black drums were stored separately. In the warehouse, small cylinders of material were stored on a wooden pallet. These cylinders were red and were spaced appropriately to prevent a criticality. Security personnel remember seeing Fissile Material signs associated with this material.

Chemical Operators had a wide variety of responsibilities. Some of the high-exposure jobs included manning the dumping stations, cleaning equipment (i.e., dust collectors, reduction pots, crucibles, furnaces, reaction vessels, etc.), inventorying the rabbit hutches, and decontaminating areas when needed. Graphite molds were cleaned with a broom handle and steel wool. After the removal of the MgF_2 from the uranium, individuals would stick their heads down as far as they could to clean the slag out of the pot. During this operation, there was no respiratory protection worn. These job responsibilities provided opportunities for exposure to high concentrations of radioactive material. A Chemical Laborer performed the same type of jobs, and was in training to become a Chemical Operator.

There were both building-specific maintenance crews and a general maintenance pool. The general maintenance pool could be sent anywhere on the Fernald site. Although an individual may be assigned to a particular plant, he may be assigned to another plant during overtime. There were shop areas near the production buildings and a central shop area for handling maintenance on equipment. There were areas in the plants accessed by maintenance that were not routinely occupied (e.g., tanks, entry into pots). Contamination was present in these areas.

Tools in the production area were generally contaminated. Some maintenance workers had "hot-side tools" and "cold-side tools." Maintenance personnel also had tool boxes, which they took from area to area. When they started to monitor tools in these tool boxes, they were found to be contaminated.

Laborers stamped the cores, shipped materials on conveyors, packaged products, and loaded transport vehicles. They had to strap the material down, bringing them in close proximity to uranium. Supervisors, clerks, and administrative support personnel had offices in the production area. The ventilation system in production buildings was recirculated air, potentially exposing those in the administrative areas of the building. The offices tended to be dusty. A clerk was responsible for tracking the uranium as it was received and shipped.

Transportation Labor was responsible for a wide range of duties, including unloading rail cars, hauling waste to the disposal pits, transporting material (e.g., samples, orange oxide, green salt, uranium metal, molds, drums, etc.) between plants with fork trucks and tow motors, and loading and banding offsite shipments of ingots, slugs, and derbies. When using the Tow Motor, the drums were not always secured adequately, so the drums would fall off and break open. This was a fairly routine occurrence. When transporting red drums, a Radiological Control Technician (RCT) had to accompany the Tow Motor operator.

Uranium Characteristic

Enriched uranium, depleted uranium, and natural uranium were all handled. The maximum allowed enrichment at the site was <20% U-235. Small quantities of enriched uranium (>1%) were stored in red drums. This material was used as a sweetener to increase the enrichment in the product. Standard production was 0.95% and 1.25% for Hanford. Special production orders for higher enrichments were made for other facilities, as requested and approved by DOE. The feed uranium compounds sent to Fernald were not chemically pure. Fernald products, however, were of excellent purity in order to meet strict requirements of the managers of the AEC production reactors at various sites throughout the U.S. The product was evaluated by the collection of samples from the process stream.

Fernald also received materials from the Savannah River Site (SRS), Hanford, Paducah Gaseous Diffusion Plant (Paducah), and Y-12 Plant in various forms. Fernald was responsible for taking the intermediate product and creating a final product. Cores returned from SRS came back containing crystallized material. Fernald became the repository for surplus uranium. They stored cladded uranium carbide and uranium alloys.

The chemical forms of uranium handled at Fernald included uranium ore, UO_3 (orange oxide), U_3O_8 (black oxide), UF_6 (uranium hexafluoride), UF_4 (green salt), diuranates (e.g., calcium or ammonium diuranate), UNH, UO_2 (brown oxide), and uranium metal. The oxides were extremely insoluble.

The Fernald site did not process U-233 or have it in pure form in any production processes. It was present in trace amounts in some of the uranium or thorium feeds. If present in thorium feeds, the concentration of U-233 could have increased in extraction liquids reused in the Pilot Plant. Material Accountablity kept track of the quantity of U-233 onsite.

Recycled uranium introduced fission products and transuranics to the site. Fernald was not authorized and not set up to process plutonium materials. Trace amounts of plutonium (<10 ppb) were found in recycled uranium processed at the site, especially green salt. The Fernald process was not designed to handle plutonium. Engineering controls were based on uranium hazards and dust. There was plutonium embedded in the uranium that went airborne. The T-hopper operation filtration created a situation where there was a plutonium buildup. Plutonium Out of Specifications (POOS) was received and stored at Fernald for a period of time. NLO, Inc., did not attempt to maintain accountability for this material. Analyses for plutonium were made only on special occasions when the specific receipts of recycle material warranted such analyses.

Thorium

Thorium was associated with the Pilot Plant, Plant 9, the storage warehouses (Buildings 64 and 65), Building 61, and some raffinate streams. Plant 9 was referred to as the Thorium Plant from the initiation of its operations. If this accurately described the operations in the plant, thorium work was probably here from the beginning of operations. Building 61 (Quonset Hut 2) was a storage area for ThO_2 sintering and machining slugs. Fernald became the Thorium Repository and had the largest inventory of thorium in the United States at one time.

Chemical forms of thorium handled at Fernald included ThO_2 (light oxide), ThF_4 crystals and solution, $Th(OH)_2$ (sol gel); ThC_2O_4 (oxalate), thorium nitrate tetrahydrate, and thorium metal. There was high-fired thorium oxide created in the processes. Thorium gel was shipped in via railroad and pumped to the Pilot Plant when thorium operations were underway.

Most of the stored thorium was located in Building 64 in white drums with blue rings. Site experts indicated the drums had noble gas labels on the outside. These drums eventually deteriorated and white powder, similar to soap powder, was seeping out of a subset of these drums. An over-packing campaign was initiated in the early 1990s to place the disintegrating drums into burial boxes. The drums were dropped into a burial box and a lid bolted on the box. Cleanup of the loose thorium powder was also done. This campaign involved over 5600 drums. The thorium redrumming project involved remote handling of material with the use of fork lifts to put lids on the overpack containers. The Co-60 vault was also used for thorium storage.

Radon

There were roughly 4,000 grams of radium placed in the silos. This equates to 4,000 Ci, plus a similar amount of each of the daughters. This was the largest concentration of radium in the country. The majority of this radium was included in the K-65 residue; however, it is distributed throughout the silos.

Health and Safety (H&S) was aware of the radon and thoron issues from very early on. Radon measurements were initiated for the dumping of drums in the 1950s, although the measurements were not routinely collected until much later. Radon monitoring started with the development of electronic radon monitoring devices. Eberline radon instruments (WLM-2s) with scintillation tubes were used at Fernald field radon measurements. If there was an inversion, this would cause issues because of the increase in ambient radon present. Later, E-perms and eventually Track-Etch detectors were placed around the silos for radon monitoring.

Individual radon monitoring was done on a job-specific basis and not on a routine basis during the time Westinghouse was the contractor. Time-motion studies were done in the 1990s corresponding to Radon Measurements. The working level (WL) unit was implemented in the later years at Fernald.

When individuals had to take samples or enter the silos, a glove bag was used to control exposure. The manhole on the top of the silo is opened and the sample is taken through the in and out port. There were attempts to measure radon in the glove bags, but these were not successful.

The Communication Center received real-time radon concentration data. If this exceeded a trigger point (100 pCi/Liter), Security made an announcement asking individuals to stay indoors. A technician was dispatched to the area to verify the conditions. These announcements didn’t typically occur during the workday. This was a more current practice and did not occur in the 1950s, 1960s, 1970s, and 1980s.

The Radon Treatment System (RTS) was engineered to lower the radon levels in and around the silos. The system was composed of a large charcoal bed, PVC piping, and a fan. The idea was to blow the radon back into the silos. Significant gamma dose rates were measured at the charcoal filter of this system. Shielding was used to minimize exposure to the daughters.

A Radon Control System (RCS) was put online during the remediation of Silos 1 and 2. The function of the system was collection of radon gas to reduce exposures. The systems in the mixer rooms of the treatment facility would become plugged, and they had to be unplugged. It was difficult to tell where the collection line was plugged, because there was no sensing equipment on the mixer line. The sensors available on the system would indicate everything was okay if at least one line was clear. Entry into this area resulted in exposures to radon gas.

Radon cups were placed on the fence line to monitor radon concentration. This began around 1987 or 1988. The track-etch cups were changed out quarterly, and above background annual averages were noted at several locations near the K-65 Silos.

There were two aerial surveys done at Fernald by EG&G. There was detectable gamma shine from the silos. Prior to 1986, the cloud of radon drifting from the silo area could be identified.

General Radiological Control

When Fernald began operation, the Health and Safety Division (H&S) included the Medical Department, the Industrial Hygiene and Radiation Department (IH&R), and the Fire Protection and Safety Department. Later, the Bioassay Laboratory Department was added. The first manager of the NLO H&S department was Dr. Joseph Quigley. He was working with the AEC, and was asked by the AEC to take the job as division manager and set up the health and safety functions at the new plant. The bioassay laboratory was also a part of the H&S Division. In 1958, the site formed a Criticality Safety Department that was added to the H&S Division. The Fernald budget was based on the tons of material produced by the site. Although the budget was as high as 50 million dollars, limited funds were dedicated to safety.

The current Radiological Control Organization consists of a field group matrixed to the projects and a central Radiological Control group that handles the programmatic implementation of the program. The field was matrixed to the project starting in about 1996.

With the implementation of DOE Order 5480.11, the Radiological Control Program became more formalized and the Radiological Organization became centralized. When Westinghouse arrived, there was more communication with the workers and the public in relation to operations and safety hazards. The Radiological Control Program was generally improved. Following their release, Fernald implemented the DOE Radiological Control Manual and 10 CFR 835.

Training primarily consisted of safety meetings held once a month during the NLO era. Workers reported that the meetings did not always focus on safety issues. With the change of contractors to Westinghouse, the first formal radiological worker training was implemented. There were two levels of Radiation Workers (Rad Workers) when the formalized training program was implemented; Rad Worker I and Rad Worker II. Rad Worker I was for workers who had a potential for exposure <2% Derived Air Concentration for U-238. These individuals were exempt from bioassay. Rad Worker II-qualified individuals had the potential to exceed this level and were required to participate in the bioassay program.

Operating procedures contained safety requirements. The procedural requirements were determined by production (process steps) and H&S (safety requirements).

During the NLO time period, there were less than 10 H&S technicians onsite. Initially the technicians served the entire plant. As more technicians were hired, they were assigned to particular areas. The early technicians were responsible for environmental monitoring, industrial hygiene, radiological control, and fire and safety. There was a shortage of technicians, making it difficult to cover both routine work and incident response. In the 1980s, the site started hiring more RCTs. Both project-specific support groups and a site-wide routines group were initiated.

When Westinghouse took over the Fernald site, they brought in more RCTs. All RCTs became subcontractors in February 2005, providing full coverage for all radiological areas. The increase in technician staff occurred in the 1990s after production had shut down and the site's mission changed to environmental cleanup.

Posting

Historically, contamination areas were designated as Zone 1, Zone 2, or Zone 3 prior to the current posting requirements. Zone 1 had the least amount of contamination, while Zone 3 had the most contamination. There were additions and changes to postings starting in about the mid-1980s. Workers started noticing an extensive increase in postings. The high-radiation areas included RTR, Building 65, the area around the dosimeter calibration source, parts of the RCS, parts of the TTA, and historically the silo domes. These locations were posted as a High Contamination Area, an Airborne Radiation Area, and a High Radiation Area. High-radiation logs are maintained.

Engineering and Administrative Controls

The principal engineering control for dust was to use dust collectors or scrubbers to ventilate an operation, and to remove dust before discharging the air out a plant stack. Dust of all sizes was collected; the efficiency for collecting large particles was greater than the efficiency for collecting smaller particles. A great deal of information about actual dust size in stack effluents is available in Fernald records.

Dust collectors were changed when there was a change in the differential pressure or an indication that they were plugged. The bag house contained several bags with a blow ring connected to a vacuum hose. The material passing from the dust collector went into a hopper and then into a drum. Originally, the bags for the dust collectors were made of wool. Teflon eventually replaced wool. This was not very effective, and the seams had to be caulked so they would not leak as much. To replace the bags, the blow ring was removed and the 100-lbs bag was dropped in. During the replacement of the bags, the Chemical Operators would clean the hoppers. For this job, the individual would wear an extra pair of coveralls, but prior to about 1978, they were not using respiratory protection.

Portable shielding was used in the Rockwell Furnace area of the reduction process starting in about the 1960s. Heavy rubber mats were also used to reduce external exposure starting in about the 1960s. Additional shielding was added to the process area in the early 1980s, due to a ramp-up of production at this time.

Several materials were tested as dust collectors to see which would hold up to collection of particulates best. Virgin wool was determined to work most efficiently. The particles deposited in the bags had sharp edges and would damage the bags over time. With significant damage, the dust bags would rupture and material was released from the stack. A lot of the released material deposited on the roof or the ground near the plant. There were two methods to identify reduced efficiency in the dust collectors. First, there was a differential pressure gauge, which was monitored by operations. When the differential pressure was outside acceptable limits, the dust collector was changed. Second, there was stack monitoring with an audible alarm to alert personnel to releases.

Prior to the addition of Bentonite to the silos, a layer of bentonite 2–4 ft thick was added on top of Silo material in about 1991 to prevent radon from escaping through cracks. Prior to this, there were dose rates above 100 mrem/hour. Personnel would burn out when working in the silo areas. After the Bentonite was added, the dose rates dropped to approximately 10 mrem/hour. There were some concerns that the material would lose its effectiveness as the bentonite dried over time.

Starting with the arrival of Westinghouse, there were concerns about overexposure. They implemented a system where an employee was allowed to work a set amount of time per week on a particular job. The time limits were determined from dose rate measurements taken by a Radiation Monitor. When working on two jobs, the time limit for the second job may have to be reduced due to exposure received on the first job. For example, if an individual worked on a job where he received 50% of his allotted exposure, and the second job allowed him to work 20 hours per week, he would have to reduce his time to 10 hours per week. It was the employee's responsibility to keep track of the time limits. There were some individuals who didn't know how to recalculate time limits as they went on to other jobs. Supervisors kept a daily log of work tickets each day. Although they collected the information, there was no formal review of this data. The time restrictions were assigned by job tasks. There was no policing of the time limits set for particular jobs. If an individual was not done with a job, he may keep working until it was completed. Time limits ranged from minutes to days per week on a particular job.

Radiation Work Permits

There were job-specific permits prepared by the IH&R Technicians. If it was felt a job was high risk (e.g., changing out dust bags), a technician would perform a survey and determine time limits for the particular job. These time limits were based on skin dose exposure most of the time. The original permits did not specify protective clothing or bioassay requirements. Respiratory Protection was specified for each task.

Westinghouse initiated the modern version of the Radiological Work Permit (RWP). RWPs were implemented with the issuance of DOE 5480.11. Technicians prepared RWPs on a daily basis. Once per week, the RWPs were rewritten. Supervisors approved the RWPs. The older RWPs were similar to a fire permit. Requirements were based on process knowledge. Areas within the plants required RWPs; however, there was no RWP for general access. In about December of 1992, Work Planning and Radiological Compliance took over the responsibility for RWP preparation. Procedures for RWPs outlined the requirements for RWP issuance. Sign-in sheets were adopted in later years.

Field Instruments

Portable survey instruments that have been used at FEMP include the following:

- Ludlum Model 3 with beta/gamma pancake probes
- Ludlum Model 12 with ZnS
- Ludlum Model 2221 with ZnS in Scalar mode
- Eberline RO-20 Ion Chambers
- Bicron Micro-Rem Meters
- AP2 Radon Discriminator – PIP's detector by SAIC
- HP-210 Frisker Probe
- Portable Working Level Instrument

For the Silos Project, the release criteria were set at 20 dpm/100 cm^2 alpha. Smears were counted on a Ludlum 2221 Desktop Scaler for 5 minutes. The minimum detectable activity for this count is 8 dpm. In the calculation of activity, an area correction factor is applied.

Prior to the early to mid-1980s, there was no particular survey frequency. Routine surveys were first adopted for administrative areas and break rooms. Neutron surveys were started in 4B, due to a request from a DOE Facility Representative. In 1995–1996, a study proved that there was no neutron hazard at the plant. There were criticality specifications implemented to prevent criticality accidents, and criticality safety alarms were present at Fernald.

Air Monitoring

Richard Heatherton was working for Health and Safety Laboratory (HASL) when he was asked to take the position of Manager of the Industrial Hygiene Department at the same time that Dr. Quigley was asked to become the H&S Division Director. Other HASL employees were sent, on loan, to Fernald, and they did much of the initial air monitoring as new operations were tested in the Pilot Plant or brought online. Dust studies of the various plants and jobs within those plants were conducted in the 1950s and 1960s, including Breathing Zone (BZ) and General Area (GA) sampling. Breathing zone air samples were taken based on the methodology implemented at HASL. This is not the same type of sampling as the current day Personal Air Sampler. Radiological Control concentrated their studies primarily on the Chemical Operations, because they were believed to have the highest potential for exposure. Generally, three samples were taken per task. The early method for collecting breathing zone samples consisted of holding an air sample pump with a 1" diameter filter paper as close to the nose of the worker as possible. Later, tubing was used draped over the shoulder and positioned at the lapel. The technician would follow the individual around with a stop watch to capture the exposure from each task. This included walking to the cafeteria. These types of annual air studies were discontinued in about 1968. Formal reports of these dust studies were issued. There was no routine air sampling in the 1950s throughout the facility.

After the reduction in force in the 1970s, air sampling decreased. In 1989, Extensive Air Monitoring Plans were developed. Air sampling increased again in the 1980s, and was extensively used in the 1990s during the remediation of the site. About 1,000 BZ air samples were processed per month. The primary method for detection of isotopes other than uranium was BZ air sampling. The air sampling was used instead of bioassay sampling. One hundred percent of the thorium workers wore BZ air samplers. Derived Air Concentration-hour tracking was implemented at Fernald with the extensive use of BZ monitoring in the 1990s. Air samples underwent a gross alpha/beta count, and if they were elevated, alpha spectroscopy was performed to identify the radionuclide of concern. There was a Personnel Air Sampling Card (Form 602-10-25) used to record internal exposure.

In 1994, Field Radiological Control attempted to do a 12-hour, 24-hour, and 7-day decay count on air filters. An extrapolation was done on the initial counts to determine if there were issues. The filters would then be decayed up to 14 days and counted again. The counting responsibility was centralized, and air samples were forwarded to the Centralized Air Sample Counting group. Prior to this, samples were counted in the area and then results were forwarded to the Central group.

The air monitoring program was required to support the internal dosimetry program. The internal dosimetry program requires 25% personnel air sampling use. This is described in the site Internal Dosimetry Technical Basis Document.

Contamination Control

Contamination control in the production areas was poor. At Fernald, it was common to see green salt, yellow cake, and black oxide on the floor in the production areas or on the plant road. Even though the floor was scrubbed once per shift, it was difficult to clean out the nooks and crannies. Releases and spills from equipment occurred routinely. Spills were commonly cleaned up with brooms. Operations in Fernald plants created a great deal of dust in the area. The production area was divided into a “hot side” and a “cold side.” There were administrative offices in the production areas.

When individuals came to work, they came through the turnstiles, went to the locker room and put on company-issued coveralls and cloth caps, and went to work. At lunch time, employees showered and put on clean clothes. Workers had one pair of shoes that were to be worn in the production area, and another pair to be used in the clean areas. Contaminated shoes were worn into the clean areas (blue areas) of the site. After the work day was over, workers were just required to shower and change clothes before leaving the production areas. Prior to Westinghouse, there were no Radiation Monitors or monitoring machines around to determine if an individual had picked up contamination. Visitors were provided with smocks and shoe covers when entering the production areas. In later years, Personal Protective Equipment (PPE) ranged from none up to Level A protection. The Level A suits were wiped down and reused. PPE requirements were consistent for workers in the same immediate area by plan, but not necessarily enforced.

The company cut the sleeves off the coveralls at one point, leaving their arms bare. Radiological Control found out about this practice and was not pleased. The company could not retrieve the sleeves to have them sewn back on. All these coveralls had to be disposed of and new coveralls procured.

The contamination monitoring improved when Westinghouse took over the site. Hand and foot monitors were introduced in some areas in the late 1980s/early 1990s. These units were not available in all areas. Fernald implemented hand and foot monitors around 1987. Hand and foot monitors were on the clean side of the change room. Personnel Contamination Monitors (PCMs) were put into service about 18 months later. PCMs were stationed at the doors in the locker room. PCMs were on the dirty side of the shower (process area to the service building). The alarm set points were based on the uranium contamination limits on the dirty side. The PCM count times were calculated based on the background radiation, and were determined automatically by the instrument. This made sure the count time was long enough to detect the prescribed alarm limit. There were daily occurrences of external contamination from radon with the initiation of egress monitoring. This was especially true when thermal inversions occurred. The individual was recounted after the radon was allowed to decay. They now use Passivated Implanted Planar Silicon detectors with energy discrimination set >5 MeV for monitoring.

Laundry collected coveralls twice a day. The coveralls were often contaminated with orange oxide, green salt, black oxide, and yellow cake, exposing these workers to radioactive material. These individuals were not required to use respiratory protection. Site experts recollect that there was no airborne monitoring in the laundry area.

Respiratory protection was optional in most cases, and use was intermittent. Initially, half-mask respirators were used. Respirators and/or filters were used more than once. Maintenance, operations, and others would wear their respirators around the neck. Frequently there was visible dust (e.g., green salt) on the respirator. Some individuals put Chem Wipes in the face piece of the respirator until the respirator was needed. When they were ready to use the respirator, they removed the Chem Wipes and donned the respirator. Other individuals just blew their respirators out prior to putting them on. Respirators were carried around in pouches or stored in lockers. It was also common in the early days to hang respirators on the machinery in case they were needed. Respiratory protection was not supplied to all areas. Prior to the implementation of a formal respiratory protection program, some individuals had respirators with a poor fit.

It was common to use respiratory protection to reduce chemical exposure potential. For example, during the removal of radioactive asbestos in the laboratory, an airline respirator was used. Initially, the subcontractors had to supply their own respirators. Other respirators used included full-face respirators (starting in the late 1980s) and Positive Air Purifying Respirators. Initially, there was a multiple-use policy for respirators. It was not uncommon to wear a respirator around the neck in production areas, so it could be slipped on as needed for a particular job. Personnel would simply rinse the respirators out. Respirator surveys were not implemented at the time. In 1989, a single-use policy was adopted for respiratory protection use.

In general, respirators were required during dusty conditions, such as drum dumping and certain maintenance activities (e.g., dust bag changes). It was up to the supervisors to enforce the wearing of respirators. In the case of the thorium overpacking, personnel wore a full-face respirator, a single set of Anti-Contamination clothing (Anti-Cs), and pencils. No respiratory protection was used during the reduction, gulping, cleaning of graphite molds, and machining. Machinists were not required to use respiratory protection, and were prone to exceeding monitoring action levels. Site experts noted that with the same operations where a respirator was not used before, respirators were all of the sudden required. The change seemed to correspond to the arrival of Westinghouse.

Historically, workers were instructed not to eat in the process areas. Some individuals disregarded these instructions and ate there anyway. This was identified by the RCTs as a big issue in the early years. Personnel were allowed to drink water in the area. In fact, there were multiple drinking fountains available. Personnel would chew tobacco or gum in the area. Smoking was allowed in the smoking areas set up in the production areas during NLO management. Employees were supposed to shower before lunch and change into their personal clothing. There was no requirement to shower prior to breaks. As a result, contamination was brought into the break rooms. Facility drinking water came from a deep aquifer of the groundwater. Both the shallow aquifer and the final drinking water were tested for contamination. Eating, drinking, and smoking were not allowed in contamination areas, high-contamination areas, radiation areas, and high-radiation areas after implementation of formal Radiological Control Requirements (e.g., 10 CFR 835).

Truck drivers delivered brickets to the West Coast from Fernald. They would also retrieve empty containers on their way back to Fernald. There was a team of two drivers in the truck. Dose rate measurements were not routinely made in the cab area. Drivers were not directed to wear their dosimeters during transportation. The truck had Radioactive Material placards.

External Dosimetry

Initially, all personnel were assigned a dosimeter. The security and dosimetry badge were separate at the beginning of operations. In approximately 1960, the badges were merged, and everyone on site was monitored. At this time, the badge contained high-dose film, low-dose film, sulfur, and foils. Late in the 1980s, they started separating the dosimeter and security badge. During the period of time when the security credential was merged with the dosimeter, all personnel were monitored for external exposure. When the dosimeter and security credential were separated, all individuals entering the process area were required to wear a dosimeter. Dosimeters were required for the process areas; however, they were not required for the blue areas. With the implementation of 10 CFR 835, anyone who entered a posted area was assigned a dosimeter. If the area was 50 microrem per hour or greater, an area was posted with an insert indicating that a TLD was required.

Dosimeters were taken home during some time periods and stored onsite for other periods. During the 1950s, the security badge was turned into security as an individual went through the turnstile. The employee received an identification card, which he/she would exchange in the morning for their security badge. There were about 8–10 Security Guards at the turnstiles at the time. The storage onsite corresponded to the period of time when dosimeters and the security credential were separate. At one time, badges were left in a rack at the guard post for a period of time. The dosimeter and security credential were retrieved when an individual came into work. Individuals were told to wear their dosimeter between the waist and neck. Dosimetry was worn on the outside of the garment. With the implementation of Anti-C’s, employees were instructed to wear their dosimeter inside of the Anti-C’s, where skin exposure was not a concern. RadCon did not police the use of dosimeters. Individuals would be questioned about not having the security badge, including the era where the dosimeters were combined with the employee badge.

Fernald was responsible for monitoring subcontractors onsite. Dosimeters (initially visitor badges) were assigned by the Security Department, but not all individuals were monitored. Badges could be assigned to more than one person for the monitoring period. Badges were read, but unless there was a positive reading, the dose was not tied to a particular individual. If the badge received measurable dose, an investigation into who wore the badge and where they worked was completed. Later, subcontractors entering radiological areas were assigned individual dosimeters. Years ago, subcontractors were treated differently than regular employees, and they believe this affected their radiation monitoring.

The use of extremity dosimetry was fairly common with those who handled material. For example, uranium machinists were originally assigned wrist dosimeters, and later ring dosimeters. The site switched from the use of wrist dosimeters to ring dosimeters, which became standard issue for some jobs. When RWPs were implemented, the need for extremity dosimetry was specified in the RWP. Non-uniform exposure badges were not used, to the recollection of the site experts. Dose from surface contamination was calculated with Varskin in more recent years. There was no personnel neutron monitoring at Fernald.

According to some site experts, there was non-uniform exposure to personnel in Plant 6 at the rolling mill area where the ingots were rolled out. There have been no issues with partial body exposure since 1994. Multiple badges were rarely used. The routine dosimeter was moved to the area of the body between the neck and the knee, where the highest dose rates were.

Self Reading Pocket Dosimeters (SRPDs) were used in some areas, such as the thorium area. The field maintained an SRPD Issue Log. The initial and return readings (i.e., reading in and reading out) were recorded in the log. An investigation resulted if there were unusual results with SRPDs. The readings themselves are maintained with the field records. There were specific jobs, such as the roof repair on Plant 1, where individuals were instructed to wear SRPDs on other portions of their body (e.g., lower extremity). A comparison between the SRPDs and the primary dosimeter demonstrated that the results were generally within 30% of one another. Timekeeping was used to control individual external exposure for a particular job.

There was an issue with contamination of badges. Green salt, orange oxide, and other materials would settle on the badge. In general, workers were told just to wipe the uranium off their badge. Badges were wrapped for a period of time to prevent contamination. Badges used in calibration were treated the same way. Baggies were used in cases where wet work was conducted. The dosimeter was surveyed by technicians during the badge exchange to make sure the badges were uncontaminated and could be sent to the processing laboratory.

Dosimeter investigations date back to the 1950s. In cases where the dosimeter was lost, damaged, or showed suspicious results, an investigation was conducted. A temporary badge was assigned in the interim. An investigation form was provided to the individual's supervisor to collect information on the exposure period, such as job task involvement. The average dose for each particular task was determined and the sum of doses from all tasks was determined. The technicians had a field procedure for assigning these doses. There is a code in the electronic system where doses were assigned based on this process. If the original badge were found, this information would be reflected in the dosimetry evaluation. Later, co-worker doses were used to assign dose for lost or damaged dosimeters. If the dosimeter was returned after it was lost, the dosimeter was read; however, the co-worker dose was the dose of record. This was to account for the possibility that the dosimeter was not worn during a part of the monitoring period. If the investigation indicated a zero dose should be assigned, this was the dose of record. Investigation results were placed in the dosimetry file.

There were dozens of investigations conducted on high skin doses. Individuals were asked what they had been doing and who they worked with for the given period of time. There was also an evaluation of the glow curve to determine whether an anomaly had occurred during the reading process. It was very clear from evaluation of the glow curve if reader difficulties had occurred. A hard copy of the glow curve was included in the employee file.

Fernald contracted with the University of Michigan to irradiate badges with pure irradiation sources using low-energy betas and high-energy betas. They thought the two sources would also be representative of intermediate energy betas. At the time, they were using two elements to determine the beta dose at the site. An algorithm was developed and put into use at Fernald. They later discovered issues with the algorithm and hired the Idaho National Engineering and Environmental Laboratory (now INEL) to develop a revised algorithm for them. Upon completion, this algorithm replaced the previous algorithm.

There was an overestimation of beta doses using the 802 TLD badges in the mid-1980s. Initially, this exposure was believed to be caused by contamination of the ledge in the holder adjacent to the E1 chip. As a result of collection of contamination on the badge holder, E1 would be irradiated more than E2. This theory was discounted as the problem once the error in the algorithm was discovered.

Historically, the Bioassay Laboratory Department was responsible for testing new dosimetry systems and processing dosimeters. Fernald was the first DOE site to receive accreditation under Department of Energy Laboratory Accreditation Program (DOELAP). Studies on angular dependence are documented in the DOELAP package created by Fernald. There are no negative dosimetry results in the dose of record.

Fernald implemented an extensive area dosimetry program in the late 1980s/early 1990s. There was a wide distribution of these badges throughout the buildings. Area badges were changed on the same frequency as personnel dosimeters.

Annual Radiation Reports were provided to the workers starting in the 1990s. The annual dose from the annual reports dropped for some workers in about 1996. The reason for this drop was not explained to the workers. [SC&A verified the drop in dose between annual reports.] There was no change in dose calculation methodology that would have resulted in a drop in cumulative exposure.

Internal Dosimetry

Individuals who were thought to have potential for internal exposure (e.g., work in airborne radioactivity areas) were monitored for internal exposure. There was a graded approach to the frequency of bioassay collection (i.e., monthly, bimonthly, or quarterly), based on the particular job title. Bioassay samples were also submitted upon hire and at termination. Radiation workers submitted bioassay samples from the beginning of production. An individual was considered a radiation worker if they received 100 mrem or more of internal and external dose in a year. In general, Fernald erred on the conservative side and monitored individuals who did not need to be monitored. Notification cards were sent out when it was time to leave a urine sample. If they were not cooperative, they could be excluded from radiological areas.

Fernald used the fluorometric technique originally developed by HASL to determine total uranium in urine. To obtain an isotopic analysis, samples were sent to an offsite laboratory. The best detection level achieved for fluorimetry was 0.005 mg/L. When the bioassay laboratory was moved outside the service building in the production area, the decision level was 0.015 mg/L. A trigger point of 0.05 mg/L was implemented for uranium bioassay. Kinetic Phosphorimetry Analysis was implemented in 1993 and Inductively Coupled Plasma/ Mass Spectroscopy in 2002. The method for recording a "less than detection level" bioassay value was era-dependent. Zeros were recorded in the 1950s and 1960s, due to the limitations of the data processing equipment. Later, bioassay results were recorded as less than the detection limit.

A neutron activation method, using the nuclear reactor at Wright Patterson Air Force Base, was eventually developed by NLO personnel for the determination of thorium in urine. However, there was no way to correlate the urine concentration with body burden. This problem went away when the mobile in-vivo counter became available in 1968. There was some breath thoron analysis utilizing the method developed by HASL. This was not a routine monitoring method, and there were no positive results.

The first in-vivo counts were conducted in 1968 with the Y-12 Mobile in-vivo counter. The in-vivo counter visited Fernald twice per year. A permanent in-vivo counter was put into service around 1987. The focus of the in-vivo program was to measure the Maximum Permissible Lung Burden (MPLB). In-vivo counting was the bioassay method of choice for insoluble uranium and thorium. Counters were capable of detecting uptakes in the most exposed workers. Over the period of operation, there was only a single individual restricted for an extended period of time as a result of a high in-vivo count. There were situations where individuals were sent offsite (e.g., Hanford, Argonne National Laboratory) for follow-up counts.

In-vivo counts were conducted after the employee's weekend. The delay in counting was done to reduce the possibility of surface contamination on the individual. There was a tendency for protein-binding of the radioactive material to the body hair, especially in men. An additional reason for performing counts after the employee's weekend was to allow particles deposited in the trachea to work their way up the respiratory system by cilia transport, and be swallowed. Radioactive material in the trachea would create erroneous results when trying to determine the activity in the lungs. There was no delay in the collection of urine samples. Dose was calculated in accordance with internal dosimetry procedures of the time, with any detectable amount on an in-vivo count. If the individual reached 75%–80 % of the MPLB, they were pulled off the job and special counts were completed.

Other types of bioassay data collected at Fernald included chemical, thorium, radium, and later plutonium. Breath analysis was used to try to detect radon in breath. Although this data was collected, there was little faith in the results. These results may be documented in the weekly progress reports. There were two cases where in-vivo counting equipment detected positive plutonium burdens. These individuals were sent to Chicago and Richland for in-vivo counts, which confirmed the uptake of plutonium.

Studies on radon concentrations at Fernald were conducted in the 1999/2000 time frame. Radon Breath Analysis studies were conducted by NIOSH. Individuals were required to be off work for some period of time prior to participating. The results from this study indicated that Cincinnati had the 10th highest radon backgrounds in the nation. Pulmonary function tests were completed as a part of the study. There were a significant number of individuals taking the test that had circulatory or pulmonary health problems.

With a suspected intake, individuals were requested to leave special bioassay samples, which could include urine and/or fecal samples. One sample was collected at the end of the shift and the other was collected the next morning. Follow-up bioassay samples were requested when an individual had a positive urine sample. Historically, trigger levels were used as a basis for requiring special bioassay samples. If anything off-normal occurred, employees were directed to leave a sample at the end of their shift and the beginning of the next shift. Codes associated with specific bioassay samples in the record indicate why the bioassay sample was taken (e.g., routine, special, etc.). After the implementation of DOE Order 5480.11, special bioassays were requested in the case of an incident or when a urine sample had a uranium concentration greater then 0.05 mg/liter. Any employee could initiate an Incident Investigation Form (IIF) if they felt they were exposed. They simply had to document the reason why they felt a Special Bioassay sample was warranted. The employee left a sample at the end of their shift and a second sample at the beginning of the next shift. In the early days, incident reports and urinalysis results were put into the medical record.

Fecal sampling was used primarily as a special bioassay technique or for particular jobs. There was no routine sampling program in the early years. Baseline fecal samples were collected for workers involved in thorium work. Subsequent fecal sampling was incident-based. After the initial bioassay sample, air sampling and in-vivo counting were used as the primary means of bioassay for thorium. A background study using approximately 500 fecal samples was conducted in the mid-1980s to determine the background level of thorium in feces.

Thorium workers were on a routine program to receive an annual in-vivo count. If there was an incident or a suspected intake, a special bioassay sample was taken. The emphasis for determining potential intake was based on BZ air sampling. After the thorium overpacking job, thorium-contaminated material was still handled. For example, work with the silo remediation potentially exposed personnel to thorium. Once the in-vivo counter was shutdown in 2002 or 2003, the capability for thorium monitoring went away. There was also no program for sending individuals to other sites for routine in-vivo counting.

The silos were built in the shape of a hemisphere. Silos 1 and 2 were surrounded by dirt, while Silo 3 was not. Silo 4 never held radioactive material. Each silo had a manhole to allow for continued monitoring and collection of samples. Most of the time, the silos were left alone. There was a sump between Silos 1 and 2 for collection of run-off material. No special routine monitoring requirements were implemented for work at the silos during production. During the remediation of the silos, Fernald implemented a more specialized bioassay for silo workers.

Subcontractors were not thought to be Radiation Workers and may not have had bioassays prior to 1986. Starting in the late-1980s, subcontractors were monitored based on the same criteria as permanent employees. Eventually, urine bioassay was collected bimonthly. Routine bioassay samples were followed with special bioassay samples when there was a positive result. Baseline thorium samples (fecal) were collected from individuals working in thorium areas. If an exposure was confirmed, an individual was moved to the "clean area" temporarily. Subcontractors were given an in-vivo count once per year or when ending work at the site. They were told if the count was positive or negative, but further explanations were not provided. Subcontractors did not participate in radon monitoring; however, there were times they were right on top of the source term. It was a challenge to get subcontractors to submit samples prior to them leaving. In later years, Fernald was required to send subcontractor dose reports to the employer (e.g., Wise, Rust Engineering, etc.) A good source of this information is the RadCon letter log.

Technology shortfalls identified in the personnel-monitoring program were limited to the existence of extremely insoluble material.

A field hearing was conducted with Senator Glenn as chair in about 1985. There was some concern raised over the background of the Y-12 in-vivo counter. During a congressional hearing, an independent Health Hygienist was asked to review the early body counts and explain the results. The reviewer could not understand the data. Former health physics staff indicated that the background of the in-vivo counter was well characterized, as quality control checks, including backgrounds, were completed on a regular basis and documented in logbooks.

Environmental Monitoring

The Environmental program involved air sampling, water sampling, soil sampling, biota sampling, and radon monitoring. Early in Fernald operations, gum papers were distributed to collect uranium fallout, and subsequently analyzed by the Bioassay Laboratory. This included an offsite-monitoring program. Radon monitoring was implemented in the 1980s.

Environmental air monitoring stations were originally located in the four corners of the 100 acre production area. Stations were moved in the 1970s from the four corners of the production area out to the site boundary. Some of the stations at the production area boundary were kept in operation after the boundary fence-line stations were added. Offsite stations were added later. Air samples were collected and analyzed weekly. The number of air sampling stations increased over time, especially when the EPA became actively involved in reviewing the releases offsite. When the existence of trace materials in recycled uranium became an issue, the site shipped composite samples from each monitoring station to Oak Ridge National Laboratory to be analyzed for plutonium and neptunium. The results, published in the annual environmental report, indicated there was no issue with release of these radionuclides.

From 1956–1969, microscopic techniques were used to collect particle size information. Particle size studies of the uranium processes were conducted in the 1980s. The particle size results from this study were consistent with the default value of 1.0 micron assumed by the site for environmental dose calculations. National Emission Standard for Hazardous Air Pollutants made particle size determination a requirement for environmental monitoring. A report was issued on the elimination of nonrespirable particles in the 1960s or 1970s.

The stack monitoring program was developed and initiated by the H&S Division to show the Production Division that uranium was present in some stack discharges, and that routine dust collector inspections by Production were needed. Thorium releases from the Fernald facility were also monitored and are documented in an historical emissions report published around 1986. An accident involving a dust collector in Plant 9 occurred. Prior to the accident, there was little stack monitoring. After the accident, monitors were installed on the stacks on all production buildings. The original stack monitors were designed in-house. Strip charts recorded the releases from the stack to the environment.

Large releases of material were the result of malfunctioning equipment or accidents. Releases were not deliberately made to the environment, although releases did occur. Fernald was investigated several times as a result of releases of dust to the environment. Uranium inventory was under tight control by the Material Accountability personnel at the site.

There was an atmospheric release of UNH from Plant 2/3 over a period of weeks in the late-1980s/early 1990s due to a scrubber failure. There was detectable activity at air monitoring stations, which is documented in the Annual Site Environmental Report for that year. The release resulted in a shutdown of the refinery after the air sampling results were communicated to the Fernald management team. There was a shift in DOE policy on release to the environment. DOE did not effectively inform Fernald of this change.

A release of uranium hexafluoride occurred at an operation in the Pilot Plant on February 14, 1966. The Pilot Plant released approximately of 3,800 lbs of UF_6, carrying it from the Pilot Plant, over the administration building and main laboratory, over the parking lot, and into the cow pasture. The site was not well prepared for this type of emergency at the time. This release was referred to as the Cutter release, and is formally documented. There was a large amount of bioassay samples collected around this time.

Routine sampling of rivers, sumps, wells, etc., was performed. Fernald developed an Advanced Wastewater Treatment System to pump and treat water from the aquifer. Once it is treated, the water is released to the Great Miami River or injected back into the aquifer. The extraction wells were supposed to be free of contamination, although the wells were periodically found to be contaminated. There were indicators of contamination in the groundwater. The rain would fall on contaminated soil and migrate offsite, creating a plume. The source of groundwater contaminated was water that found its way to Paddy Run Creek through a sand lens and eventually down to the aquifer.

Prior to construction of the Fernald plant, soil samples were made for engineering purposes, and groundwater flow rates were determined to evaluate water supply and quantity. In the remediation era, soil samples were conducted under the process buildings. During remediation, individuals were exposed to the contaminated soil after buildings were demolished. During soil remediation at Fernald, there were areas where the contamination went deeper into the soil than anticipated.

During the Shaw Project, soil was located into railcars and shipped to Envirocare. If the maximum acceptable concentration was not met, uranium metal would be thrown into the railcar as well. Site experts were uncertain whether Envirocare was aware of this practice.

Until at least 1991, a Reuter-Stokes High Pressure Ionization Chamber was used for environmental radiation measurements. In addition, micro-R surveys were conducted. Since these measurements were easier to take, more Micro-R measurements were taken at each location. These measurements were taken to compare them with the Reuter-Stokes data. There was usually good agreement. In about 1991, environmental TLDs were also implemented to measure radiation levels in the environment.

Once the radioactive material was placed in the silos, there wasn’t much of an issue with exposure to personnel. The silos were left alone, except that the grass around the silos had to be mowed, because there was a snake issue. This exposed individuals to radon from the silos. Individuals also found contaminated animals in the site buildings.

Both episodic and routine releases are documented in the environmental report. There is a separate chapter addressing episodic releases. The most important episodic releases from an occupational standpoint were those that occurred inside the buildings, rather than to the environment. There have been no calculations of environmental dose to onsite workers to the knowledge of site experts.

Dr. Quigley met with a representative of the Ohio Department of Health, and they agreed on limits for uranium, alpha and beta radioactivity, and fluoride in the Greater Miami River. There was also an agreement on how periodic reports would be made to the Ohio Department of Health. The local AEC office followed the lead of the Oak Ridge and Washington AEC offices in their dealings with local and state governmental agencies. If there was compliance with a state or local request, it was usually identified by the local AEC office in written documents as a matter of “comity.” The State of Ohio and Fernald periodically did split sampling (e.g., milk from cows grazing on Fernald property). Eventually, the state established a few offsite radon-monitoring locations. They also monitored air pollution parameters throughout the county and region, and did let Fernald co-locate some background radon monitors at one of their stations near the University of Cincinnati for a period of time. There were cooperative studies with Hamilton County. The county established its own radon monitoring locations. Fernald and the county shared data.

Incidents

The Communications Center was notified when there was a safety incident or unusual event. The Communications Center would, in turn, send emergency responders if there was a fire or if individuals were injured. During an incident, Security guarded the area. There were incidents (major and minor) almost on a weekly basis.

There were IIRs that a worker could fill out if an anomaly had occurred. These were self-initiating reports, with which workers could request special bioassay when they suspected an uptake. The technicians could also issue an IIR if they felt there was a possible intake. There were no formal trigger levels for special bioassay. The IIRs were filed in the employees dosimetry file. Samples associated with incidents were analyzed and, if they were positive, there may have been a further investigation. The results of the investigation were communicated to the worker. If an incident resulted in the assignment of dose, a formal report was issued. If an injury occurred, a description of the injury and the treatment were documented in the medical file. If Fire and Safety responded, they also issued a report. Industrial Hygiene incidents were documented in letters to the division director. Other sources of incident information include urinalysis records, in-vivo counting records, and various ancillary records.

Significant incidents had to be reported to the DOE or its predecessor within 24 hours of occurrence. The DOE would do an investigation of the incident. Corrective actions were determined during the investigation. The site also had internal reports, which succinctly described the incidents. Lessons learned were also developed throughout the complex and shared with other sites. Although Fernald per se did not maintain a database of these incidents, they were input into a database by DOE.

Uranium fires occurred in Plants 5, 6, and 9 on a daily basis. When shavings or derbies would catch on fire, personnel would try to extinguish it by placing a shovel full of MgF_2 over it, or by using fire or garden hoses to cool the drums. Type D Fire Extinguishers were added later. If the material continued to burn, a forklift driver would move the drums of burning shavings to a safer area. At times, the derbies continued to burn even after fire extinguishing efforts. At this point, they had to let the material burn. At times, derbies would catch on fire during the off hours. When the day shift came in, they found a pile of black oxide rather than a derby. During welding operations in Plant 8, a fire occurred in the northwest corner.

Other incidents or unusual occurrences mentioned by site experts include the following:

- On January 20, 1992, there was a fire at the Boiler Plant. Offsite emergency personnel were called in to assist with the situation. These individuals had to be escorted by Security.

- Plant 4 shut down for 30 days, due to a spill involving plutonium in the late 1970s or early 1980s.

- In Plant 9, there was an incident where a furnace kiln blew up. There were two fatalities as a result.

- When operations cleaned the scales with a vacuum, there were occasions where the vacuum would blow up.

- There were routine Rockwell furnace blowouts during the reduction process. Material would come out both the top and the bottom of the reaction vessel. Evacuation alarms would sound to alert workers in the surrounding area. Forklift personnel would remove the material immediately from the area and individuals went back to work.

- There was an incident with the early radon treatment system, where they over-pressurized the silo, resulting in a radon release to the environment.

- There was a spill of orange oxide outside the north side of Plant 2/3 by the tank farm.

There was a glove bag failure in Plant 9 in 1984. Workers called management when they noted that there was a release occurring at about 5:25 pm. The official report indicates that the release began at 6:00 pm. During the course of the investigation, witnesses of the release were not interviewed. The formal report indicates that 4 lbs of uranium were released to the atmosphere. Witnesses believe this was an underestimation. Several hundred pounds of black oxide fell out of the bottom of the silo High Efficiency Particulate Air filter, creating a large black mushroom that settled over the South Plant 9 cement pad. An investigation of excessive uranium emissions from Plant 9 was conducted by the Oak Ridge Operations Office.

In 1985, during the night shift, an individual reportedly committed suicide in Plant 6 by immersing himself in a salt bath. There were no night shift operations at the time. The bath was covered with a metal top to keep the heat losses down. He was able to move the cover enough so that he could slide into the bath. Operations noted a blip in the salt bath temperature. On the surface of the salt bath was the outline of a person. The furnace was removed from operation and the contents of the bath were emptied after some cooling. They let the material solidify and crystallize in drums. When the bath had been emptied, they found remnants of metal. This incident resulted in a formal investigation by the local Sheriff's Department.

Poor Radiological Control Practices

Radiation Safety rules were not always followed (e.g., not wearing respiratory protection). RadCon had to correct individuals through supervision when they were not adhering to the safety requirements. They were not allowed to redirect workers themselves. This changed as the Radiological Control Program improved. Some of the poor practices observed by site experts included the following:

- Individuals sometimes turned the sensitivity of the alarms down, so the alarms would readily go off.

- There was a situation where the electrical system was rewired, which affected the ventilation system in the area.

- Badges were overexposed intentionally; however, these could be distinguished from others by the high doses, contamination of the dosimeter, and the darkened clear edges on the film.

- Personnel would commonly sit on stacks of rods, derbies, or ingots. Originally they did not use rubber mats. Eventually they directed employees to put down a rubber mat before sitting on product.

- Workers took breaks next to the silos on the hill.

When unauthorized practices were observed (e.g., failure to wear appropriate PPE) in later years, the technicians were directed to issue a Radiation Deficiency Report or an Event Discovery Report. Depending on the severity of the event, disciplinary action could occur.

Miscellaneous

Individuals were strongly encouraged to sign a form allowing the DOE to take samples post-mortem for analysis. "You signed the form or you did not work," was the reported attitude conveyed at the site. In 1981, a monetary incentive was offered to sign up for the registry. This was not effective with the workers. In 1984, workers were asked to authorize the use of their bodies upon hire for evaluation by the uranium registry. The authorization was not clearly explained, and individuals and their families did not realize the government could take the bodies. Some families would guard the bodies at the corners office to ensure the body or its organs did not disappear. For a period of time in the 1960s, there was a shortage of bodies for evaluation.

When the Health Energy Radiation Branch of NIOSH was conducting a feasibility study on whether they could obtain data for an epidemiologic study, they concluded that the necessary information was not available. There was an absence or gaps in work history, exposure, and medical data at the time, limiting their ability to conduct accurate and comprehensive studies of remediation studies.

The union questioned the integrity of the data at Fernald. Dr. Lynn Wise, a member of John Glenn's staff specializing in environmental issues, visited Fernald with two assistants. On live television, the union presented Dr. Wise with supporting documentation that records had been altered. Examples of records provided were job orders, where stay times had been altered. This was one of the reasons NLO was fired. The situation is documented in congressional reports. The outcome was that some documents were determined to be altered.

Following a congressional hearing in the mid-1980s, there was a change in the film badge program. Workers also question the discrepancies in dose results between themselves and collocated co-workers.

Workers were told by supervisors that "the only way uranium could hurt you was if it fell on your head."

Medical

Medical exam frequencies have changed over time at Fernald. Many site experts remembered receiving an annual physical at one time. During medical exams, individuals submitted urine and blood samples for medical evaluation. Routine bioassay samples were collected at the time of the annual physical. Each individual was seen by a doctor. Initially, subcontractors were not provided with medical exams and x-rays. Later, medical x-rays were provided every other year. According to some site experts, NLO lost some of the worker medical records in the 1970s.

Limited information was known regarding the x-ray units. Medical x-ray units were surveyed by the RCTs in the past. The Food and Drug Administration has also done inspections.

Audits and Assessments

The New York Operations Office Health and Safety Representative conducted annual assessments of the Radiological Control program for the first few years. These audits were ad hoc at first, but became more formal by the end of the 1950s. Fernald fell under the jurisdiction of the Oak Ridge Operations Office, who conducted semi-annual to annual audits of all safety program areas. During the mid-1980s, the site had one audit after another. The Defense Nuclear Facility Safety Board completed a Program Review Audit at this time. Oak Ridge Operations office and DOE headquarters also performed audits of the overall safety program. Eventually, the Ohio Field Office became responsible for conducting assessments of Fernald. Audits included evaluations of Environmental Monitoring, Industrial Hygiene and Radiation, Fire Protection and Safety, and Criticality Safety.

Other Hazards

Radiological hazards were not the only health hazards individuals encountered at Fernald. In addition to radioactive material, beryllium, mercury, asbestos, and lead were also used on the site. Some of the chemicals used in the processes included ammonia, nitric and hydrofluoric acids, degreasers, solvents, magnesium fluoride, etc. There were pounds of Be handled at the Pilot Plant. Beryllium was used as a coating for the ingot mold and crucibles, similar to a nonstick coating on a frying pan. Asbestos was reported as prevalent in many of the plants. There were releases of hydrogen fluoride into the work area and environment. When opening a system, it was not uncommon to get sprayed with hydrofluoric or nitric acid. Workers were exposed to nitric acid and hydrofluoric acid fumes, and sometimes overcome by these fumes. Acid burns were not uncommon, and some workers eventually developed chemical dermatitis. Plant 6, Plant 7, and Building 13 had issues with bird droppings, causing a health hazard.

At Plant 2/3, they would release rust-colored material to the environment. Transportation personnel were asked not to park the trucks in the general area of Plant 2/3, especially at the truck dock. Plant 9 also released nitric acid to the environment. Releases also occurred from the Pilot Plant, the Tank Farms, and Plant 4. Workers indicated that the material would burn their lungs and sometimes their skin.

Hoppers had seals that would breach, releasing hydrofluoric acid and product. This was particularly a problem when the product got low. Alarms for this type of release were not consistent, and at times did not work or did not sound. If the workers visually saw the clouds, they would exit the area. There was no guidance given for re-entry. If they were able to breath, individuals would re-enter the building.

A beryllium surveillance program exists; however, it is not inclusive of all individuals potentially exposed to beryllium at Fernald. There have been positively diagnosed cases of Berylliosis in Fernald workers. Some bioassay sampling was completed prior to and after lead jobs.

There were also industrial safety hazards at Fernald during both the production and remediation era. For example, there were problems a couple of times during remediation with vehicles (dozers and trucks) falling into the pits.

Technical Basis Document Comments

Several comments were made by site experts concerning the NIOSH Fernald TBD.

- The NIOSH TBD is based on urine, air monitoring, and dosimeter results. These values may not be representative of the exposure conditions.

- NIOSH/ORAU has been provided with Plant-by-Plant process information.

- Tables of projected exposures to employees in the NIOSH TBD include a Decontamination Factor (DF) for many operations, based on use of a respirator. There is no indication of when the DF is applied. Workers, particularly those working prior to the mid-1980s, indicate that respirators were rarely used. Consequently, the potential exposures in the TBD may be underestimated.

NIOSH held a worker outreach meeting in November 2003. The TBD was completed March 2004.