Attachment 4.3-10 (Continued)

example, if I stood on one side, the reading might be zero while on the other side, the reading might be 50 times Maximum Allowable Concentration ("MAC").

6. In order to obtain an accurate result of what the employee is breathing, it is important that the air dust survey be done as close as possible to the production plant employee's breathing zone. The sample should be taken in the direction that the dust is blowing if the employee is subjected to the dust.

7. On several occasions during the term of my employment, when I got air dust survey results that were above the MAC, I was told by my supervisors that the results were in error and I was told to go back and resample. I remember one specific occasion when I was sampling the jolter in plant 5 where ventilation modifications had just been made and I was sent out there to sample the air. The production plant employee was working over the jolter and the dust was coming up into his face. I obtained results that were above the MAC. I think that my results were correct the first time that I sampled because they were similar to the results that I had obtained before the modifications and the modifications were not effective. Nevertheless, my supervisors told me to go back and resample. When I resampled, the results were still above the MAC. I was sent back by my supervisors five or six times. Finally, I stood in the opposite direction from the employee from the way that the dust was blowing and I obtained a result that was below the MAC. When I returned the result that was below the MAC to the Health & Safety Division it was an acceptable result.

8. In air dust surveying there were many other variables that could change the results. For example,

(a) the results were lower in the summer because the windows in the plants were open;

(b) if there was dust laying on the ground or on equipment, this dust could be resuspended and become airborne;

(c) fork truck traffic would increase the airborne activity;

(d) if the ventilation ducts were partially or completely plugged, the air dust would be higher in the work areas;

(e) production rates would affect air dust results; and

(f) whether the standard operating procedures were followed would affect the results.

9. When there were fires in the buildings, the windows and doors were opened to get the smoke out and sometimes the air dust surveys were not taken until after the smoke had cleared.

10. When there were fires outside the buildings, generally on a storage pad, the air dust surveys that were taken were random as to location and time.

11. In the annual air dust survey reports I wrote recommendations for reducing air dust levels in the plants. Some of these

Attachment 4.3-10 (Continued)

recommendations would not cost anything to implement. For example, I would recommend vacuuming up the radioactive material in the work areas, wearing respirators properly, making sure that all ventilation lines were clear and operating in accordance with the standard operating procedure. Nevertheless, these recommendations were sometimes not followed.

12. On occasion, the employees were exposed needlessly to airborne radioactive dust and fumes because the production supervisors were operating at a rate in excess of the production rates set forth in the standard operating procedures. Sometimes when ventilation lines were blocked, production supervisors told the employees to go ahead and dump uranium anyway causing the radioactive dust and fumes to billow out into the plant.

13. In the 1950s no industrial hygienists worked on the second shift, third shift or on weekends. It is my understanding that many operations that would not be condoned by the Health & Safety Division would be done on the second shift, third shift and on weekends when no industrial hygienists were present.

14. There was no fit testing for respirators used at Fernald during the years that I was employed there. Respirators were not used by the production plant employees as frequently as recommended by Health & Safety Division. Often the respirators were left in the production areas uncovered where the respirators became dirty and covered with radioactive dust. The employees would then pick up the dirty respirators and use them.

15. Management condoned smoking in the production plants. Employees would carry the cigarettes in their coveralls where the cigarettes would become contaminated with radioactive dust and then the employees would smoke the cigarettes.

16. People that were injured in the production plants were assigned "light duty". Light duty could be anything - such as sitting in a chair for eight hours. These injured employees were picked up at their homes and brought to work so that the statistics on lost time accidents would be favorable to the company. The lost time statistics reported by NLO are inaccurate.

17. Dust collectors often were not shut off as soon as possible when a bag ruptured. This resulted in a decrease in ventilation at the work stations and excess uranium dust released into the atmosphere and onto the ground.

18. Many times during my employment plants 2 and 3 had to be evacuated because of nitric acid fumes. No samples were taken at the time of evacuation, however samples were taken before the employees were allowed to return to the buildings.

19. Supervisory personnel were aware that employees were being

Attachment 4.3-10 (Continued)

overexposed to radioactive dust and fumes and also overexposed to acids. Nevertheless, supervisory personnel allowed the employees to continue to work in areas where they were being overexposed to radioactive dust and fumes and to acids. These overexposures continued throughout my seventeen years of employment at Fernald.

Further Affiant Sayeth Naught.

State of Ohio)
County of Hamilton) SS

Sworn to me and subscribed in my presence this second day of February 1993.

JANE A. WALKER
Notary Public, State of Ohio
My Commission Expires August 4, 1997

4.4 GENERIC LIMITATIONS AND FINDINGS ASSOCIATED WITH THE USE OF MIVRLM DATA FOR URANIUM AND THORIUM DOSE ESTIMATES

Sections 5.3.7 and 5.3.8 of FMPC TBD describe the Mobile In Vivo Radiation Monitoring Laboratory (MIVRML) that was used to monitor FMPC workers between 1968 and 1989. Data presented include the frequency by which individuals were selected for MIVRML analysis, radionuclide-specific MDA values, and **assumptions** regarding the method(s) employed for the interpretation/quantification of data. Presented below is a critical evaluation that challenges the credibility and usability of MIVRML data for the in vivo detection of uranium and **thorium**.

Generic Design Limitations of the MIVRML

Not considered a finding by SC&A, a critical component of the MIVRML lung counting system, however, was the radiation detection system, which employed two very large sodium iodide detectors measuring 9 inches in diameter by **4 inches thick**. While such large crystal detectors offer maximum counting efficiency that is highly desirable for **whole-body** counting of high-energy photons of fission/activation products (e.g., Cs-137, Co-60), the use in detecting low-energy photons is severely compromised by their 4-inch thickness.

This limitation in sensitivity is due to the fact that for large/thick crystals, the low-energy photons fall into that region of Compton-scattered photons that is maximal. For illustration, Figure 4.4-1 depicts a MIVRML gamma spectrum that is defined as "background."

The already high counts per channel at the left-site of the "background" spectrum are further enhanced by the presence of high-energy photons in the environment or within the person being chest counted. Figure 4.4-2 is an in vivo gamma spectrum from an "unexposed" or normal person. Note, one of the two peaks is due to Cs-137 (a weapon fallout product) and one is due to K-40. Their contribution to Compton-scattered photons diminishes the sensitivity of the system to detect the in vivo presence of low-energy photons associated with thorium.

In order to improve the signal to noise ratio (or sensitivity) for the detection of low-energy photons, other DOE facilities during this time period employed NaI detectors with a nominal thickness of only 4 **millimeters** (or $1/25^{th}$) of the 4-inch thick crystals employed by the MIVRML system.

Operator Inexperience

For the first 2 years of operation, the MIVRML was operated by Y-12 personnel. Starting in 1970, the MIVRML was operated by FMPC personnel who had a limited understanding of the complexity of in vivo counting and the proper interpretation of results. In a letter to the DOE dated November 25, 1981, R.M. Spenceley, Manager at FMPC stated the following:

> *. . . Many lung counts are made for screening purposes and are made under circumstances which require interpretation of the count results by someone familiar with vagaries of in vivo measurements. While all count data are retained*

in the employees' files, not all results are useful as an expression of the true lung burden.

In combination, these two factors raise concerns about the sensitivity as well as credibility of lung count data involving the MIVRML.

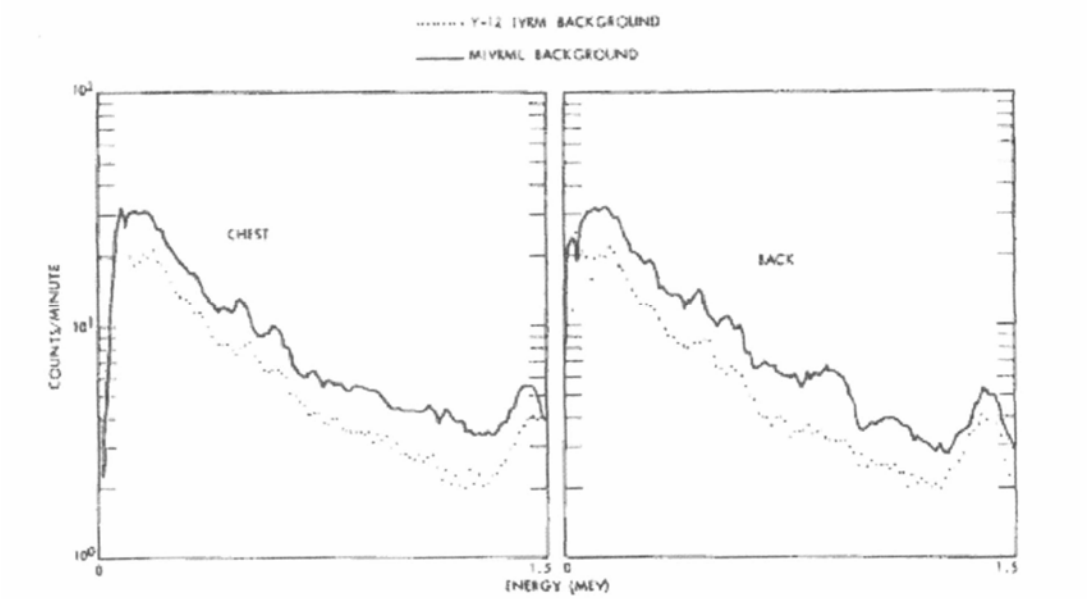


Figure 4.4-1. Comparison of Background Radiation Levels inside Y-12 Iron Room and the MIVRML Iron Room

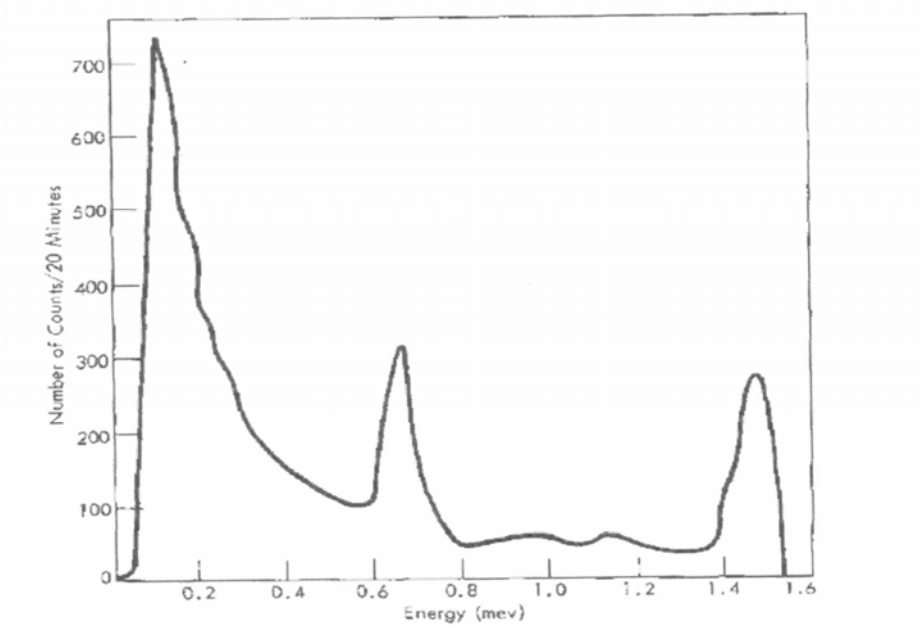


Figure 4.4-2. Normal In Vivo Spectrum From an Unexposed Person

Finding 4.4-1: Limitations Regarding the Use of Th-234 and U-235 for Estimating Intakes of Uranium

Section 5.3.7 of the FMPC TBD states that:

> *. . . Uranium-235 was detected primarily by the emission of its 186 keV photon. Uranium-238 was calculated from measurement of the Th-234 progeny assumed to be in equilibrium with the U-238.*

Limitations regarding the use of Th-234 for estimating intakes of uranium by means of the MIVRML lung counter are two-fold:

(1) Th-234 emits two very low-energy photons of 63 keV and 93 keV, which moreover also have very low yields of 3.5% and 4%, respectively. From the foregoing discussion, detection limits for Th-234 are compromised by the high background that characterizes the large detectors employed by the MIVRML.

(2) While the surrogate use of Th-234 can provide quantitative data for estimating the presence of U-238, it provides no information regarding the presence of U-234, which may exist in equilibrium with U-238 or in various states of disequilibrium that reflect the use of depleted or variably enriched uranium.

Limitations regarding the use of the 186 keV photon emitted by U-235 in part parallel the limitations defined for the use of Th-234. While the 186 keV photon emitted by U-235 has a higher energy as well as yield, its detection is compromised by the fact that this photon energy coincides with the 180° backscatter energies of more energetic gammas such as Cs-137, K-40, etc.

Equally, a quantitative estimate for the presence of U-235 provides limited information regarding the presence of U-238 and U-234 for the aforementioned reasons. Thus, in the absence of definitive information regarding the isotopic composition of the source material(s) to which a worker was exposed, interpretation of MIVRML data poses serious limitations and uncertainties.

Finding 4.4-2: Use of Surrogate Daughter Products and Unsupported Assumptions for Thorium Exposure

Thorium isotopes of concern at FMPC include Th-232, which is the parent isotope of the 4 η thorium series, and Th-228, which is a radioactive daughter within the decay chain. Exhibit 4.4-2 identifies crucial information regarding the thorium decay series that are relevant to SC&A's concerns.

Inspection of Exhibit 4.4-2 points to the fact that Th-232 does not emit photon(s) and can, therefore, not be directly detected by a lung counter; and Th-228 emits two low-energy photons with very low yields that limit their use in lung counting for reasons discussed above.

EXHIBIT 4.4-2

Thorium Series (4n)*

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities† α	β	γ
$^{232}_{90}Th$	Thorium	1.41×10^{10}y	3.95 (24%) 4.01 (76%)	---	---
$^{228}_{88}Ra$	Mesothorium I	6.7y	---	0.055 (100%)	---
$^{228}_{89}Ac$	Mesothorium II	6.13h	---	1.18 (35%) 1.75 (12%) 2.09 (12%)	0.34c‡ (15%) 0.908 (25%) 0.96c (20%)
$^{228}_{90}Th$	Radiothorium	1.910y	5.34 (28%) 5.43 (71%)	---	0.084 (1.6%) 0.214 (0.3%)
$^{224}_{88}Ra$	Thorium X	3.64d	5.45 (6%) 5.68 (94%)	---	0.241 (3.7%)
$^{220}_{86}Rn$	Emanation Thoron (Tn)	55s	6.29 (100%)	---	0.55 (0.07%)
$^{216}_{84}Po$	Thorium A	0.15s	6.78 (100%)	---	---
$^{212}_{82}Pb$	Thorium B	10.64h	---	0.346 (81%) 0.586 (14%)	0.239 (47%) 0.300 (3.2%)
$^{212}_{83}Bi$	Thorium C	60.6m	6.05 (25%) 6.09 (10%)	1.55 (5%) 2.26 (55%)	0.040 (2%) 0.727 (7%) 1.620 (1.8%)
64.0% 36.0%					
$^{212}_{84}Po$	Thorium C'	304ns	8.78 (100%)	---	---
$^{208}_{81}Tl$	Thorium C''	3.10m	---	1.28 (25%) 1.52 (21%) 1.80 (50%)	0.511 (23%) 0.583 (86%) 0.860 (12%) 2.614 (100%)
$^{208}_{82}Pb$	Thorium D	Stable	---	---	---

*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{232}_{90}Th$ (4n).....4(58) = 232
†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.
‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Lederer, C. M., Hollander, J. M., and Perlman, I., Table of Isotopes (6th ed.; New York: John Wiley & Sons, Inc., 1967) and Hogan, O. H., Zigman, P. E., and Mackin, J. L., Beta Spectra (USNRDL-TR-802 [Washington, D.C.: U.S. Atomic Energy Commission, 1964]).

In behalf of these limitations, Section 5.3.7 of the FMPC TBD and Section 6.1 of the ER provide the following statements relative to the use of MIVRML data for thorium:

> . . . *Thorium-232 and Th-228 activities were determined based on* ***equilibrium assumptions*** *and detection of their progeny,* ***most likely Ac-228*** *for Th-232, but* ***Pb-212 may*** *have been used for assessment of both Th isotopes.* [Emphasis added.]

At FMPC, thorium existed in various physical and chemical forms that included thorium ores, crushed thoria, (powdery thorium dioxide) pellets, thorium oxalate, thorium hydroxide, thorium tetrafluoride purified thorium metal, etc. Based on the relative half-lives of decay chain members and/or their chemical properties, NIOSH's basic assumptions of equilibrium conditions between (1) Th-232 and Th-228, (2) Th-232 and Ac-228, and (3) Th-232/Th-228 and Pb-212 are technically incorrect and unsupported as explained below.

Even if thorium ores that served as a primary feedstock can be assumed to have contained all members of the decay chain in full equilibrium, disequilibrium would first occur at time of chemical separation of Th-232 and Th-228 from all other decay chain members.

At the time of thorium extraction, Ra-228 (and its short-lived daughter Ac-228) would, therefore, not be present. The slow rate of ingrowth of Ra-228 (and Ac-228) in chemically extracted thorium products is governed by the 6.7-year half-life of Ra-228 and the 1.9-year half-life of Th-228. Thus, the relative activity of Th-228 to Th-232 is governed by three factors that include:

(1) The starting activities of Th-232 and Th-228 in the ore

(2) The age of the thorium material, which determines the loss of Th-228 by radioactive decay

(3) The age of the thorium material, which determines the ingrowth of Ra-228 that in turn gives rise to Th-228

From this brief discussion, it must be emphasized that assumptions of equilibrium among Th-232, Ac-228, Th-228, and Pb-212 for all thorium materials and all time periods are technically incorrect. Correspondingly, the surrogate use of Ac-228 and/or Pb-212 for estimating lung burdens of Th-232 and Th-228 is technically flawed and would **consistently** lead to results that are claimant **un**favorable. As an extreme case, consider a worker who is exposed to a freshly isolated thorium extract or a purified thorium metal. Since the thorium would not contain any **significant** amounts of Ra-228/Ac-228, a chest count would imply a false negative result.

A most puzzling set of data pertaining to MIVRML lung counts is contained in Table 6.2 of NIOSH's SEC Evaluation Report. As summarized above, Section 6.1 of the ER specifically identifies the use of Ac-228 and/or Pb-212 as the potential surrogate radionuclides for estimating the lung burden of Th-232 and/or Th-228. These two isotopes are specifically cited in Table 6.2 of the ER. Thus, for example, Table 6.2 identifies that in 1971, only three lung counts were performed for Pb-212 and two lung counts were performed for Ac-228. Yet, Column 4 of Table 6.2 identifies a total of 680 lung counts for "thorium" (along with 686 lung counts for U-235 and uranium).

SC&A interprets these data to represent the following:

(1) Column #4 of Table 6.2 and identified as "Thorium" is, in fact, a reference to Th-234. Th-234, the daughter of U-238, however, has **no relationship** to Th-232 and Th-228, which are the thorium isotopes of concern in the SEC petition.

(2) Based on Table 6.2, the total number of in vivo bioassays for Th-232/Th-228 for the period of 1965 to 1977 was **fewer than 15**.

(3) In vivo assessments for Th-232/Th-228 only began in earnest in **1979**.

(4) The value of conducting thorium-specific lung counts **after 1979**, however, is questionable. According to Table 5-13 of the FMPC TBD, **all thorium production** lung counts would principally assess the inhalation of Th-232/Th-228 associated with the repackaging and shipping operations of thorium products.

(5) Since inhalation of even insoluble forms of thorium (i.e., Type S) can be expected to remain in the lung for a finite time, the use of lung counts in the post-1979 era has limited value for workers exposed during the **production years** that predate 1979.

Finding 4.4-3: Worker Selection Criteria and Infrequent Use of MIVRML

Section 5.3.7 of the FMPC TBD states that:

> *Lung counting became available to FEMP in 1968 in the form of the Mobile In Vivo Radiation Monitoring Laboratory* [MIVRML]. *The mobile van visited the Fernald plant on a **routine** schedule and counted the workers on a schedule **based on their internal exposure potential** and **their urine sampling results**.*
> [Emphasis added.]

In a **Health Protection Appraisal Report** for NLO dated September 1968, the following statements were noted regarding the use of air monitoring data as the **selection criteria** of workers for MIVRML evaluation:

> *Recent in vivo monitoring of NLO employees utilizing the IVRML indicated eight employees apparently sustaining 70 to 100% of a permissible lung burden of uranium . . . A serious question has been raised regarding the validity of the job weighted air dust sampling approach long used by NLO since that data would **not suggest** lung exposures for these employees at the in vivo indicated level.*
> [Emphasis added.]

Two years later in another NOL Health Protection Appraisal Report dated September 1970, the following concerns were noted regarding the frequency/completeness of the MIVRML program:

> *The IVRML visited NLO on two occasions during CY 1970. It was on site for two weeks, beginning March 30, and again from early July through the end of*

> *September. During the first counting period, about 24 employees were counted and during the second period 103 employees (including the 24 previously counted) were monitored . . . It is estimated that about 200 employees are currently working in production areas and have a generally comparable potential for uranium lung exposures.* ***It is therefore noted with concern*** *that only about half of those potentially subject to exposure have been monitored by IVRML during this year. It is further noted that a* ***substantial fraction*** *(approximately 20-24 percent) of the* ***production*** *workforce has not received at least one IVRML count since the counter first went to NLO in 1968.* [Emphasis added.]

These statements support two concerns that SC&A has raised elsewhere in this report. The first concern is the apparent lack of correlation between air sampling data (used to identify workers with the highest potential for exposure) and the workers' measured lung burdens as assessed by the MIVRML. The failed correlation between air sampling data and lung counts may imply errors and uncertainties associated with either or both air sampling and lung counting.

Use of air sampling data, for selection of a subpopulation of workers to be monitored by lung counting, poses yet a second concern. The lack of reported correlation between air sampling data and lung count data suggests that persons monitored by lung counts may not represent the higher exposed worker group(s) and conversely, that maximally exposed workers may not ever have been lung counted.

Finding 4.4-4: The Improper Correlation of MIVRML Thorium Lung Count Data with Thorium Air Sampling Data as Proposed by NIOSH

As suggested in Exhibit 4.3-1 above, for thorium intakes, NIOSH intends to correlate the results of ". . . 6000 in vivo results for thorium (Ac-228 and Pb-212) . . . with 2000–4000 thorium air sample results."

Based on data presented in Table 6-2 of the SEC-00046 Evaluation Report and reproduced herein as Table 4.4-1, it is SC&A's understanding that NIOSH intends to establish a correlation between BZ air sampling data that may have been taken as early as the 1950s with MIVRML data for thorium that only began in earnest in **1979**. Important to note is that thorium production had ceased by 1979, as acknowledged in Section 5.2.3 of ORAUT-TKBS-0017-5, which states:

> *Thorium processing was* ***completed*** *in 1979, with exposure from that time being limited to* ***repackaging*** *and shipping operations.* [Emphasis added.]

Based on the relative time periods, it is inconceivable how lung burdens of thorium measured post-1979 (and corresponding to "repackaging and shipping") can be correlated to BZ air samples taken decades earlier when thorium was processed.

Table 4.4-1. Number of *In-vivo* Measurements Performed Annually at the FMPC
(as reported in MIVRML)

Year	Uranium-235	Uranium	Thorium	Lead-212	Actinium-228
1965	2	2	0	2	2
1968	306	362	310	2	1
1969	107	108	107	0	0
1970	168	168	164	0	0
1971	686	686	680	3	2
1972	277	277	274	1	0
1973	235	235	233	2	1
1974	324	324	321	1	1
1975	277	277	275	0	0
1976	267	267	262	1	1
1977	219	218	217	3	3
1978	212	214	161	40	41
1979	216	224	26	198	197
1980	232	239	5	214	219
1981	171	176	3	166	170
1982	209	215	3	204	210
1983	212	217	4	195	200
1984	410	419	4	408	415
1985	426	418	3	405	407
1986	506	507	10	467	467
1987	577	576	12	570	566
1988	229	228	3	111	107
1989	6	6	0	1	1

It is, therefore, concluded that NIOSH's proposed method for linking air monitoring data with MIVRML lung count data for estimating thorium intakes **prior** to 1979 is without scientific merit.

Finding 4.4-5: The Inappropriate Use of ORAUT-OTIB-0002 for FMPC Claims

In a presentation to the Advisory Board on February 8, 2007, in Mason, Ohio, NIOSH presented summary data regarding the number of claims that had been completed as of that date. Attachment 4.4-5 is a reproduction of viewgraph #7 presented to the Board. It shows that 90% or a total of 619 dose reconstructions had been completed.

While SC&A has access to individual claims, no analysis of the types of DR methods used in the 619 claims that have been completed is available. But a review of some randomly selected claims shows that many FMPC claims that were denied on the basis of a maximized dose reconstruction that employed ORAUT-OTIB-0002.

SC&A regards the use of OTIB-0002 inappropriate of **all** FMPC claims, as explained below.

Section 2.0 of OTIB-0002 explains the **regulatory** basis for its use as an **efficiency** measure in which a dose is determined using **worst-case** assumptions that substitute for further research and

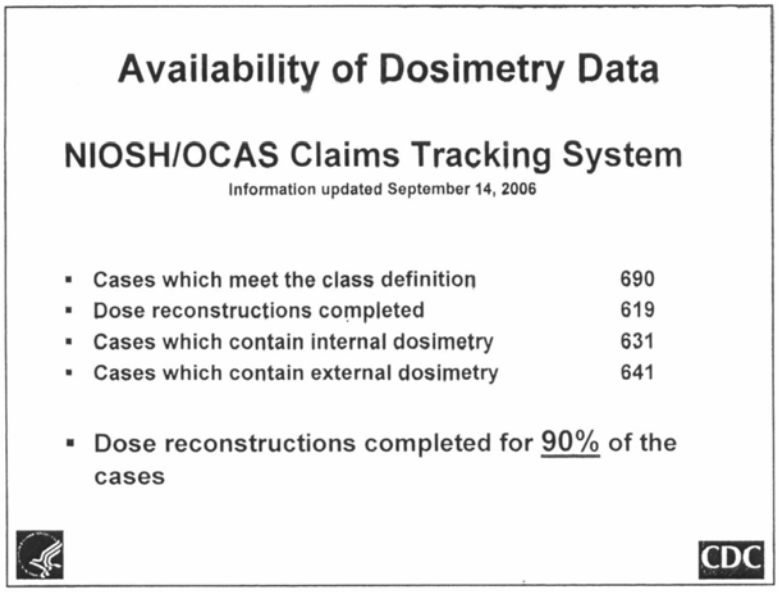
analyses. Worst-case is defined as "the highest reasonable value based on reliable science, documented experience, and relevant data . . ."

Section 3.0 (*Implausible Undiscovered Intakes*) further explains the **technical** basis and justification for its use by providing the following:

> *For claims where it is considered likely that the covered employee had no significant internal radiation exposure, a method to expedite claims has been developed in accordance with 42 CFR 82.10(k)(2). This method assumes the "largest reasonably possible value" of the source term comprised of radionuclides that are/were typically the more significant radionuclides (by either preponderance or by internal dose significance) on a site. For this "worst-case" estimate of internal dose, it is assumed that on the* ***first day of the first year of employment****, the covered employee had an* ***acute inhalation*** *intake of* ***each of the radionuclides in the source term****, in the amounts listed below.*
>
> ***Based on historical data, it is believed to be highly unlikely that such an intake could have occurred without being detected by workplace monitoring at the time****. It is also believed that this is a significant overestimate of internal dose for an unmonitored covered employee or a covered employee with no internal monitoring above detection thresholds.* [Emphasis added.]

Given the limitations and deficiencies of internal monitoring as described in Sections 4.1, 4.2, 4.3, and 4.4 of this report, SC&A concludes that the use of OTIB-0002 for any FMPC claimant is inappropriate and unjustified.

ATTACHMENT 4.4-5



4.5 FINDINGS ASSOCIATED WITH EXTERNAL EXPOSURE MONITORING AT FMPC

Finding 4.5-1: Absence of Performance Standards/Quality Assurance for Personnel Dosimeters

Throughout the period of facility operation, workers were monitored for external radiation by means of film dosimeters and TLDs, and extremity exposures were monitored with wrist film/TLD badges starting in 1970. Although SC&A is not generically questioning the merits of external dose data, the credibility of external dosimetry data has to be viewed in context with several limitations, as described in a document entitled *Response to Dosimetry Assessment Fact Sheet*, September 11, 1981. In this response (to a DOE inquiry), the following statements were made (see Attachment 4.5-1):

(1) *All dosimeter evaluations were "in house" except for approximately the first 12 months of operation when film badges were processed by DOE's Health and Safety Laboratory…*

(2) *No procedure is available* [for the processing/evaluation of personnel dosimeters].

(3) ***Test** dosimeters* [i.e., control badges] *are **not** routinely processed.* [Emphasis added.]

(4) *Initially, heat damage from leaving badges in cars during hot weather was a problem. However, this has not been a real problem for many years. Leaving badges in desks, cars, etc. did not have a significant impact on the overall external dosimetry program.*

(5) *There were no specific training requirements for the film badge technicians when this program began in 1951. The technician received on-the-job training. The technician now performing [i.e., in 1981] all film badge process began this work in 1952 and has been **only technician** doing this task since 1959.* [Emphasis added.]

In summary, while it appears that FMPC monitored workers for external exposures, there are concerns about the quality and accuracy of these data due to the absence/unavailability of standard operating procedures, quality control measures, and formal training of dosimetry technician(s).

ATTACHMENT 4.5-1

September 11, 1981

NLO, INC.

RESPONSE TO
DOSIMETRY ASSESSMENT FACT SHEET

I. History of "Hazards" to Assess Overall Monitoring Program

A. The primary radiation hazards at the FMPC have always been from uranium. Uranium of various U^{235} content, ranging from depleted to slightly enriched, has been processed with the average content being close to normal. Periodically, small amounts of natural thorium have been processed.

B. There have been no significant radiation hazards that have not been monitored.

C. External Radiation Monitoring: film badge dosimeters have always been used to measure whole body penetrating and skin doses. From 1951 through 1960 the film packet was sealed in plastic and placed in a metal case which attached to the worker's security badge. A portion of the film was not covered by the metal case and served as a means of monitoring skin dose. Beginning January, 1961, the ORNL Badge Meter, Model II was put into service at this site. This dosimeter is described in detail in the report ORNL-3126.

Extremity exposures were monitored with wrist film badges from 1969 until 1977. From 1977 through the present, TLD's have been used for this purpose. The TLD's are the Telydyne teflon impregnated with calcium sulfate type.

Internal Radiation Monitoring: all measurements of internal (lung) depositions have been made with DOE's mobile body counter which is operated and maintained by Union Carbide's Y-12 personnel. The counter has been used at this site from 1968 until the present time.

D. Additional information on our present film badge dosimetry system is contained in the two attachments.

II. External Monitoring Data

A. Personnel Monitoring Badges

1. Types of badges used:
   Film for whole-body and skin exposure
   Film for extremity exposure (limited program)
   TLD for extremity exposures

2707904

3455935

Attachment 4.5-1 (Continued)

NLO, Inc.

2. Dates each type dosimeter used:
   Film (whole-body monitoring): since plant start-up (1951) to date
   Film (extremity monitoring): 1969 to 1977
   TLD (extremity monitoring): 1977 to present

3. Types of measurement:
   Gamma whole-body dose
   Beta and gamma skin dose
   Beta and gamma extremity (hands and forearm) dose

4. All dosimeter evaluations were "in house" except for approximately the first 12 months of operation when film badges were processed by DOE's Health and Safety Laboratory, New York, NY (presently called EML).

5. No procedure manual is available.

   a. Calibration procedure and frequency. Film badges: Gamma calibration are performed by exposing badges to a radium source at various distances. Beta and Gamma calibration are obtained by exposing films to a uranium metal slab for various lengths of time. Six to eight sets of calibration films are prepared at a time. One set is processed each month along with the films from the personnel dosimeters.

      TLD extremity dosimeter: calibration exposures are made in essentially the same manner as with film badges by exposing the TLD's to a slab of uranium metal. Calibration checks of the entire TLD system are made each month. The individual TLD's are calibrated after every two or three uses.

   b. The radium source used for gamma calibrations was calibrated at NBS. The uranium metal slabs used for beta and gamma calibrations have not been calibrated. The published surface dose rate for aged natural uranium metal is assumed for the metal slabs.

   c. For film dosimeters, a calibration curve of film density versus exposure is prepared from the calibration films. The density of the personnel films is converted to dose using the calibration curve. This was done manually at first but is now performed by computer.

   d. "Test" dosimeters are not routinely processed. However, five or ten gamma and six or eleven beta and gamma calibration films were processed along with each batch of personnel films. Also, as mentioned previously, TLD's are exposed for calibration purposes after every two or three uses.

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Attachment 4.5-1 (Continued)

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e. Test dosimeters were not routinely evaluated.

f. Special care was always taken in the method used to store films, to carefully control film processing conditions, and in preparing calibration films. Calibration films were always from the same lot and processed along with the workers' films. See also attached Report On Examination "Audit of Controls Over Radiation Badges" dated June 6, 1978.

G. There were no specific training requirements for the film badge technicians when this program began in 1951. The technicians received on-the-job training. The technician now performing all film badge processing began this work in 19[redacted] and has been only technician doing this task since 195[redacted].

6. Personnal who make use of the dosimetry results are convinced that the dosimetry procedures provide a reliable measurement of radiation doses. Knowledge of the calibration, development and read-out processes leads them to conclude that the precision would be better than ±25%.

B. Use of Badges

1. Since badges were always a combination security-dosimeter badge and also contained nuclear accident dosimetry materials, all employees have always worn badges. However, exposures were not always determined for all employees. During certain periods female employees were not routinely monitored. Periods when male and female employees were monitored were:

1951 - 1960: male employees only
1961 - 1968: male and female employees
1969 - 1978: male employees only
1979 - present: male and female employees

2. AEC (ERDA, DOE) Manual Chapter 0524. Female employees were not monitored during certain periods because the potential did not exist for them to exceed 10 percent of the quarterly standards.

3. Yes.

4. Because of the dual nature of the badge, the time employees did not wear badges was minimal.

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

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

Attachment 4.5-1 (Continued)

NLO, Inc.

5. Initially, heat damage from leaving badges in cars during hot weather was a problem. However, this has not been a real problem for many years. Leaving badges in desks, cars, etc., did not have a significant impact on the overall external dosimetry program.

6. Temporary badges were provided if a worker left his badge at home or lost his badge. If the dose registered on the temporary badge was considered to be of no consequence, no adjustment was made to the individuals dose record.

7. Workers normally wore their badges on the upper part of the body (on shirt collars or shirt pockets).

C. Other External Monitoring Techniques

Only film badges or TLD's have been used for determining actual personnel exposures. Neutron monitoring is not required at this site.

D. Administration and Recordkeeping

1. Initially, external radiation doses were reported in mrads and later in units of mrem.

For our gamma (whole body) exposures, the units of roentgen, rad and rem were assumed to be equivalent and no conversion factors were used to convert from one to the other. For beta and gamma (skin) exposures no conversion factors were used to convert from rads to rems. The published value for the absorbed dose rate produced by natural uranium metal expressed in mrad/hr was assumed to be equal to the same dose expressed in mrem/hr.

2. No quality factors or modifying factors were used to evaluate dose equivalent.

3. Anytime a reading was considered questionable, an investigation was conducted. A decision as to whether or not the reading was legitimate was based on the findings of the investigation.

4. A dose is assigned to a worker if his dosimeter is lost or damaged. The amount of dose assigned is based on which jobs the worker performed during the unmonitored period.

5. Several films (blanks) are taken from the supply of films which are stored in a refrigerator and developed with the calibration and personnel films. The blank films are used to zero the film densitometer. This automatically compensates for background radiation.

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Attachment 4.5-1 (Continued)

6. Records are complete.

7. This has not been necessary.

8. Most of the monitoring data is computerized. Data is not computerized for workers who terminated before computerization of records. Computer records also do not contain monthly or yearly breakdown of exposures for workers prior to 1961.

   The format of the computer records has not always been the same. For 1958 through 1960, exposures for each badge period and yearly totals are listed. From 1961 to present, exposures for each month, quarter, year and employment total are listed.

9. One week, two week and month (four or five weeks) long monitoring periods have been used. Since 1959, only monthly monitoring periods have been used.

10. The only summaries available are those reported annually since 1961 on AEC Form 190. There are yearly summaries of whole body (gamma) penetrating radiation. There are no summaries available for skin or extremity exposures.

III. Internal Monitoring Data

A. Bioassay Program

Uranium in urine analyses have been performed on a regular basis to monitor employees for exposure to airborne uranium. However, we have not used these results to make estimates of internal exposure.

B. Whole-Body Counting

1. Whole-body counting has been used since 1968.

2. Groups of employees doing the same jobs are scheduled for counting on the basis of their potential for exposure to airborne uranium. Additional counts are obtained on individuals whose count results are above 50% of a permissible lung burden.

3. Whole-body counting was done "in house."

4. We use the DOE's mobile body counter which was designed and is maintained by Union Carbide's Y-12 personnel. Initially, Y-12 personnel operated the counter at our site. Since about 1970 we have been operating the counter ourselves.

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Attachment 4.5-1 (Continued)

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5. The mobile body counter was programmed to provide radionuclide content of the workers. Consequently, we were not required to calculate this from the raw counting data.

6. The amount of U^{235} in one lung burden or uranium at various U^{235} enrichments has been calculated on the basis that 0.017 µCi of uranium produces a dose to the lung of 15 Rem/year. The enrichment of the uranium in the lung is calculated from the total uranium and U^{235} values provided by the body counter. The amount of U^{235} representing one lung burden for that enrichment is then divided into the amount of U^{235} in the lung to obtain the percent of a lung burden.

C. Other Internal Monitoring Techniques

1. Air monitoring results were never used to estimate internal deposition.

2. No other monitoring methods were used to estimate internal deposition other than whole-body counting.

D. Administration and Recordkeeping

1. Internal monitoring reports are not computerized.

2. Unusual values are validated by additional counts obtained on the individual. If a medically administered radioisotope is suspected, confirmation is obtained from the individual's doctor or the hospital.

3. If artifacts are discovered, a notation that the count results are unreliable is made in the worker's record. The reason for judging the count to be unreliable is also included in the notation.

4. Prior to 1979, there was no formal procedure for merging internal and external dosimetry data although this was done for the higher exposures. Since 1979 a listing has been prepared of those employees with either internal or external exposures above certain levels.

Attachments: Radiation Records Survey Questionnaire
Report on Examination, "Audit of Controls Over Radiation Badges"

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Finding 4.5-2: Unaccounted Doses to Extremities

Radioactive daughter products of the U-238 and Th-232 decay chains emit both beta and gamma radiation. Of particular concern is the high-energy beta emitted by Pa-234. For select processes such as the reduction of uranium and thorium to produce derbies or their remelting/casting, causes a separation of daughter impurities not only to concentrate on the surface of the derbies and ingots, but also the volatilization of these impurities.

Statements contained in Attachment 4.5-2A indicate that the ratio of recorded skin dose (beta and gamma) to deep dose (gamma only) varied significantly with time, as given in the following statement:

> *The highest skin exposure for 1963 was reported as 22.9 rem which includes 4.4 rem of penetrating radiation. The beta plus gamma to gamma ratio for the plant population has **decreased** significantly since 1960 when the ratio was 20.7 to 1 as compared to a ratio of 5.4 to 1 for 1963.* [Emphasis added.]

SC&A interprets these data to reflect monitoring data as recorded by the **whole-body dosimeters** normally worn on the chest area of the body.

Considerably high skin exposures involved **extremities** of the body as acknowledged in a **1970** Health Protection Appraisal Report (see Attachment 4.5-2B), which states the following:

> *NLO has performed a study of exposure to the forearms of some Plant 5 employees. The results of this study showed projected annual forearm exposure from about 14,000 to 46,000 mrem. According to NLO estimates, about 300 employees **would** require extremity monitoring because of potential exposure to the hands. It appears necessary that further attention by given by NLO to this matter. Extremity dosimeters should be provided as appropriate and an evaluation of involved operations should be made . . .*
>
> *The study does **not** indicate the level of **hand** exposure for these employees. From previous experience at other uranium facilities, it would be expected that the **hand** exposure could be 2-3 times the wrist exposure.* [Emphasis added.]

From these statements, SC&A concludes the following:

(1) The ratio of recorded "skin dose" to deep dose was highly variable over time as measured by the **whole-body dosimeter**.

(2) Shallow doses to extremities were likely several times higher, but were **not** monitored for a large fraction of FMPC's operating period.

(3) Potential extrapolation and use of the measured shallow dose (as recorded by the whole-body dosimeter) for deriving extremity doses to the forearms/hands poses serious