Review of the Bioassay Program at the Cabot Performance Materials Corporation Boyertown, Pennsylvania Plant

Prepared by:

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1. INTRODUCTION

This report provides the details of a review of the bioassay program that is in place at the Cabot Performance Materials, Inc. (CPM) Boyertown plant. The Boyertown plant holds radioactive materials license SMB-920, which was issued by the U.S. Nuclear Regulatory Commission (NRC). On the basis of this technical evaluation, a series of recommendations is provided.

This report is an update of an evaluation of the bioassay program that was performed during 1995 by the Canberra Special Services Division (Canberra 1995). The present report was prepared in response to item A of a Notice of Violation issued on October 23, 2001 by the NRC (Kinneman 2001).

This document is a companion report to the *Review of the Occupational Air Sampling Program at Cabot Performance Materials Corporation Boyertown, Pennsylvania Plant*, which was prepared for Cabot by Weston Solutions, Inc. during August 2002 (Weston Solutions, Inc. 2002). The air sampling program review develops the basis for the mixture derived air concentration (DAC) and gross alpha DAC. The whole body retention and excretion characteristics of the radioactive materials of concern are described in the present report.

2. EXPOSURE SCENARIOS AT THE BOYERTOWN PLANT

The CPM plant in Boyertown, Pennsylvania, extracts tantalum and niobium from ore materials that contain low concentrations of natural uranium and thorium. Almost all of the ores contain less than 1 percent uranium plus thorium (U + Th) by weight. The radioactive constituents are not extracted or concentrated from ore material during this process. Consequently, workers may be exposed to low concentrations of airborne uranium and thorium plus their radioactive progeny during routine plant operations.

During non-routine operations, however, higher air concentrations may exceed the DAC. These non-routine operations are presently performed in respirators to ensure that doses are as low as reasonably achievable (ALARA).

3. BASIS FOR THE BIOASSAY REQUIREMENTS

Cabot assigns internal radiation doses based on air sampling. Currently, Cabot is performing both area sampling and breathing zone sampling. As an ALARA measure, Cabot requires workers to wear respirators in Building 73. The use of respirators triggers the need for bioassay under Title 10 Code of Federal Regulations, Section 20.1703(C)2 (10 CFR 20.1703(c)2).

4. BIOASSAY PERFORMANCE REQUIREMENTS

NRC Regulatory Guide 8.9 (NRC 1993) provides the technical performance requirements for a bioassay program. The bioassay program is designed to detect acute intakes of radioactive materials that correspond to 40 DAC hours of exposure from the mixture. In addition, the bioassay program applies to all workers who wear respirators for protection against radioactive materials.

Based on annual whole body counting, CPM's current bioassay program was described as inadequate. The following discussion is provided to explain the basis for the CPM program.

5. DERIVATION OF INTAKES THAT WOULD CORRESPOND TO 40 DAC HOURS AND 200 DAC HOURS

This section establishes a rationale for a gross alpha DAC that may be used to estimate the committed effective dose equivalent from inhalation at the CPM Boyertown plant. The DAC is believed to be protective of workers and is reflective of the historical variability of the uranium-238 to thorium-232 ratio.

5.1 COMPOSITION OF THE ORE MATERIALS

A conservative composition of ore materials was developed during August 2002 and reported in the *Review of the Occupational Air Sampling Program at Cabot Performance Materials Corporation Boyertown, Pennsylvania Plant* (Weston Solutions, Inc. 2002). That evaluation of the uranium and thorium content of ores processed by CPM was based on 2001 as the reference year. Figure 1 is a graph of the activity percent uranium-238 versus the rank of the activity ratio for the ore received in 2001. Summary statistics for ores received in 2001 are provided in Table 1.

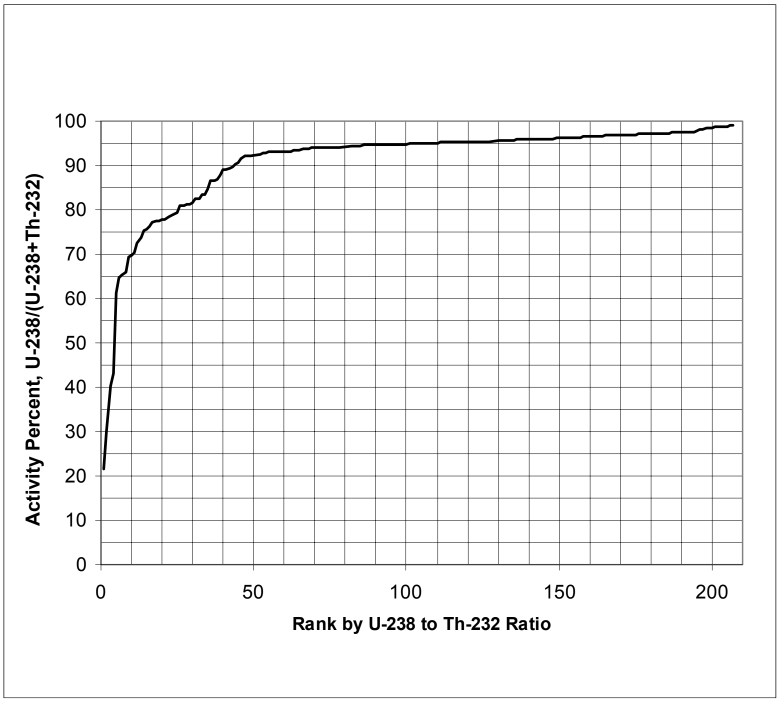

Figure 1. Plot of the Activity % Uranium Versus the Rank by U-238 to Th-232 Ratio

Table 1. Summary Statistics for the 207 Ta-Nb Ore Shipments Received by CPM During 2001

Average activity ratio: U-238/[U-238 + Th-232]	0.91
Median activity ratio: U-238/[U-238 + Th-232]	0.95
0.1 quantile activity ratio: U-238/[U-238 + Th-232]	0.78
95% lower confidence limit on 0.1 quantile activity ratio	0.75

As the ratio U-238/[U-238 + Th-232] gets smaller, the dose per picocurie (pCi) of intake increases. The assessment presented in this document is based on the ratio of 0.75 U-238 : 0.25 Th-232, which corresponds to the 95% lower confidence limit on the 0.1 quantile of the ratio distribution. Therefore, at least 90% of the time this ore composition is expected to overestimate the dose.

5.2 DECAY CHAINS FOR PRINCIPAL ISOTOPES

The uranium-238 decay chain is depicted in Figure 2. The nuclides below radium-226 in the decay chain are assumed to be present at 90% of their equilibrium values.

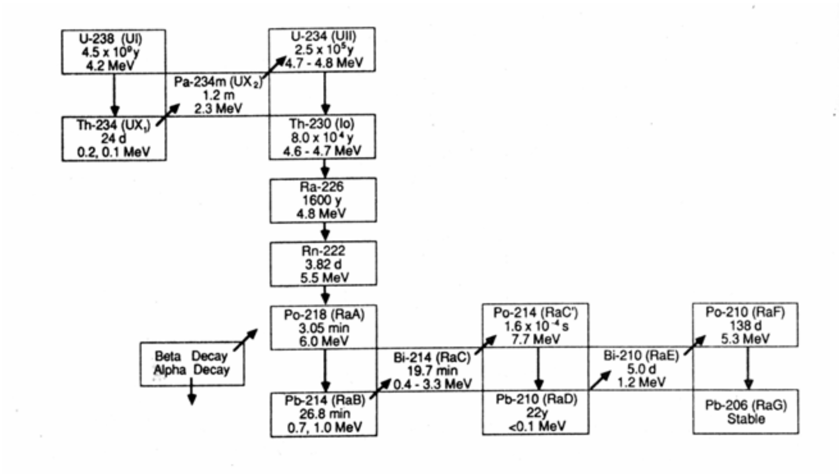

Figure 2. Uranium-238 Decay Chain (after NCRP 1988)

The thorium-232 decay chain is depicted in Figure 3. The nuclides below radium-224 in this decay chain are assumed to be present at 90% of their equilibrium values.

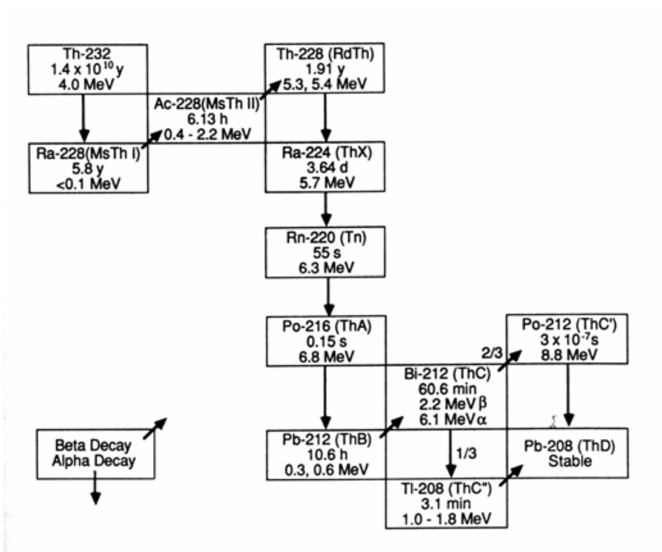

Figure 3. Thorium-232 Decay Chain (after NCRP 1988)

5.3 ANNUAL LIMITS OF INTAKE AND RELATED FACTORS

Tables 2 and 3 provide the annual limits of intake (ALIs) and related factors that were considered in developing a bioassay program. The detection limits for beta emitters are generally much higher than those for alpha emitters; thus beta emitters such as radium-228 (Ra-228) and lead-210 (Pb-210) were not considered suitable for in vitro bioassay analysis.

Table 2. Annual Limit of Intake and Related Factors for Ore Having an Activity Ratio of 75% U-238 : 25% Th-232 (3:1)

Isotope	ALI (μCi)	Lung Clearance Class	0.02 ALI (pCi)	Intake That Corresponds to 40 DAC Hours for Mixture[a]
Th-232	0.004	Y	80	24.1
Th-228	0.02	Y	400	24.1
U-238	0.04	Y	800	72.3
U-234	0.04	Y	800	72.3
Th-230	0.02	Y	400	72.3
Ra-226	0.6	W	12000	72.3
Po-210	0.6	W	12000	65.0

[a]Uranium-238 and chain are assumed to be present at three times the activity of Th-232 and chain.

Table 3. Airborne Radionuclide Concentrations for a Mixture of Decay Chains with an Activity Ratio of 3 U-238: 1 Th-232 That Corresponds to 1 DAC

Isotope	Airborne Concentrations in Mixture Corresponding to 1 DAC
Th-232	5.02E-13
Th-228	5.02E-13
U-238	1.51E-12
U-234	1.51E-12
Th-230	1.51E-12
Ra-226	1.51E-12
Po-210	1.36E-12

5.4 RETENTION AND ELIMINATION OF RADIONUCLIDES FROM THE BODY (ACUTE EXPOSURE)

Consistent with Regulatory Guide 8.9 requirements (NRC 1993), this section provides retention and elimination models that conform to the models provided in ICRP 30 (ICRP 1977) and ICRP 54 (ICRP 1988). The models for thorium-class Y, uranium-class Y, and radium-class W were implemented in Berkeley Madonna version 8.0.1, a commercially distributed dynamic simulation software package.[1] The models were validated by comparison with retention and excretion curves that were published in ICRP 54 and by mass balance considerations.

The excretion rate curves provided in Figures 4, 5, and 6 differ from ICRP 54 excretion rate curves in only one respect. The ICRP 54 curves are based on the excretion rate averaged over one day, while Figures 4, 5, and 6 (which are provided for information purposes only) represent the instantaneous excretion rates calculated by Berkeley Madonna. The instantaneous elimination rates are slightly lower than the daily average elimination rates during the first few days after an acute exposure occurs.

Figures 7, 8, and 9 provide the whole body retention and the total amounts of radioactivity excreted as a function of time. These figures are useful for estimating the cumulative amounts excreted at various times after an acute intake. Daily excretion rate data that are entirely consistent with ICRP 54 excretion curves are provided in Tables 4, 5, and 6; these values were obtained by subtracting the cumulative amount excreted for each day from the cumulative amount excreted as of the previous day. These tables also provide the amount of thorium-232, uranium-238, and radium-226 that are expected to be excreted per day following an acute intake of uranium-238 and thorium-232 (both with progeny) that is equivalent to 40 DAC hours. These estimates are based on an activity ratio of 3 uranium-238 : 1 thorium-232. Based on this activity ratio, the activity of thorium-230 excreted per day would be three times the amount of thorium-232 excreted per day; a separate table is not provided for thorium-230.

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[1] A freeware version of Berkeley Madonna is available at www.berkeleymadonna.com. Copies of the model definition files are available on request.

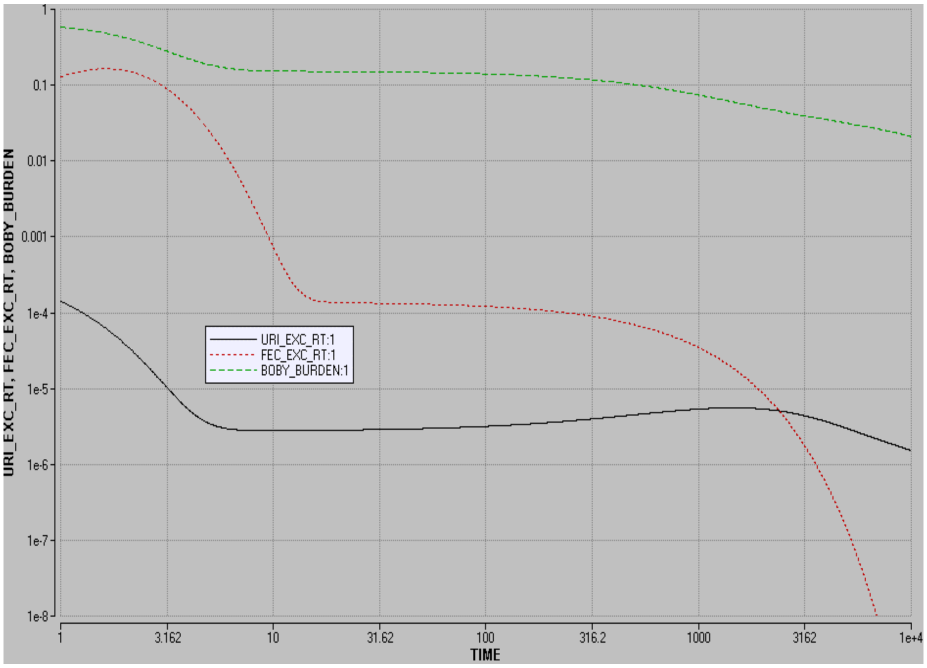

Figure 4. Instantaneous Daily Thorium Excretion Rate Versus Time (days)

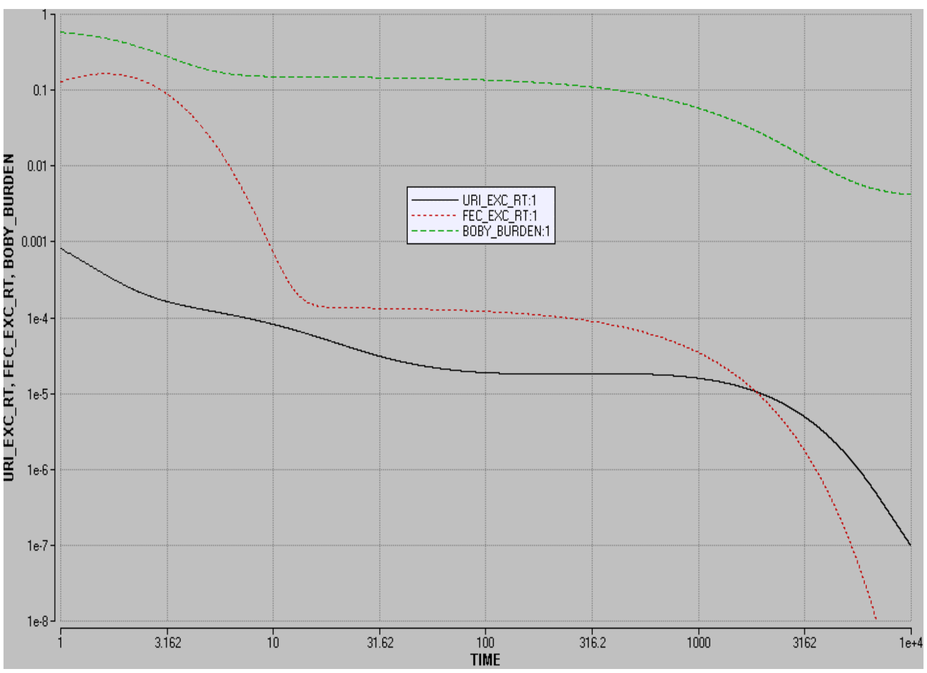

Figure 5. Instantaneous Daily Uranium Excretion Rate Versus Time (days)

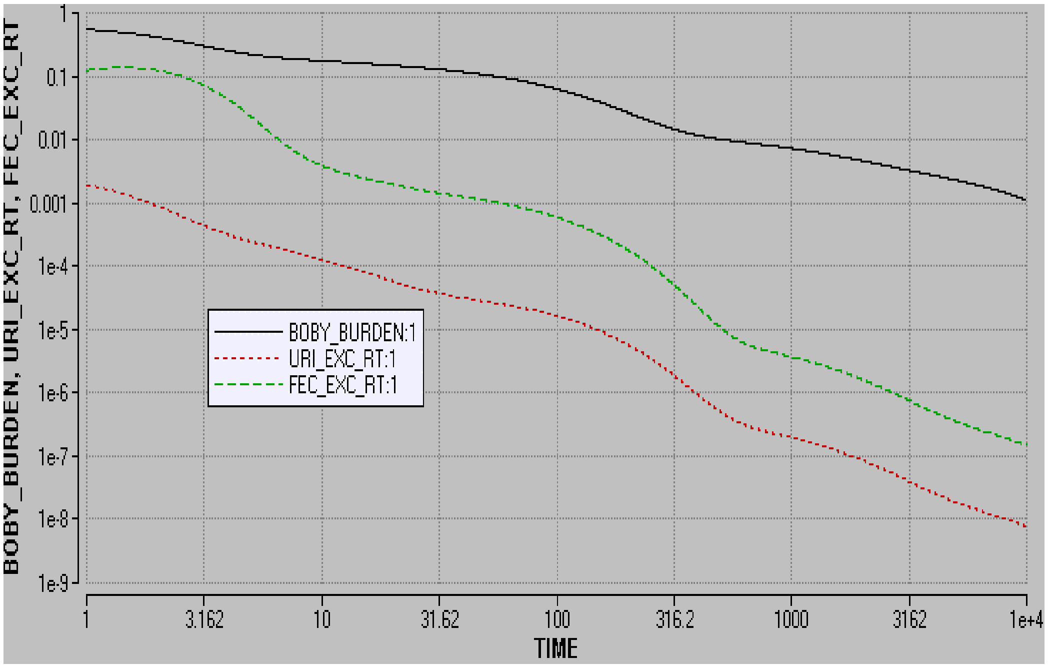

Figure 6. Instantaneous Daily Radium-226 Excretion Rate Versus Time (d)

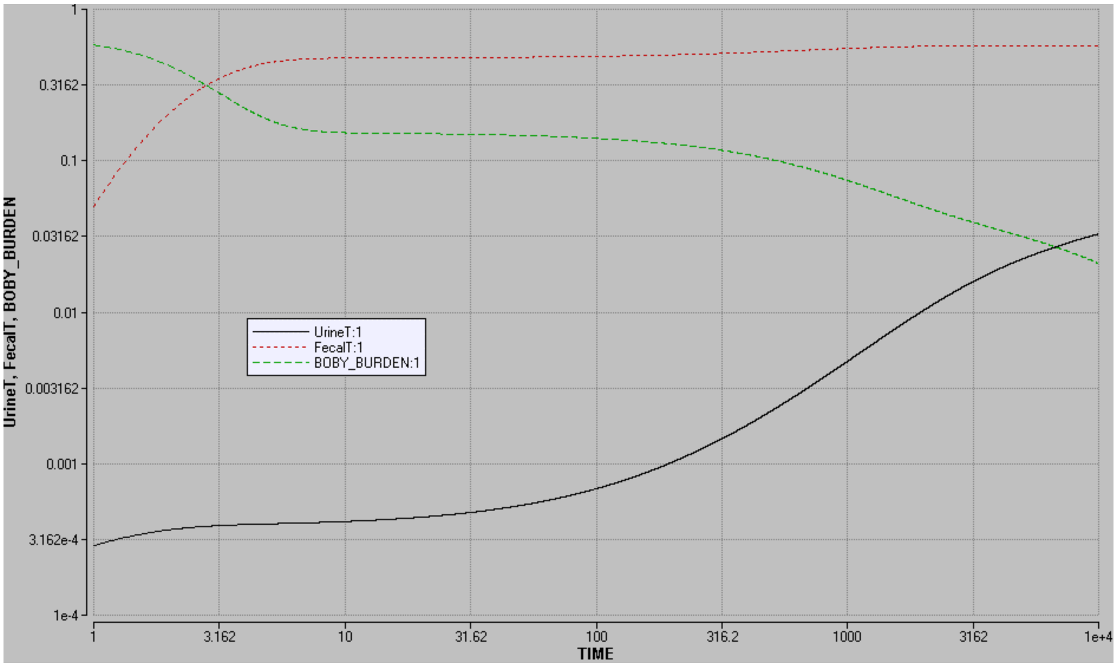

Figure 7. Thorium-230, -232 Whole Body Retention and Cumulative Excretion

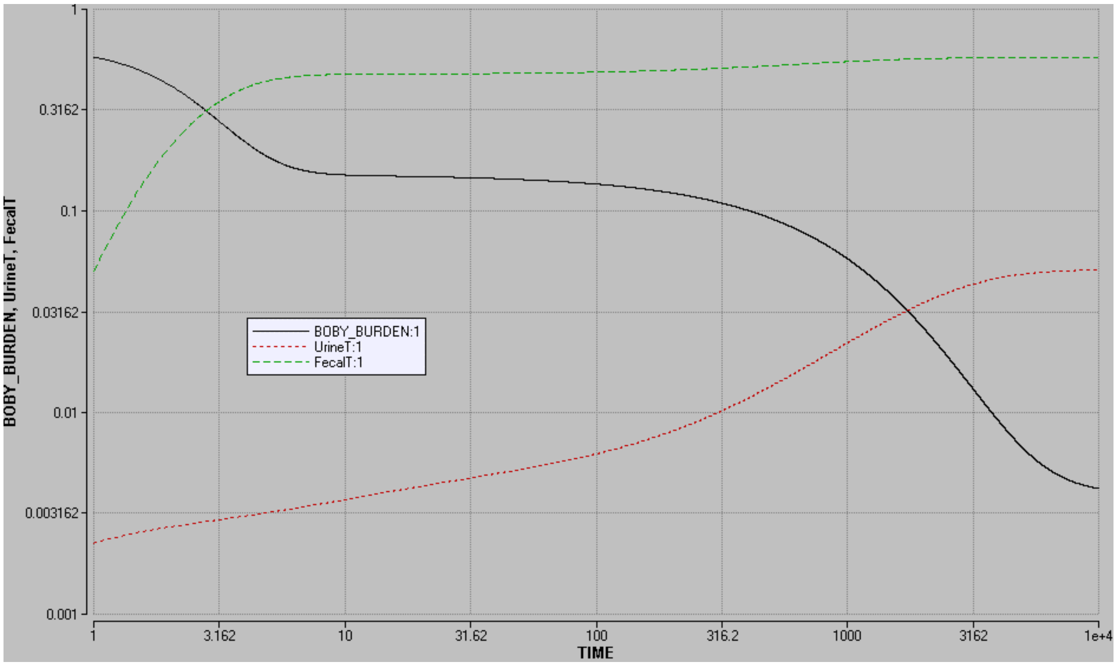

Figure 8. Uranium Whole Body Retention and Cumulative Excretion

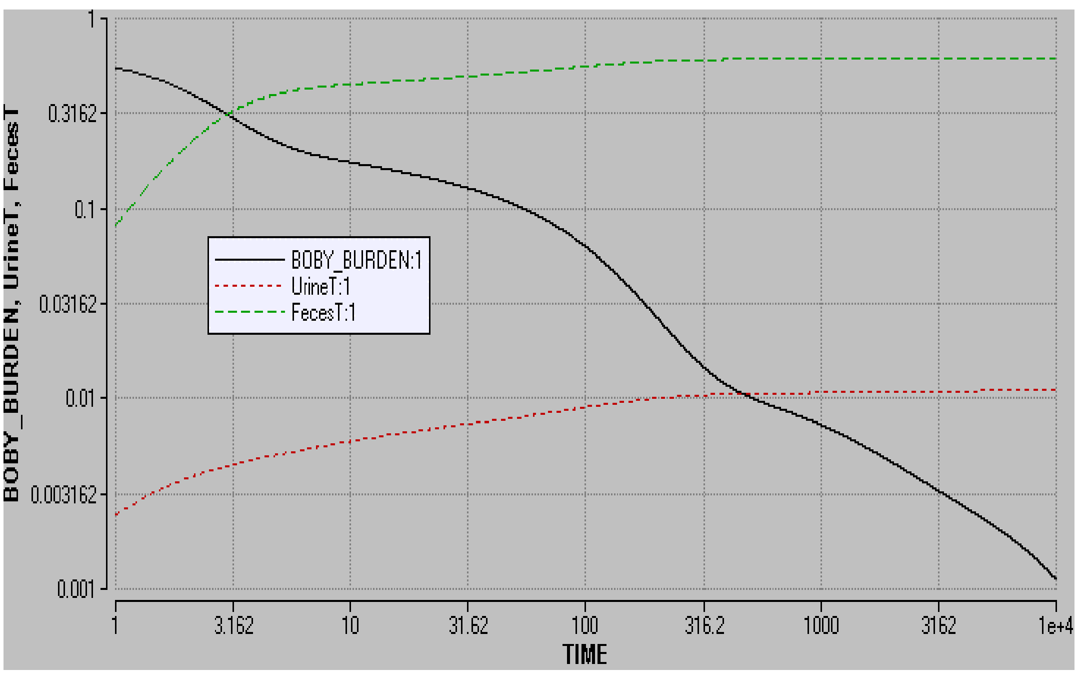

Figure 9. Radium-226 Whole Body Retention and Cumulative Excretion

Table 4. Thorium-232 Daily Excretion Rates

Time (d)	Fractional Excretion Rates		Activity Excreted per Day Following a Mixture Intake Equivalent to 40 DAC Hours	
	Daily Fecal	Daily Urine	pCi/d Feces	pCi/d Urine
1	5.01E-02	2.87E-04	1.21E+00	6.91E-03
2	1.56E-01	7.87E-05	3.76E+00	1.90E-03
3	1.28E-01	2.25E-05	3.08E+00	5.42E-04
4	7.30E-02	7.95E-06	1.76E+00	1.92E-04
5	3.64E-02	4.16E-06	8.77E-01	1.00E-04
6	1.73E-02	3.16E-06	4.17E-01	7.61E-05
7	8.19E-03	2.89E-06	1.97E-01	6.96E-05
8	3.92E-03	2.81E-06	9.44E-02	6.77E-05
9	1.94E-03	2.79E-06	4.67E-02	6.72E-05
10	9.98E-04	2.79E-06	2.40E-02	6.72E-05
11	5.54E-04	2.79E-06	1.33E-02	6.72E-05
12	3.40E-04	2.79E-06	8.19E-03	6.72E-05
13	2.36E-04	2.80E-06	5.69E-03	6.75E-05
14	1.85E-04	2.80E-06	4.46E-03	6.75E-05
15	1.61E-04	2.80E-06	3.88E-03	6.75E-05
16	1.48E-04	2.81E-06	3.57E-03	6.77E-05
17	1.42E-04	2.81E-06	3.42E-03	6.77E-05
18	1.38E-04	2.82E-06	3.32E-03	6.79E-05
19	1.37E-04	2.82E-06	3.30E-03	6.79E-05
20	1.36E-04	2.83E-06	3.28E-03	6.82E-05
21	1.36E-04	2.83E-06	3.28E-03	6.82E-05
22	1.35E-04	2.84E-06	3.25E-03	6.84E-05
23	1.35E-04	2.84E-06	3.25E-03	6.84E-05
24	1.34E-04	2.85E-06	3.23E-03	6.87E-05
25	1.34E-04	2.85E-06	3.23E-03	6.87E-05
26	1.35E-04	2.85E-06	3.25E-03	6.87E-05
27	1.34E-04	2.86E-06	3.23E-03	6.89E-05
28	1.33E-04	2.86E-06	3.20E-03	6.89E-05
29	1.34E-04	2.87E-06	3.23E-03	6.91E-05
30	1.33E-04	2.87E-06	3.20E-03	6.91E-05
31	1.34E-04	2.88E-06	3.23E-03	6.94E-05
32	1.33E-04	2.88E-06	3.20E-03	6.94E-05
33	1.32E-04	2.89E-06	3.18E-03	6.96E-05
34	1.33E-04	2.89E-06	3.20E-03	6.96E-05
35	1.33E-04	2.89E-06	3.20E-03	6.96E-05
36	1.32E-04	2.90E-06	3.18E-03	6.99E-05

Table 5. Uranium Daily Excretion Rates

Time (d)	Fractional Excretion Rates		Activity Excreted Per Day Following a Mixture Intake Equivalent to 40 DAC Hours	
	Daily Fecal	Daily Urine	pCi/d fecal	pCi/d Urine
1	5.00E-02	2.25E-03	3.62E+00	1.63E-01
2	1.56E-01	4.58E-04	1.13E+01	3.31E-02
3	1.28E-01	2.08E-04	9.27E+00	1.50E-02
4	7.28E-02	1.53E-04	5.26E+00	1.10E-02
5	3.63E-02	1.31E-04	2.62E+00	9.48E-03
6	1.73E-02	1.18E-04	1.25E+00	8.51E-03
7	8.17E-03	1.07E-04	5.91E-01	7.76E-03
8	3.92E-03	9.88E-05	2.83E-01	7.14E-03
9	1.93E-03	9.13E-05	1.39E-01	6.60E-03
10	9.97E-04	8.48E-05	7.21E-02	6.13E-03
11	5.52E-04	7.90E-05	3.99E-02	5.71E-03
12	3.39E-04	7.38E-05	2.45E-02	5.33E-03
13	2.36E-04	6.91E-05	1.71E-02	5.00E-03
14	1.85E-04	6.49E-05	1.34E-02	4.69E-03
15	1.61E-04	6.12E-05	1.16E-02	4.42E-03
16	1.47E-04	5.78E-05	1.06E-02	4.17E-03
17	1.42E-04	5.47E-05	1.03E-02	3.95E-03
18	1.38E-04	5.19E-05	9.97E-03	3.75E-03
19	1.37E-04	4.94E-05	9.90E-03	3.57E-03
20	1.36E-04	4.71E-05	9.83E-03	3.40E-03
21	1.35E-04	4.50E-05	9.76E-03	3.25E-03
22	1.35E-04	4.31E-05	9.76E-03	3.11E-03
23	1.34E-04	4.14E-05	9.68E-03	2.99E-03
24	1.35E-04	3.98E-05	9.76E-03	2.87E-03
25	1.34E-04	3.83E-05	9.68E-03	2.77E-03
26	1.34E-04	3.70E-05	9.68E-03	2.68E-03
27	1.33E-04	3.58E-05	9.61E-03	2.59E-03
28	1.34E-04	3.47E-05	9.68E-03	2.51E-03
29	1.33E-04	3.37E-05	9.61E-03	2.44E-03
30	1.33E-04	3.28E-05	9.61E-03	2.37E-03
31	1.33E-04	3.19E-05	9.61E-03	2.31E-03
32	1.33E-04	3.11E-05	9.61E-03	2.25E-03
33	1.33E-04	3.04E-05	9.61E-03	2.20E-03
34	1.32E-04	2.97E-05	9.54E-03	2.15E-03
35	1.32E-04	2.91E-05	9.54E-03	2.10E-03
36	1.32E-04	2.85E-05	9.54E-03	2.06E-03

Table 6. Radium-226 Daily Excretion Rates

Time (d)	Fractional Excretion Rates		Activity Excreted Per Day Following a Mixture Intake Equivalent To 40 DAC Hours	
	Daily Feces	Daily Urine	pCi/d Feces	pCi/d Urine
1	8.12E-02	2.45E-03	5.87E+00	1.77E-01
2	1.32E-01	1.35E-03	9.54E+00	9.77E-02
3	1.01E-01	6.47E-04	7.29E+00	4.68E-02
4	5.87E-02	3.80E-04	4.25E+00	2.75E-02
5	3.18E-02	2.76E-04	2.30E+00	1.99E-02
6	1.76E-02	2.24E-04	1.27E+00	1.62E-02
7	1.06E-02	1.92E-04	7.63E-01	1.39E-02
8	7.03E-03	1.69E-04	5.08E-01	1.22E-02
9	5.21E-03	1.50E-04	3.77E-01	1.09E-02
10	4.21E-03	1.35E-04	3.04E-01	9.74E-03
11	3.62E-03	1.22E-04	2.61E-01	8.80E-03
12	3.23E-03	1.11E-04	2.33E-01	8.00E-03
13	2.95E-03	1.01E-04	2.13E-01	7.30E-03
14	2.74E-03	9.26E-05	1.98E-01	6.69E-03
15	2.57E-03	8.52E-05	1.86E-01	6.16E-03
16	2.43E-03	7.88E-05	1.75E-01	5.69E-03
17	2.30E-03	7.31E-05	1.66E-01	5.29E-03
18	2.19E-03	6.82E-05	1.58E-01	4.93E-03
19	2.10E-03	6.38E-05	1.52E-01	4.61E-03
20	2.01E-03	6.00E-05	1.45E-01	4.34E-03
21	1.93E-03	5.66E-05	1.40E-01	4.09E-03
22	1.87E-03	5.36E-05	1.35E-01	3.88E-03
23	1.80E-03	5.10E-05	1.30E-01	3.69E-03
24	1.75E-03	4.87E-05	1.26E-01	3.52E-03
25	1.70E-03	4.66E-05	1.23E-01	3.37E-03
26	1.65E-03	4.47E-05	1.19E-01	3.23E-03
27	1.61E-03	4.31E-05	1.16E-01	3.11E-03
28	1.57E-03	4.16E-05	1.13E-01	3.01E-03
29	1.53E-03	4.03E-05	1.11E-01	2.91E-03
30	1.50E-03	3.91E-05	1.08E-01	2.82E-03
31	1.47E-03	3.80E-05	1.06E-01	2.74E-03
32	1.44E-03	3.70E-05	1.04E-01	2.67E-03
33	1.41E-03	3.61E-05	1.02E-01	2.61E-03
34	1.39E-03	3.53E-05	1.00E-01	2.55E-03
35	1.36E-03	3.45E-05	9.85E-02	2.50E-03
36	1.34E-03	3.38E-05	9.69E-02	2.45E-03

5.5 IMPLICATIONS FOR URINE BIOASSAY

The urine excretion rates following a 40 DAC hour exposure to the anticipated mixture of radionuclides at CPM's Boyertown Plant are provided in the extreme right columns of Tables 4, 5, and 6. On average a person excretes about 2 L of urine per day, so the typical concentrations in pCi/L of the radionuclides in urine would be about one-half of the values given in the last column of Tables 4, 5, and 6. Appendix C of ANSI/HPS N13.30-1996 (HPS 1996) provides reasonably achievable minimum detectable concentrations (MDC) for urine bioassay samples, which are summarized in Table 7.

Table 7. MDC Values by Alpha Spectroscopy From ANSI/HPS N13.30-1996 (HPS 1996)

Thorium-232, Thorium-230	0.1 pCi/L
Uranium-234, Uranium-238	0.1 pCi/L
Radium-226	0.1 pCi/L

Based on the excretion rates given in Tables 4, 5, and 6 and the MDC values in Table 7, urine bioassay samples would be of very limited value in detecting a 40 DAC hour exposure, as shown in Table 8. Table 9 presents the maximum time that bioassay could be useful in detecting a 200 DAC hour intake.

Table 8. Maximum Time Following a 40 DAC Hour Acute Exposure That Urine Bioassay Would Be Feasible

Thorium-232, Thorium-230, Class Y	Not recommended
Uranium-234, Uranium-238, Class Y	1 day[a]
Radium-226, Class W	1 day[b]

[a]Assuming that the exposure is instantaneous, the urine sample is collected over the 24 hours following the exposure, and that the laboratory ensures that they can achieve an MDC of 0.05 pCi/L. ANSI/HPS N13.22-1995, *Bioassay Programs for Uranium*, (HPS 1995) does not recommend urine bioassay for Class Y uranium.

[b]Assuming that the exposure is instantaneous, the urine sample is collected over the 24 hours following the exposure, and that the laboratory ensures that they can achieve an MDC of 0.05 pCi/L.

Table 9. Maximum Time Following a 200 DAC Hour Acute Exposure That Urine Bioassay Would be Useful

Thorium-232, Class Y	Not recommended
Thorium-230, Class Y	1 day
Uranium-234, Uranium-238, Class Y	2 days
Radium-226, Class W	3 days

If it be becomes commercially available thermal ionization mass spectroscopy (TIMS) is a new technology that would markedly improve the detection limits for urine bioassay.

5.6 IMPLICATIONS FOR FECAL BIOASSAY

The fecal excretion rates following a 40 DAC hour exposure to the anticipated mixture of radionuclides at CPM's Boyertown Plant are provided in the extreme fourth columns of Tables 4, 5 and 6. Appendix C of ANSI/HPS N13.30-1996 (HPS 1996) provides reasonably achievable minimum detectable activity (MDA) for fecal samples; these are restated in Table 10.

Table 10. MDA Values by Alpha Spectroscopy

Thorium-232, Thorium-230	1 pCi/sample aliquot, from ANSI/HPS N13.30-1996 (HPS 1996)
Uranium-234, Uranium-238	1 pCi/sample aliquot, from ANSI/HPS N13.30-1996 (HPS 1996)
Radium-226	0.5 pCi/sample aliquot.[2]

Based on the excretion rates given in Tables 4, 5, and 6 and the MDA values in Table 10, fecal bioassay samples would be useful for quantifying acute intakes for a few days following the event, as shown in Tables 11 and 12.

Table 11. Maximum Time Following a 40 DAC Hour Acute Intake That Fecal Bioassay Would Be Useful[a]

Thorium-232, Class Y	4 days
Thorium-230, Class Y	5 days
Uranium-234, Uranium-238, Class Y	5 days
Radium-226, Class W	6 days

[a]Each fecal sample will be split into two parts.

[2] Conversation with Eberline Services, Inc. Laboratory Manager, Karen Schoendaller, August 28, 2002.

Table 12. Maximum Time Following a 200 DAC Hour Acute Intake That Fecal Bioassay Would Be Useful

Thorium-232, Class Y	6 days
Thorium-230, Class Y	7 days
Uranium-234, Uranium-238, Class Y	7 days
Radium-226, Class W	13 days

5.7 IMPLICATIONS FOR WHOLE BODY COUNTING

The Canberra Special Services Division of Canberra Industries performed whole body counting for CPM during 1995 (Canberra 1995). Canberra reported the MDAs provided in Table 13 for that work.

Table 13. Whole Body Counting MDA Values Provided by Canberra Special Services Division

Isotope	Minimum Detectable Activity
Thorium-232 (based on Thallium-208)	1,000 pCi
Radium-226 (based on Bismuth-214)	1,300 pCi

Thorium-232. Based on the data in Table 2, the amount of thorium-232 that represents a 2,000 DAC hour exposure to an ore dust mixture is 1,205 pCi [= 2000 DAC hours *(24.1 pCi/40 DAC hours)]. At a deposition efficiency of 63%,[3] a 1,205-pCi intake of thorium-232 corresponds to a deposition of 759 pCi of thorium-232. This is less than the MDA of the whole body counter. Thus the whole body counting system would not detect the thorium-232 component in a 2,000 DAC hour exposure that occurred an instant before the count.

Uranium-238. Uranium-238 cannot easily be directly detected by whole body counting. The uranium-238 concentration can best be inferred from the gamma emissions of bismuth-214. A 2000 DAC hour exposure to the ore dust mixture would result in an intake of 3,615 pCi of bismuth-214 and a deposition of 2,207 pCi. Because this exceeds the 1,300-pCi MDA for the

[3] According to the ICRP 30 lung model (ICRP 1977), inhalation of radioactive particulate having a 1 μm activity median aerodynamic diameter (AMAD) results in a deposition of 63% in the respiratory tract. The remainder of the intake is exhaled.

system, the uranium-238 would be detected if the exposure occurred the instant before the count. Based on the intake whole body retention curve for uranium given in Figure 8, the hypothetical acute 2,000 DAC hour intake event would be detectable for about 2.5 days.

6. CONCLUSIONS AND RECOMMENDATIONS CONCERNING THE BIOASSAY PROGRAM

The following conclusions are offered concerning the CPM bioassay program:

- Urine bioassay is not sensitive enough to reliably detect intakes of ore material mixtures that correspond to 40 DAC hours or a dose of 100 mrem, even if samples are collected during the 24 hours following an acute exposure.
- As indicated in Table 10, analysis of fecal samples is a sufficiently sensitive method to detect intakes of ore material mixtures that correspond to 40 DAC hours or a dose of 100 mrem, for several days following an acute exposure. Samples should be collected that represent the fecal elimination over a 24-hour interval beginning 24 hours after the acute exposure. Undoubtedly a fecal bioassay program would be very unpopular with the CPM staff.
- Whole body counting is not sensitive enough to detect an acute deposition of the thorium-232 in ore dust that corresponds to an acute exposure of 2,000 DAC hours regardless of the elapsed time between the exposure and whole body count.
- Whole body counting would not be sensitive enough to detect a deposition of uranium-238 in ore dust that corresponds to an acute exposure of 2,000 DAC hours for more than about 2 or 3 days after event.
- The need for bioassay is triggered by respirator use.

Suggestions that result from this study:

- Minimize the number of people who wear respirators and who are thus required to participate in the bioassay program.
- Obtain approval from NRC to use dust cyclones for personal air sampling in order to demonstrate that radionuclide air concentrations do not exceed 10% of the DAC. This would reduce DAC hour estimates for routine, non-dusty activities to levels where routine respirator use could be discontinued while still maintaining radiation exposures ALARA.
- Implement feasible engineering controls and plan radiological work so that airborne radionuclide concentrations are minimized during dusty, non-routine activities. This change will minimize respirator use and limit the impact of the bioassay program on operations.

- Implement a bioassay program where a continuous air monitor alarm during respirator use triggers the need for a special bioassay sample. A bioassay program based on fecal sampling would be suitable.
- If TIMS analysis for uranium and thorium in urine becomes available, the feasibility of urine bioassay should then be re-evaluated.

7. REFERENCES

Canberra, 1995. *Report of Whole Body Counting for* Cabot *Performance Materials from June 21, 1995 to June 22, 1995*. CAB001. Canberra Special Services Division. Meriden, CT.

Health Physics Society (HPS), 1996. *Performance Criteria for Radiobioassay*. An American National Standard, ANSI/HPS N13.30-1996. McLean, VA.

HPS, 1995. *Bioassay Programs for Uranium*. An American National Standard, ANSI/HPS N13.22-1995. McLean, VA.

International Commission on Radiological Protection (ICRP), 1988. *Individual Monitoring for Intakes of Radionuclides by Workers: Design and Interpretation*, ICRP Publication 54, Annals of the ICRP, Pergamon Press, New York.

ICRP, 1977. *Limits of Intakes of Radionuclides by Workers*, ICRP Publication 30, Part 1, Annals of the ICRP, Volume 2. Pergamon Press, New York.

Kinneman, 2001. Letter from John D. Kinneman (U.S. Nuclear Regulatory Commission) from Martin O'Neill (Cabot Corporation). Inspection 04006940/2001001, Cabot Corporation, Boyerstown site and Notice of Violation, Docket 04006940, October 23, 2001.

National Council on Radiation Protection and Measurements (NCRP), 1988. *Measurement of Radon and Radon Daughters in Air*, NCRP Report 97. Bethesda, MD.

U.S. Nuclear Regulatory Commission (NRC), 1993. *Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program*, Regulatory Guide 8.9, Rockport, MD.

Weston Solutions, Inc., 2002. *Review of the Occupational Air Sampling Program at the Cabot Performance Materials Corporation Boyerstown, Pennsylvania Plant.* Albuquerque, NM.