Draft

ADVISORY BOARD ON RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

REVIEW OF THE NIOSH SITE PROFILE FOR BAKER-PERKINS, SAGINAW, MICHIGAN

BATTELLE-TBD-6001, APPENDIX P

Contract No. 200-2009-28555
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Prepared by

James East
S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, VA 22182

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Task Manager/Lead Author: _____ Date:_____ James East	Supersedes: N/A
Project Manager: _____ Date:_____ John Mauro, PhD	Peer Reviewer(s): John Mauro William C. Thurber

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	09/15/2010	Initial issue

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1.0 STATEMENT OF PURPOSE

The purpose of this report is to provide a critical review of Battelle-TBD-6001, Appendix P, Baker-Perkins (B-P) of Saginaw, Michigan. In this report, we assess the merit and technical basis of data and guidance to be used for dose reconstruction.

2.0 INTRODUCTION

On September, 12, 2007, NIOSH issued Appendix P to Battelle-TBD-6001, which provides data and guidance for dose reconstruction of workers at B-P. Equipment testing was performed with uranium trioxide over 5 days, May 14–18, 1956. No evidence is presented to suggest other Atomic Weapons Employer (AWE) work was performed at this site.

Equipment was being tested by National Lead of Ohio (Fernald) for performance in mixing uranium trioxide with water-ammonia solutions (Baumann 1956). Two kneading machines popular in the baking industry were being considered. These machines were also adopted by the plastics industry and held promise for use in uranium processing. The tests performed for National Lead of Ohio were not successful. Little is known about the exact location beyond the building noted as the "Laboratory Building, #15." Internal doses are reconstructed based on air samples taken before, during, and after the trial runs and documented on Analytical Data Sheets (pp. 16–25 of SRBD 9505). These data sheets are included as Exhibit 1 here. External doses are reconstructed using the default guidance provided in TBD-6001.

3.0 REVIEW OF SECTIONS P.2 THROUGH P.6 OF APPENDIX P: OBSERVATIONS AND/OR FINDINGS

Appendix P of Battelle-TBD-6001 is a brief document consisting of 7 pages that include 2 pages of text and 4 pages of tables. Because our review of Appendix P makes frequent reference to statements and numerical data and, owing to its brevity, Appendix P is enclosed herein as Attachment 1. Our review follows the sequence of topics as presented in Appendix P.

3.1 REVIEW OF SECTION P.2 "SITE DESCRIPTION"

Observation 1: Baker-Perkins site description is insufficient.

Many questions regarding the AWE operations at B-P remain open. The reader is left to assume that the only radioactive material on site was from the equipment testing. No guidance is provided on ventilation characteristics, B-P personnel that may have been in the area, or housekeeping practices that may aid in assigning dose. Data capture failed to identify the location of "Laboratory, Building 15" and its relative location to other buildings in the complex.

3.2 REVIEW OF SECTION P.3 "OCCUPATIONAL MEDICAL DOSE"

Appendix P states the following:

> *No documentation regarding occupational medical dose specific to Baker-Perkins--Michigan was found. Information to be used in dose reconstruction for which no specific information is available is provided in ORAUT-OTIB-0006* [ORAUT 2005].

A review of ORAUT-OTIB-0006 shows that Table 6-5 contains organ-specific default dose values for pre-1970 diagnostic posterior-anterior (PA) and lateral (LAT) x-rays. Table 6-5 also provides organ doses for photofluorography (PFG) exams that were commonly administered between 1945 and January 31, 1962. Lastly, Section 6.0 of ORAUT-OTIB-0006 also acknowledges the following:

> *At some sites, lumbar spine radiographs were routinely required for certain classes of male workers to determine the presence of back problems. The frequency of lumbar spine views, if required, was variable.*

Finding 1: Current guidance for assigning occupational medical dose is insufficiently prescriptive.

ORAUT-OTIB-0006 provides a menu of various types of diagnostic medical x-rays to which a worker may have been exposed. Section P.3 of Appendix P, however, provides no definitive guidance to the dose reconstructor with regard to the type(s) and frequency of x-rays that should be assigned. Since the subject project only lasted five days, one x-ray may be appropriate. In brief, guidance for dose reconstruction needs to be more prescriptive.

3.3 REVIEW OF SECTION P.4 "OCCUPATIONAL INTERNAL DOSE"

Tables P.1 and P. 2 of Appendix P provide daily inhalation and ingestion quantities for workers based on four job categories. Data contained in Tables P.1 and P.2 are to be used exclusively for the reconstruction of internal dose to workers.

The intake values are based on a rigorous air-sampling effort during the testing with 43 air samples documented in the Analytical Data Sheets. General area (GA) measurements were made before, during, and after the testing. Breathing zone (BZ) measurements were made during testing. In addition, some grab or point samples were taken from the exhaust of the HEPA vacuum and over the feed hopper. The air sampling appears to have documented the work environment for this very brief (5 days) testing period. The sampling period represented in the Analytical Data Sheets covers time periods consistent with the engineering test report (Baumann 1956). The test report indicates that all equipment was decontaminated at the completion of the testing, including disassembly of tested equipment.

The original data sheets indicate that dust masks, "Dust-Foe," were worn. To be claimant favorable, no protection from intake was applied for the masks.

In Appendix P, the data are condensed into geometric means for both GA and BZ samples. There are 26 GA samples, and 14 BZ samples reported in the record (Analytical Data Sheets, SRBD 9505) and transcribed into Table 1 below. Geometric means and standard deviations were recalculated for verification (see Exhibit 3). Values of geometric means and standard deviations in Appendix P appear reasonably consistent with verification values.

Table 1. Air Sample Data from Analytical Data Sheets, Baker-Perkins

Page	Date	Bkgnd cpm	Geo	Sample No	Time	Type	R	T	Q	Count	Time	C/min	d/m/m^3
8537	5/14/1956	0.27	0.4	6900	12:37	GA	0	10	0.2	7	15.3	0.19	3
8537	5/14/1956	0.27	0.4	6901	13:28	GA	0	10	0.2	14	15	0.66	12
8537	5/14/1956	0.27	0.4	6902	15:00	BZ	0	3.5	0.1	32	0.29	110.1	6,616
8537	5/14/1956	0.27	0.4	6903		BZ	0	3.5	0.1	32	0.97	32.72	1,669
8537	5/14/1956	0.27	0.4	6904		BZ	0	3.5	0.1	640	2.32	275.6	14,061
8537	5/14/1956	0.27	0.4	6905		GA	0	10	0.2	32	0.21	162	2,714
8538	5/14/1956	0.19	0.44	6906	15:32	GA	0	12	0.2	32	1.56	20.32	276
8539	5/15/1956	0.19	0.44	6907	8:39	GA	0	15	0.3	32	0.585	54.61	590
8539	5/15/1956	0.19	0.44	6908	8:39	GA	0	15	0.3	32	10.47	2.87	31
8539	5/15/1956	0.19	0.44	6909	9:03	GA	0	10	0.2	32	4.82	6.45	106
8539	5/15/1956	0.19	0.44	6910	9:03	GA	0	10	0.2	32	8.88	3.41	55
8540	5/15/1956	0.19	0.44	6911	9:19	GA	0	10	0.2	32	1.81	17.49	284
8540	5/15/1956	0.19	0.44	6912		BZ	0	5	0.1	32	0.22	145.3	4716
8540	5/15/1956	0.19	0.44	6913		BZ	0	2.5	0.1	640	2.97	215.3	13981
8540	5/15/1956	0.19	0.44	6914		Control	0			3	15	0.01	
8541	5/15/1956	0.19	0.44	6915	11:19	GA	0	15	0.3	32	8.35	3.64	39
8541	5/15/1956	0.19	0.44	6916	11:19	GA	0	15	0.3	13	15	0.68	7
8541	5/15/1956	0.19	0.44	6917		GA	0	12	0.2	32	7.27	4.21	57
8541	5/15/1956	0.19	0.44	6918		GA	0	12	0.2	32	8.45	3.6	49
8542	5/15/1956	0.13	0.46	6919		BZ	0	2	0	17	14.44	1.06	82
8542	5/15/1956	0.13	0.46	6920		BZ	0	2.5	0.1	20	11.59	1.6	99
8542	5/15/1956	0.13	0.46	6921	13:31	GA	0	20	0.4	20	12.08	1.53	12
8542	5/15/1956	0.13	0.46	6922		GA	0	20	0.4	20	8.16	2.32	18
8542	5/15/1956	0.13	0.46	6923		BZ	0	3	0.1	20	2.73	4.2	373
8542	5/15/1956	0.13	0.46	6924		BZ	0	5	0.1	20	1.11	1.89	556
8544	5/16/1956	0.13	0.48	6925		GA	0	10	0.3	20	6.79	2.82	44
8544	5/16/1956	0.13	0.48	6926	11:15	P	0	2	0	13	19.69	0.53	41
8544	5/16/1956	0.13	0.48	6927	11:19	P	0	1	0	8	16.79	0.35	54
8544	5/16/1956	0.13	0.48	6928	12:07	GA	0	15	0.3	20	9.8	1.91	20
8544	5/16/1956	0.13	0.48	6929		GA	0	15	0.3	20	10.79	1.72	18
8544	5/16/1956	0.13	0.48	6930		GA	0	20	0.4	20	20.88	0.83	6
8544	5/16/1956	0.13	0.48	6931		GA	0	20	0.4	20	2.39	8.24	64
8545	5/18/1956	0.19	0.44	6932	9:03	GA	0	15	0.3	32	0.88	36.17	391
8545	5/18/1956	0.19	0.44	6933		BZ	0	3	0.1	32	1.25	26.41	1375
8545	5/18/1956	0.19	0.44	6934		BZ	0	2	0	32	2.16	14.62	1187
8545	5/18/1956	0.19	0.44	6935		GA	0	15	0.3	32	1.41	22.51	244
8545	5/18/1956	0.19	0.44	6936		BZ	0	2.5	0.1	32	4.38	7.12	462
8545	5/18/1956	0.19	0.44	6937		BZ	0	4	0.1	32	1.49	21.29	864
8547	5/18/1956	0.19	0.44	6938		BZ	0	3	0.1	32	1.14	27.88	1509
8547	5/18/1956	0.19	0.44	6939	9:44	GA	0	15	0.3	32	0.21	152.2	1647
8547	5/18/1956	0.19	0.44	6940		GA	0	25	0.5	32	0.16	213.1	1384
8547	5/18/1956	0.19	0.44	6941		p	0	1	0	32	15	1.01	164
8547	5/18/1956	0.19	0.44	6942	12:35	GA	0	22	0.4	32	0.91	34.97	258
8547	5/18/1956	0.19	0.44	6943	14:17	GA	0	20	0.4	32	2.45	12.87	104

The following definitions of parameters are assumed:

Parameter	Definition
Page	Data sheet page number
Sample No	Sample number
Geo	Geometry factor for detector
Time	Time of day sampling started
Type	GA and BZ for General Area and Breathing Zone
R	Air sampler flow rate in cubic meters per minute.
T	Sampling duration in minutes
C/min	Counts per minute
d/m/m^3	Designations per minute per cubic meter of air sampled

Guidance is provided for each of the four worker categories in Tables P.1 through P.4. Exposure for the four worker categories is adjusted based on perceived proximity to the source term. More about this practice may be found in the external dose section below.

Table P.1 states that the inhalation intake for an operator (Plant Floor High) is 31.5 pCi/ day, based on using the BZ data for 50% of the work-day and the GA data for the balance of the day. The GA and BZ air concentration values are 92 and 1,210 dpm/m^3, respectively, as determined by geometric mean of reported observations. Converting this information to intake in pCi/day results in an inhalation exposure of 2,815 pCi/day, as shown below. However, Table P.1 shows a value of 31.5 pCi/day, which appears to be the result of spreading the 5 days of intake over the year. There is a concern that this approach will lead to confusion in applying the guidance. The directions say to multiply this value by 73 (believed to be based on 365 ÷ 5) for daily intake for the year. This essentially reverts back to an intake of 2,815 pCi/d now applied to the whole year. We further note that generally, the dose reconstruction guidance is presented in units of pCi/calendar-day, not per work-day as was done in Appendix P. The approach taken in Appendix P is confusing and likely to lead to errors of interpretation.

Parameters used to calculate inhalation intakes include GA air concentration of 92 dpm/m^3, BZ air concentration of 1,210 dpm/m^3, an inhalation rate of 1.2 m^3/h (IR), time conversion of 8 work hours per day (WH), and a unit conversion factor of 1 pCi/2.22 dpm (UC). Unit analysis yields final units of pCi/day.

The inhalation of the Plant Floor High (PFH) may be determined by the following equation:

$$\begin{aligned} \text{Inhalation(PFH)} &= (GA*0.5 + BZ*0.5) * [IR] * [WH] * [UC] * [wfrac] \\ &= (92/2 + 1210/2) * 1.2 * 8 *1/2.22 \\ &= 2{,}815 \text{ pCi/day} \end{aligned}$$

The inhalation of the Plant Floor Low (PFL) may be determined by the following equation:

$$\begin{aligned} \text{Inhalation(PFL)} &= (GA*0.75 + BZ*0.25) * [IR] * [WH]* [UC] \\ &= (92*0.75 + 1210*0.25) * 1.2 * 8 *1/2.22 \\ &= 1{,}606 \text{ pCi/d} \end{aligned}$$

The above values represent the daily intake for workers based on geometric means, exposure fractions of GA and BZ, and an 8-hour work day. Appendix P goes one step further to apply this 5-day data to the whole year by dividing by 73. If we now divide our results by 73, we obtain 39 and 22 pCi/d for inhalation PFH and PFL, respectively.

These results compare favorably with the Appendix P values of 32 and 17 pCi/d, with the slight variation unexplainable. The remainder of the intake values in Tables P.1 and P.2 were also consistent with the first two examples.

Finding 2: The approach taken in the Appendix P exposure tables of annualizing the dose from 5 days of exposure and presenting the data in terms of exposure per work-day is confusing and can lead to errors by the dose reconstructor.

No guidance is provided for choosing the applicable value for a case. What exposures, if any, are to be assumed for workers in buildings other than Laboratory Building #15?

Finding 3: NIOSH should include guidance on how to reconstruct doses for employees not working in Laboratory Building #15.

Observation 2: Table P.1 incorrectly describes 1,210 dpm/m^3 as the Plant Floor High air concentration as the "Daily Weighted Air Concentration," but according to Section P.4, it is the median BZ concentration.

As noted above, NIOSH estimates the inhalation exposure by assuming that half of the operator's exposure is based on median BZ measurements and half is based on GA samples. Given that the exposures at B-P were from laboratory work, it is possible that some workers received high-end exposures. Therefore, assigning median values may understate the exposures actually experienced by some operators.

Finding 4: NIOSH should demonstrate that the chosen approach is claimant favorable, or consider using an alternative metric such as the 95th percentile.

3.4 REVIEW OF SECTION P.5 "OCCUPATIONAL EXTERNAL DOSE"

Annual external whole-body doses from **penetrating** radiation and external doses to the **skin** for four categories of B-P workers are defined respectively in Section P.5 and Tables P.3 and P.4. There are no data for external exposure on the Analytical Data Sheets. Records indicate that the material was in drums, and there may have been two drums, but no basis to assume more than two (SRDB 9505).

Whole-body exposures are presumably taken from Table 7.1 of TBD-6001 for Boildown and Denitration operations, and are stated in Table P.3 to be 1.28 mR/d Plant Floor High (operator). Exposures for Plant Floor Low, Supervisor, and Clerical are listed as 1.27, 1.26, and 4.08E-04 mR/d, respectively. Since, the external doses are based on default values in TBD-6001, we have included in Attachment 2 the issues matrix that was prepared and used at the last TBD-6001 work group meeting. The TBD-6001 findings regarding external exposures pertain to the external exposures for this review.

Observation 3: NIOSH should document the basis to justify reduced exposures for job categories other than Plant Floor High.

The data for the Denitration and Boildown operations in Table 7.1 of TBD-6001 appear to contain errors. For example, the exposure at 1 m from a 55-gallon drum of uranium products is listed as 3.10 mR/h and the source for this information is cited as Table 7.2 of TBD-6001. A value of 3.1 mR/h does not appear in Table 7.2. In addition, the data for exposure at 1 cm are actually for 100 cm.

One case has been reviewed in the course of this assessment revealing a lack of information regarding the location of the subject testing and raises concerns of the application of job

categories. It is clear that workers would have been in close proximity of the sample drums and equipment to be exposed, yet NIOSH has not established where on this multi-building site the material was handled. As a result, guidance on how to determine job categories in the external dose tables is lacking. Without guidance, the dose reconstructor has no option but to choose the highest dose category.

Finding 5: Table 7.1 of TBD-6001 apparently contains errors, which makes it difficult to trace information in Table P.3 to its source.

If one assumes per Table 7.2 of TBD-6001 that the external dose at 100 cm from a 55-gallon drum is 0.3 mR/h[1], then the dose per calendar-day would be 1.64 mR (0.3 × 8 × 250/365). Averaging this value over a full year, rather than the 5 days of exposure at B-P, results in a whole-body exposure of 0.022 mR/calendar-day, a value much lower than that presented in Table P.3.

Similarly, Table P.4 lacks transparency. The dose to the hands and arms from non-penetrating radiation is stated to be based on a value of 9.0 mrem/day (4.5 mrem/hr × 2 hr/day) from Table 7.1 (Boildown and Denitration). This value is, in turn, attributed to Table 7.2, which presents photon plus Bremsstrahlung doses, not beta doses. Exposure of the hands to non-penetrating radiation 50% of the time, as stated in Table P.4, would result in an exposure of 24.7 mR/calendar-day (9 × 0.5 × 8 × 250/365). Averaging this value over a full year, rather than the 5 days of exposure at B-P, results in a dose to the hands of 0.34 mR/calendar-day, a value about one-third that presented in Table P.4. Exposure to the skin other than the hands and arms is reported in Table 7.1 of TBD-6001 as 2.65 mrem/hr, but no source is provided for this value. Elsewhere in TBD-6001 (Section 3.3.1), the authors note that the beta dose can be estimated to be 10 times the photon dose at 1 foot. Under the estimation tool, one can calculate from Table 7.2 that the beta dose is 6.5 mrem/hr (1.3 mR/h ÷ 2 × 10).

Finding 6: NIOSH should provide sufficient detail to permit the reader to duplicate the external dose calculations in support of Tables P.3 and P.4.

3.5 REVIEW OF SECTION P.6 "RESIDUAL CONTAMINATION"

The assumption that there is little potential for significant residual contamination appears to be valid. The documented cleanup of the equipment and post-job air sampling indicate a careful effort to restore the equipment and work area to pre-test conditions. Whereas measurable quantities of UO_3 contamination above release limits are typically visible to the unaided eye, simple cleaning of the area to levels that would be presentable housekeeping to the next potential customer visiting the test lab would have reduced residual contamination below measurable values of contamination. Such housekeeping relieves concern of resuspension, and therefore potential worker exposure to UO_3.

There are no findings regarding residual contamination.

[1] This value includes dose from both photons and Bremsstralung radiation.

3.6 SURROGATE DATA

The B-P site profile did not rely on surrogate data. Internal exposures were based on air sampling data and external exposures were based on MicroShield modeling.

4.0 CONCLUSION

Our review has resulted in six Findings and three Observations. Appendix P as written is not well supported, provides confusing guidance, and leaves too many options for a situation that is very limited in scope. The allowed options do not provide significant changes in the POC that would be advantageous to the claimant and raise questions of consistency of approach. With more specific guidance, the reconstructions would be direct and consistent while remaining favorable to the claimant.

5.0 REFERENCES

Analytical Data Sheets and records, re: May 14–18, 1956 at Baker-Perkins, Saginaw, MI; SRDB Ref ID: 9505.

Battelle 2006. Site *Profiles for Atomic Weapons Employers that Refined Uranium and Thorium*, Battelle-TBD-6001, Rev. F0; Battelle; December 13, 2006; SRDB Ref ID: 30673.

Battelle 2007. *Default Assumptions and Methods for Atomic Weapons Employer Dose Reconstructions*, Battelle-TIB-5000, Rev. 00; Battelle; April 2, 2007.

Baumann, J. E. 1956. Laboratory Test Report No 1246, Baker-Perkins Inc, SRDB Ref ID: 63508.

ORAUT 2005. *Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, ORAUT-OTIB-0006, Rev. 03, Oak Ridge Associated Universities Team: Cincinnati, Ohio. December 21, 2005.

Exhibit 1. Analytical Data Sheets

(Source: SRDB Ref ID 9505)

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ANALYTICAL DATA SHEET
ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

~~SEPARATED~~ MI.13 OUTPAINT THE DUST

No 8536

NLO

1956 Industrial Hygiene or Medical Dept.

I. H.# 822 Sample Nos. 3 Date Collected 5/17 by CES Route to CES

Location BAKER-PERKINS CO. Type of Sample water Analyzed for F Alpha

Remarks SAGINAW, MICHIGAN U xxx Beta

Samples of water discharged to river during steam clean- NO_3 Ra

ing of equipment. Oil pH

Be Th

Analytical Chemistry Section:

Date Received 6-21-56 by Labs.

Date Reported 6-23-56 by Labs.

Method of Analysis Fluorimeter by Lab.

Counting Data:

BKGD GEO

Sample No.	Hour	Sample Description	R	T	Q		Vol.		ppm U
		Please analyze for gm/U/gal.							
BP-1		P - KO-Kneader					130 ml.		.078
BP-2		K - KO-Kneader					130 ml.		.531
BP-3		Omega Feeder					130 ml.		64.66

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NLO-HDS-736 (2-2-56)

Exhibit 1. Analytical Data Sheets (continued)

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ANALYTICAL DATA SHEET

ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

Nº 8537

Industrial Hygiene or Medical Dept.

1956

I. H.# 813 Sample Nos. 6 Date Collected 5/14 by CES Route to CES

Location BAKER-PERKINS CO. Type of Sample air dust Analyzed for F Alpha

Remarks SAGINAW, MICHIGAN U Beta

Mixing tests conducted in Bldg. 15 (Laboratory Bldg.) NO_3 Ra

Oil pH

Be Th

Analytical Chemistry Section:

Date Received 5-21-56 by Lab

Date Reported 5-22-56 by MW

Method of Analysis Alpha scintillation opunter 2 by CJM

Counting Data:

BKGD .27 c/min GEO 40%

Sample No.	Hour	Sample Description	R	T	Q	Count	Time	C/min	d/m/M³
6900	1237	GA Background sample collected in Ko-Kneader area prior to opening or processing of any material.	.02	10	.2	7	16.30	0.19	3
6901	1328	GA Same as 6900	.02	10	.2	14	16	0.66	12
6902	1500	BZ Scooping orange oxide into Omega feed hopper. Dust-foe respirator worn.	.02	3.5	.07	32	0.29	110.07	5616
6903		BZ Same as 6902	.02	3.5	.07	32	0.97	32.72	1669
6904		BZ Same as 6902	.02	3.5	.07	660	2.32	276.59	14,061
6905		GA Ko-Kneader area during filling of feed hopper.	.02	10	.2	32	0.21	151.97	2714
		The operator was very careful in scooping material from the drum to the hopper. However, no matter how careful, the scooping produces a very fine, barely visible dust which disperses in the air around the machine.							

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NLO-H&S-736 (2-2-56)

Exhibit 1. Analytical Data Sheets (continued)

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(2)

ANALYTICAL DATA SHEET

ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

Nº 8538

Industrial Hygiene or Medical Dept.

1956

I. H.# 814 Sample Nos. 1 Date Collected 5/14 by CDS Route to CDS

Location BAKER-PERKINS CO. Type of Sample air dust Analyzed for F Alpha xx

Remarks SAGINAW, MICHIGAN U Beta

No_3 Ra

Oil pH

Be Th

Analytical Chemistry Section:

Date Received 5-21-56 by Lab

Date Reported 5-22-56 by MW

Method of Analysis Alpha scintillation counter 2 by CJM

Counting Data:

BKGD .18 c/min GEO 44%

Sample No.	Hour	Sample Description	R	T	Q	Count	Time	C/min	d/m/M³
6906	1532	GA Ko-Kneader area during calibration of Omega feeder. Material fed through feeder and dropped into cardboard container from sample chute. Only visible dusting was when box was removed and emptied.	.02	12	.24	32	1.56	20/32	276

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NLO. H&S-736 (1.2.56)

Exhibit 1. Analytical Data Sheets (continued)

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ANALYTICAL DATA SHEET

ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

Nº 8539

1956 Industrial Hygiene or Medical Dept.

I. H.# 815 Sample Nos. 4 Date Collected 5/15 by CES Route to CES

Location BAKER-PERKINS CO. Type of Sample air dust Analyzed for F Alphaxx

Remarks SAGINAW, MICHIGAN U Beta

No_3 Ra

Oil pH

Be Th

Analytical Chemistry Section:

Date Received 5-22-56 by Lab

Date Reported 5-22-56 by MT

Method of Analysis Alpha scintillation counter 2 by CJM

Counting Data:

BKGD .19 c/min GEO 44%

Sample No.	Hour	Sample Description	R	T	Q	Count	Time	C/min	d/m/M³
6907	0839	GA East side of Ko-Kneader during first trial run.	.02	15	.3	32	5/86	54.61	690
6908	0839	GA West side of Ko-Kneader during same period as above. Water line plugged up after a few minutes of operating time and water supply cut off. Dry material dropped into product drum at discharge end causing considerable dust.	.02	15	.3	32	10.47	2.87	31
6909	0903	GA Same location as 6907; during 2nd test run.	.02	10	.2	32	4.82	6.46	106
6910	0903	GA Same as 6908; during 2nd test run. Some dusting as wet material falls into drum on top of dry material. Vacuum hose from Spencer inserted into drum to reduce amount of escaping dust. Water line plugged again toward end of sampling period (simultaneous with test period) and more dry material dropped from barrel resulting in more dust.	.02	10	.2	32	8.88	3.41	55

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NLO-H&S-736 (2-2-56)

Exhibit 1. Analytical Data Sheets (continued)

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(4)

ANALYTICAL DATA SHEET

ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

Nº 8540

1956 Industrial Hygiene or Medical Dept.

I. H.# 816 Sample Nos. 4 Date Collected 5/15 by CES Route to CES

Location BAKER-PERKINS CO. Type of Sample air dust Analyzed for F Alphaxx

Remarks SAGINAW, MICHIGAN U Beta

No_3 Ra

Oil pH

Be Th

Analytical Chemistry Section:

Date Received 5-22-56 by Lab

Date Reported 5-22-56 by MW

Method of Analysis Alpha scintillation counter 2 by CJM

Counting Data:

BKGD .19 c/min GEO 44%

Sample No.	Hour	Sample Description	R	T	Q	Count	Time	C/min	d/m/M³
6911	0919	GA Ko-Kneader area during hand scooping of material into feed hopper. Machine operating during this period.	.02	10	.2	32	1.81	17.49	286
6912		BZ Hand scooping material into feed hopper from drum. Dust-foe respirator worn.	.02	5	.1	32	0.22	145.26	4716
6913		BZ Continuation of 6912, except when drum was almost empty polyethylene liner was pulled out and remainder dumped from liner into feed hopper.	.02	2.5	.05	840	2.97	216.30	13,981
6914		Control Sample				3	16	0.01	

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NLO-H&S-736 (12-2-56)

Exhibit 1. Analytical Data Sheets (continued)

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ANALYTICAL DATA SHEET
ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

Nº 8541

Industrial Hygiene or Medical Dept.

1956
I. H.# 817 Sample Nos. 4 Date Collected 5/15 by CES Route to CES
Location BAKER-PERKINS CO. Type of Sample air dust Analyzed for F Alphaxx
Remarks SAGINAW, MICHIGAN U Beta
NO_3 Ra
Oil pH
Be Th

Analytical Chemistry Section:

Date Received 5-22-56 by Lab
Date Reported 5-22-56 by MW
Method of Analysis Alpha scintillation counter 2 by CJM
Counting Data:
BKGD .19 c/min GEO 44%

Sample No.	Hour	Sample Description	R	T	Q	Count	Time	C/min	$d/m/M^3$
6915	1119	GA West side of Ko-Kneader discharge as slightly watered material is run through barrel to push out hydrate which had adhered to sides of barrel.	.02	15	.3	32	8.35	3.84	39
6916	1119	GA SE corner of Ko-Kneader; simultaneous with 6915.	.02	15	.3	13	15	0.68	7
		At this point it was decided that the mixing could not be done on the Type "P" Ko-Kneader; that the Type "K" would be better. Decontamination of the "P" Ko-Kneader started at 1:04 p.m.							
6917		GA Ko-Kneader area during initial decontamination phase; chipping dried oxide cake from the wings and teeth and using flat vacuum tool attachment to vacuum loose material from barrel.	.02	12	.24	32	7.27	4.21	57
6918		GA Same as 6917	.02	12	.24	32	8.45	3.60	49

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Exhibit 1. Analytical Data Sheets (continued)

(6)

ANALYTICAL DATA SHEET
ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

Nº 8542

1956 — Industrial Hygiene or Medical Dept.

I. H.# 818 Sample Nos. 6 Date Collected 5/15 by CES Route to CES
Location BAKER-PERKINS CO. Type of Sample air dust Analyzed for F Alphaox
Remarks SAGINAW, MICHIGAN U Beta
NO_3 Ra
Oil pH
Be Th

Analytical Chemistry Section:

Date Received 5-22-56 by Lab
Date Reported 5-22-56 by MF
Method of Analysis Automatic alpha proport counter 1 by CJM
Counting Data:
BKGD .13 c/min GEO 46%

Sample No.	Hour	Sample Description	R	T	Q	Count	Time	C/min	$d/m/M^3$
6919		BZ Removing barrel from machine and placing on paper on floor for cleaning.	.02	2	.04	17	14.44	1.05	82
6920		BZ Chipping and vacuuming loose material from wings and teeth. No respirator worn.	.02	2.5	.05	20	11.59	1.60	99
6921	1331	GA During decontamination of barrel and screw.	.02	20	.4	20	12.08	1.53	12
6922		GA Same as 6921	.02	20	.4	20	8.16	2.32	18
6923		BZ Cleaning barrel with pneumatic powered circular brush. Dust-foe respirator and goggles worn.	.02	3	.06	20	2.75	8.20	373
6924		BZ Cleaning screw with pneumatic brush. Dust-foe respirator and goggles worn.	.02	5	.1	20	1.11	17.89	556

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Exhibit 1. Analytical Data Sheets (continued)

(S)

ANALYTICAL DATA SHEET
ANALYTICAL DEPT. – HEALTH AND SAFETY DIVISION

№ 8545

1956 — Industrial Hygiene or Medical Dept.

I. H.# 820 Sample Nos. 6 Date Collected 5/17 by CBS Route to CBS
Location BAKER-PERKINS CO. Type of Sample air dust Analyzed for F Alphaxx
Remarks SAGINAW, MICHIGAN U Beta
(Decontamination) "K" Ko-Kneader No_3 Ra
Oil pH
Be Th

Analytical Chemistry Section:

Date Received 5-22-56 by Lab
Date Reported 6-22-56 by MT
Method of Analysis Alpha scintillation counter 2 by CJM
Counting Data:
BKGD .18 c/min GEO 44%

Sample No.	Hour	Sample Description	R	T	Q	Count	Time	C/min	d/m/M³
6932	0903	GA Ko-Kneader area during start of decon-	.02	15	.3	32	0.88	36.17	391
		tamination; vacuuming, chiseling							
		caked UO_3 from screw and barrel.							
		Feed hopper removed during this sample.							
6933		BZ Using hammer and chisel to chip caked	.02	3	.06	32	1.25	25.41	1375
		UO_3 from screw. Dust-foe respirator							
		and goggles worn.							
6934		BZ Using hammer and chisel to chip caked	.02	2	.04	32	2.16	14.62	1187
		UO_3 from barrel.							
6935		GA Same as 6932	.02	15	.3	32	1.41	22.61	244
6936		BZ Vacuuming UO_3 from screw and barrel.	.02	2.5	.05	32	4.38	7.12	462
6937		BZ:Emptying feed hopper into poly-	.02	4	.08	32	1.49	21.29	864
		ethylene bag inside drum. Bag taped							
		sealed to discharge hopper.							

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ATTACHMENT 1. APPENDIX P TO 6001

Battelle
The Business of Innovation

Battelle Team
Dose Reconstruction
Project for NIOSH

Document Title:	Document Number: Battelle-TBD-6001 Appendix P
Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium	Revision: 0
Appendix P – Baker-Perkins– Michigan	Effective Date: 09/14/2007
.	Type of Document: TBD Appendix
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Subject Experts: R.I. Scherpelz

Document Owner Approval: Signature on file — Robert I. Scherpelz, Staff Scientist — Approval Date: 7/24/2007

Approval: Signature on file — Jay A. MacLellan, Battelle PNWD Task Manager — Approval Date: 7/24/2007

Concurrence: Signature on file — Richard J. Traub, Staff Scientist — Concurrence Date: 7/24/2007

Approval: Signature on file — James W. Neton, Associate Director of Science — Approval Date: 9/12/2007

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BAKER-PERKINS– MICHIGAN

P.1 Introduction

This document serves as an appendix to Battelle-TBD-6001 Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium. This appendix describes the results of document research specific to this site. Where specific information is lacking, research into similar facilities described in the body of this Site Profile is used.

P.2 Site Description

Baker-Perkins in Saginaw, Michigan, manufactures commercial mixers (among other products). Documentation demonstrates that a limited quantity of radioactive material was used in a test process with its mixers at its laboratory facility (a single building). Controls were in place during the process and post-operational decontamination was implemented with radiological surveys having been performed. AWE period of performance was five days in May, 1956.

P.2.1 Site Activities

On May 14-15, 1956, Baker-Perkins performed a test of its mixing equipment for NLO (Fernald). The tests involved mixing approximately 1-2 drums of uranium trioxide (orange oxide) with water and kneading the mixture with the Baker-Perkins "P" and "K" Ko-Kneader machines. Decontamination of the equipment was conducted on May 15-18, 1956. The cleaning included chipping, power brushing and steaming. Air monitoring was conducted across the five day period (Reference #9505, page 10, 16-25).

P.2.2 Job Categories

Each claim will be evaluated to determine the most appropriate Job Category from the list below.

Plant Floor High (Involved directly in operations)
Grinder
Plant Floor Low (Involved in support of operations)
Assembler
Supervisor
Draftsman/tester
Clerk
None reviewed

P.3 Occupational Medical Dose

No information regarding occupational medical dose specific to Baker-Perkins--Michigan was found. Information to be used in dose reconstructions for which no specific information is available is provided in ORAUT-OTIB-0006, the dose reconstruction project technical information bulletin covering diagnostic x-ray procedures.

P.4 Occupational Internal Dose

Air monitoring data were found in the Site Research database relating to occupational internal dose during the five days of AEC work (Reference #9505, pages 16-25). Results

of both breathing zone (BZ) and general area (GA) monitoring for alpha radiation (alpha scintillation) were reported. The geometric mean and geometric standard deviation for BZ monitoring were 1,210 dpm/m^3 and 4.91 respectively. The corresponding values for the GA samples were 92 dpm/m^3 and 5.48. There are not sufficient data on monitoring duration to calculate time-weighted averages. Therefore, internal doses will use the geometric mean of the distribution of measured exposures to represent exposure over the entire day. Considering the nature of the work and the types of samples taken, a "plant floor high" exposure would be calculated as 50% BZ and 50% GA exposure levels. "Plant floor low" would be calculated as 25% BZ and 75% GA exposure levels, while a "supervisor" would be 100% GA exposure. The "clerk" exposure would be 10% of the "supervisor" exposure.

Tables P.1 and P.2 present these internal dose estimates in pCi per calendar day to be used for each calendar year listed. The table values should be multiplied by 73 to calculate internal dose estimates for a single day of the 5 day exposure period.

P.5 Occupational External Dose

No external dose readings were reported in the Site Research database related to occupational external dose during the five days of AEC work. However, it was reported that "at least one, but no more than two 'drums' of orange oxide are believed to have been used in the tests" (Reference #9505, page 10). Thus external dose could be calculated assuming a distance of five feet from two drums of orange oxide, or by the external dose from air concentrations of orange oxide associated with the alpha radiation levels reported in P.4.

Alternatively, the Uranium Refining TBD external exposure for either "boildown and denitration" or "oxide reduction-tray furnace" operations could be used. Either of these exposures would be very favorable to the claimant as they are based upon industrial rather than experimental process volumes.

Tables P.3 and P.4 present these external dose estimates in mrem per calendar day to be used for each calendar year listed. The table values should be multiplied by 73 to calculate external dose estimates for a single day of the 5 day exposure period.

P.6 Residual Contamination

Documentation reviewed indicates that there is little potential for significant residual contamination outside of the period in which weapons-related production occurred.

P.7 References

1. DOE Office of Health, Safety and Security, EEOICPA web site. http://www.hss.energy.gov/healthsafety/fwsp/advocacy/faclist/findfacility.cfm
2. Report on Residual Radioactive and Beryllium Contamination at Atomic Weapons Employer Facilities and Beryllium Vender Facilities. http://www.cdc.gov/niosh/ocas/pdfs/tbd/rescon/rcontam1206.pdf

Table P.1 INTERNAL DOSE PATHWAYS - Inhalation of Airborne Radionuclides

Assumptions:
Operational Period Daily Weighted Average Air Concentration, Plant Floor High: 1210 dpm/m^3, GSD: 4.84
General Area Air Concentration: 92 dpm/m^3, GSD: 5.5
TBD GSD Default is 5
Conversion Factor: 2.22 dpm/pCi
Breathing Rate: 1.2 m^3/hour
All intakes and doses assume full-time employment for the given year.
Intakes are the geometric mean of a lognormal distribution

Job Category	Year	Operation Phase	Hr/Yr	Relevant Nuclide	Intake (pCi/d)	GSD	TBD Reference or Research Justification
Plant Floor High	1956	Operations	40	U234	3.15E+01	5.5	50% BZ + 50% GA (see text): GSD Max of BZ and GA
Plant Floor Low	1956	Operations	40	U234	1.73E+01	5.5	25% BZ + 75% GA (see text): GSD Max of BZ and GA
Supervisor	1956	Operations	40	U234	5.45E+00	5.5	100% GA (see text)
Clerical	1956	Operations	40	U234	5.45E-01	5.5	10% GA (see text)

Table P.2 INTERNAL DOSE PATHWAYS - Ingestion of Airborne Radionuclides

Assumptions:
Air Concentration to Intake Conversion Factor: 3.06E-05 (M^3/d)/(hr/y) - see 7.1.6 TBD-6000 and 8.5.3 TBD-6001
Deposition velocity: 0.00075 m/s
Resuspension Factor: 1.00E-06 1/m
Intakes are the geometric mean of a lognormal distribution

Job Category	Year	Operation Phase	Hr/Yr	Relevant Nuclide	Intake (pCi/d)	GSD	TBD Reference or Research Justification
Plant Floor High	1956	Operations	40	U234	2.94E-01	5.5	50% BZ + 50% GA (see text): GSD Max of BZ and GA
Plant Floor Low	1956	Operations	40	U234	1.61E-01	5.5	25% BZ + 75% GA (see text): GSD Max of BZ and GA
Supervisor	1956	Operations	40	U234	5.08E-02	5.5	100% GA (see text)
Clerical	1956	Operations	40	U234	5.08E-03	5.5	10% GA (see text)

Table P.3 EXTERNAL DOSE PATHWAYS - Whole Body

Assumptions:
Submersion Dose Conversion Factor: 2.462E-09 mrem/h/dpm/m^3
Deposition velocity: 0.00075 m/s
Contaminated Surface Dose Conversion Factor: 5.615E-10 mrem/h/dpm/m^2
All external dose from estimated exposure to Uranium Nitrate Drums
Residual period: Assume no handling of U metal - only exposure is from residual contamination on floor and in air
Dose in the table is the geometric mean of a lognormal distribution

Job Category	Year	Operation Phase	Hr/Yr	Relevant Nuclide	External Whole Body (mR/d)	GSD	TBD Reference or Research Justification
Plant Floor High	1956	Operations	40	U234	1.28E+00	5	Generic Refining TBD, Table 7.1 (Boildown and Denitration)
Plant Floor Low	1956	Operations	40	U234	1.27E+00	5	Same
Supervisor	1956	Operations	40	U234	1.26E+00	5	Same
Clerical	1956	Operations	40	U234	4.08E-04	5	Same

Table P.4 EXTERNAL DOSE PATHWAYS - Skin

Assumptions:
All assumptions from TBD-6000 Section 6.3
Operational Period: Non-penetrating dose to skin 9.0 mR/hour (hands and forearms) 2.65 mR/hour (other)
Plant Floor High: Assume hands in contact with material 50% of time. Other skin is 100% of dose rate at 1-ft, 20.8 mrem/h
Plant Floor Low: 50% of Plant Floor High
Supervisor: assume 10% of Plant Floor Low for time in contact with material
Clerical: assume no handling of U.
Residual Period: No Residual Period
Dose in the table is the geometric mean of a lognormal distribution

Job Category	Year	Operation Phase	Hr/Yr	Relevant Nuclide	Hands & Forearms (mR/d)	Other Skin (mR/d)	GSD	TBD Reference or Research Justification
Plant Floor High	1956	Operations	40	U234	9.86E-01	2.90E-01	5	Generic Refining TBD, Section 7.1 (Boildown and Denitration)
Plant Floor Low	1956	Operations	40	U234	4.93E-01	1.45E-01	5	Same
Supervisor	1956	Operations	40	U234	4.93E-02	3.63E-02	5	Same
Clerical	1956	Operations	0	U234	0.00E+00	0.00E+00	5	Same

Exhibit 2. Sample Geometric Standard Deviation Calculation

Calculation of Geometric Mean & GSD for BZ Concentrations (x)			
Sample No	**x**	**ln(x)**	**ln(x)-μ**
6933	1375	7.226	0.014
6934	1187	7.079	0.001
6936	462	6.136	0.949
6937	864	6.762	0.121
6919	82	4.407	7.307
6920	99	4.595	6.324
6923	373	5.922	1.412
6924	556	6.321	0.623
6912	4716	8.459	1.819
6913	13981	9.545	5.932
6938	1509	7.319	0.044
6902	6,616	8.797	2.847
6903	1,669	7.420	0.096
6904	14,061	9.551	5.960
sum:		99.5	33.45
observations:	14		
Geometric mean (x50):		**1224**	
μ=ln(x50):		7.11	
σ sqrd:			2.57
Geometric Standard Dev:			**4.97**

Calculation based on methods of Battelle-TIB-5000.

ATTACHMENT 2. ISSUES MATRIX FOR TBD-6001 AS OF JUNE 14, 2010

TBD-6001 Issues Matrix				
Finding or Observation	**SC&A TBD Review[a]**	**NIOSH Initial Response**	**SC&A Comments on NIOSH Response**	
Finding 1	It is not possible to judge whether the basic approach to developing inhalation doses in TBD-6001 is claimant favorable, based on the information presented in that document. However, based on analyses presented in this review, it appears that the average inhalation doses used in TBD-6001 are not claimant favorable, particularly for the period prior to 1948 (SC&A 2008, Section 8.1).			
Finding 2	TBD-6001 oversimplifies the process descriptions from Christofano and Harris (1960) and, as a result, may have missed or understated significant pathways for external and internal exposure (SC&A 2008, Section 4.0).			
Finding 3	The approach used in TBD-6001 to calculate the contribution to external exposure of contaminated dust settled on workplace surfaces is not appropriate. SC&A addressed the same issue in its review of TBD-6000 (SC&A 2007, Item 5). (See Section 3.1 in SC&A 2008 for basis of Finding 3.)	This issue has been resolved as part of the TBD-6000 Issue Resolution Process, based on the Battelle-TBD-6000 Issue 5 White Paper (Allen 2009). NIOSH demonstrated, based on data from Adley et al. 1952, that the median settling rate was 0.00023 m/s, as compared to 0.00075 m/s assumed in TBD-6000 and TBD-6001. The lower settling rate reduces external exposure from surface contamination and resuspended contamination. The assumption of a 7-day deposition period understates the expected total deposition, but the impact on external dose is trivial.	It would be helpful if NIOSH indicated why a deposition period of 7 days was used for calculating external dose from contaminated surfaces in TBD-6000 (Section 6.1.2), while a deposition period was used in TBD-6001 (Section 7.1.2).	
Finding 4	Summary Tables 7.1 and 7.3 in Section 7 of TBD-6001 that address external exposures require additional elaboration to understand the sources of the contained data and how the data were derived (SC&A 2008, Sections 7.1 and 7.3).			
Finding 5	*The approach taken by NIOSH to develop year-specific correction factors to inhalation doses does not appear to be claimant favorable. Doses in the early years may be understated.* (SC&A 2008, Section 8.3)			

TBD-6001 Issues Matrix				
Finding or Observation	**SC&A TBD Review[a]**	**NIOSH Initial Response**	**SC&A Comments on NIOSH Response**	
Finding 6	NIOSH did not consider radon exposures in developing inhalation exposure rates. Since pitchblende ore contains significant quantities of Ra-226 and its progeny, this omission significantly understates inhalation exposure rates for workers involved with operations at the front end (ore processing) of the refining process (SC&A 2008, Section 3.2).			
Observation 1	NIOSH states in Section 1 that the report provides the technical basis for reconstructing doses for AWE sites that refined uranium under government contract during the period 1942–1958; however, no basis is provided for selecting 1942–1958 as the relevant time period. We also note that NIOSH refers elsewhere to 1944 as the start date (pg. 4, second paragraph). NIOSH should document the basis for the dates and correct any inconsistencies.			
Observation 2	As noted in Section 2.0 of TBD-6001, Christofano and Harris (1960) do not present information on exposures from the solvent extraction unit operation. NIOSH notes in Section 8.2.2 that the air concentration data for solvent extraction are under development. NIOSH should provide the appropriate data.			
Observation 3	TBD-6001 should address possible exposures to Th-230 and Ra-226 for workers handling ore (SC&A 2008, Section 3.2).			
Observation 4	TBD-6001 also does not address exposures to enriched uranium (EU) or recycled uranium (RU). In light of this, Section 1 of the report, titled "Purpose and Scope," should make it clear that this document should only be used for workers involved in the processing of uranium ores and concentrates, and that it does not provide direction regarding exposures to workers who might have handled EU, RU, or ores containing Th-232 (SC&A 2008, Section 3.2).			

TBD-6001 Issues Matrix				
Finding or Observation	**SC&A TBD Review[a]**	**NIOSH Initial Response**	**SC&A Comments on NIOSH Response**	
Observation 5	Any use of a default air concentration for non-operational areas should provide some guidance as to what should be considered "non-operational areas of the plant." Use of a value of 7 dpm/m^3 would not be appropriate for all types of non-operational locations (SC&A 2008, Section 6.1).			
Observation 6	No information is provided as to how doses are apportioned to laborers, supervisors, and clerical staff in Table 7.3 of TBD-6001 (SC&A 2008, Section 7.5).			
Observation 7	It should be noted that in several of the TBD-6001 lognormal tables in Section 8, the reported GSD is less than 1, although the GSD for a lognormal distribution must be greater than 1. Hence, there appears to be an error here that needs to be corrected (SC&A 2008, Section 8.1).			
Observation 8	SC&A provided a list of minor clarifications and corrections that should be made to TBD-6001 (SC&A 2008, Section 9).			
Observation 9	Table 8.3 lists the GSD of the daily weighted average for ore as 4.939. Although not stated in TBD-6001, we presume that the GSD is calculated based on equations 3 and 10 of Strom 2007. Using these equations, we calculate the GSD to be 3.539. NIOSH should confirm what the correct value is for the GSD, and document the procedures used to calculate median and GSD values in Section 8.0 of TBD-6001.			
Observation 10	NIOSH states in Section 3.5 of TBD-6001 that, "The dose reconstructor should use the default values shown above. The default values of ICRP-66 (ICRP 1994) should be used." This is very confusing. In one sentence, the dose reconstructor is advised to use Table 3.12 and in the next, he is advised to use ICRP-66. In addition to confusing instructions, we believe that the correct reference should be ICRP-68, Annexe F, Table F.1. There are similar problems with the introductory material at the beginning of Section 8.0 in TBD-6001.			

TBD-6001 Issues Matrix				
Finding or Observation	**SC&A TBD Review[a]**	**NIOSH Initial Response**	**SC&A Comments on NIOSH Response**	
Observation 11	While the assumption of a 5-µm AMAD is often used for calculating inhalation doses, it is of questionable relevance when calculating surface contamination levels (SC&A 2008, Section 6.1, p. 20).			
Observation 12	In its review of TBD-6000, SC&A raised some concerns about the use of an air concentration of 7 dpm/m^3 for non-operational areas of a plant (SC&A 2007, Section 5). We further note here that exposures to workers in non-operational areas may be higher than that (SC&A 2008, Section 6.1, p. 20).			
Observation 13	NIOSH should explain why the calculations discussed in Section 8.4.2 are not done on the same basis as those in Section 3.4.2 (SC&A 2008, Section 8.2, p. 36).			

a – SC&A 2008. *Draft Review of Battelle-TBD-6001, Site Profiles for Atomic Weapons Employers That Refined Uranium and Thorium*, Revision FO Dated December 13, 2006, Contract No. 200-2004-03805, Task Order No. 1, SCA-TR-TASK1-0026.

Note: The "Observations" tabulated above are based on comments made by SC&A in the text of SC&A 2008, but not specifically delineated as "Observations."

Additional Attachment 2 References:

Adley, F.E., Gill, W.E., and Scott, R.H., 1952. *Study of Atmospheric Contamination in the Metal Melt Building*. U.S. Atomic Energy Commission, HW-23352 (rev.), April 4, 1952.

Allen 2009. *Battelle-TBD-6000 Issue 5 White Paper, Comparison to Adley Contamination Data*. October 9, 2009.

Christofano E. and W.B. Harris 1960. *The Industrial Hygiene of Uranium Refining*. Env Health 1(5):74-96.

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