Division of Compensation Analysis and Support Technical Basis Document for the Baker-Perkins Company Saginaw, Michigan	Document Number: DCAS-TKBS-0005 Effective Date: 02/17/2011 Revision No.: 00 Page 1 of 12
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ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
02/15/2011	02/17/2011	0	Changes Battelle-TBD-6001 Appendix to a standalone document. Revises external dose model to eliminate dependence on Battelle-TBD-6001. Provides more detail description of other dose models. Incorporate review comments.

1.0 Introduction

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historic background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH staff in the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" (AWE facility) or a "Department of Energy facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [EEOICPA; 42 U.S.C. § 7384I(5) and (12)]. EEOICPA, as amended, provides for employees who worked at an AWE facility during the contract period and/or during the residual contamination period to receive compensation if certain requirements are met.

Employment at an AWE facility is categorized as either (1) during the contract period (i.e., when the AWE was processing or producing material that emitted radiation and was used in the production of an atomic weapon), or (2) during the residual contamination period (i.e., periods that NIOSH has determined there is the potential for significant residual contamination outside of the period in which weapons-related production occurred). For contract period employment, all occupationally-derived radiation exposures at covered facilities must be included in dose reconstructions. NIOSH does not consider the following exposures to be occupationally-derived:

- radiation from naturally occurring radon present in conventional structures; and
- radiation from diagnostic X-rays received in the treatment of work-related injuries.

For residual contamination period employment, only the radiation exposures defined in 42 U.S.C. § 7384n(c)(4) (i.e., radiation doses received from DOE/AEC-related work) must be included in dose reconstructions. Radiation dose received from DOE/AEC-related work includes: (1) radiation from radon consistent with NIOSH"s policies for including such radiation in the contract period; and, (2) medical screening X-rays, but not diagnostic X-rays for the treatment of work-related injuries. It should be noted that: (1) under subparagraph A of § 7384n(c)(4), radiation associated with the Naval Propulsion Program is specifically excluded from the employee"s radiation dose; and, (2) under subparagraph B of this section, radiation from a source not covered by subparagraph A that cannot be reliably distinguished from radiation that is covered by subparagraph A is considered part of the employee"s radiation dose. This site profile covers only exposures resulting from nuclear weapons-related work. Exposures resulting from non-weapons related work, if applicable, will be covered elsewhere.

The following summary is to help provide consistency in dose reconstructions and to help ensure that all components of dose are adequately addressed when doses are reconstructed. It also provides some information regarding the radiological processes and source terms, as well as information on the radiological controls and monitoring practices.

The following information from the Department of Energy"s Office of Health, Safety and Security EEOICPA Find Facilities webpage defines the EEOICPA covered periods for the Baker-Perkins Company.

Site: Baker-Perkins Company
Location: Saginaw, Michigan
Covered Period: May 14-18, 1956

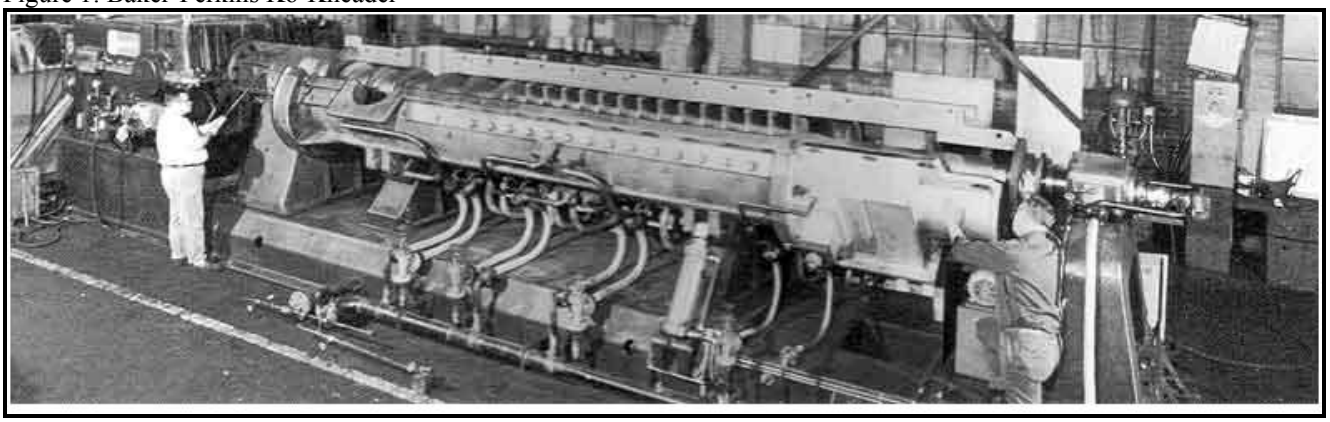
This document contains a summary of the description of the site as well as the Atomic Energy Commission activities performed there, and provides the technical basis to be used to evaluate the occupational radiation doses for EEOICPA claims.

2.0 Site Description and Operational History

Baker-Perkins Company was the result of the merger of two companies in the early 1900s. The company developed industrial mixing machines that were originally designed for and used in the food industry for mixing food products together. Considering the machinery"s operating mechanics and the characteristics of the food products that the machines processed, the transition of operations from food industry processing to chemical industry processing was straight-forward, requiring few additional modifications to the machinery. The Saginaw factory, which was purchased by Baker-Perkins around 1919, produced the first "Universal" mixer, which was identified as a key piece of machinery for processing chemical pharmaceutical products, colors, paints, varnishes, paper pulp, cellulose, foundry sands and loams, rubber materials, etc. A company catalogue produced in the mid-1920s presented many of the Baker-Perkins food machines as suitable for processing chemicals. Baker Perkins continued to refine the design of the mixers for industrial chemical uses through World War II (Baker Perkins Historical Society, 2009a; Baker Perkins Historical Society, 2009b).

In the 1950s, Baker-Perkins chemical machinery business offered products including heavy duty mixers for use in industrial operations. One line of continuous heavy duty mixer produced by Baker-Perkins was called the "Ko-Kneader," shown below in Figure 1. In 1956, it was this line of mixer that was tested for its use in mixing uranium compounds for National Lead of Ohio (Fernald). These tests were performed on May 14-16, 1956, at Baker-Perkins in Saginaw, Michigan. Equipment used during the tests was decontaminated and cleaned on May 15-18, 1956 (Baumann, 1956).

Figure 1: Baker-Perkins Ko-Kneader



Source: Baker Perkins Historical Society, 2009a

3.0 Process Description

The quantity of orange oxide (also known as uranium oxide or uranium trioxide) powder used during the tests is not specifically defined in the available documentation (Baumann, 1956). However, based upon descriptions of operations in analytical data sheets, it is indicated that at least one but no more than two "drums" of orange oxide are believed to have been used in the tests at its laboratory facility (a single building). Based on the information associated with the processing of uranium-trioxide at the Feed Materials Production Center at Fernald, the uranium-trioxide consisted of refined natural uranium (Snapp, 1951, p. 9).

The tests involved mixing uranium-trioxide (orange oxide) with a water-ammonia solution and kneading the mixture, first in their "P" Ko-Kneader (on May 14-15, 1956) and then in their "K" Ko-Kneader (on May 15-16, 1956). The Baker-Perkins equipment used during the test included the P-100 Ko-Kneader, K-100 Ko-Kneader, Omega feeder, Proportioneers pump, and the Milton Roy pump. The Omega feeder was used to charge the uranium into the hopper of the Ko-Kneaders (configured to prevent dust generation). The Proportioneers pump and the Milton Roy pump were used to pump the water-ammonia solution into the Ko-Kneaders (Baumann, 1956). It was determined that the tests were not successful, in terms of continuous-use equipment.

After the tests were completed, both Ko-Kneader machines and the feeder were completely decontaminated (using a wire brush for polishing and washing the units with dilute nitric acid and using a hammer/chisel and vacuum). The decontamination of the "P" Ko-Kneader began on May 15, 1956, after it was determined that it would not be successful in the mixing test. Decontamination of the "K" Ko-Kneader began on May 17, 1956. The Omega feeder had to be disassembled to ensure complete cleaning of the unit (Baumann, 1956). Because all equipment was decontaminated and cleaned after the completion of the tests, there is no defined residual radioactivity period for the Baker-Perkins Company site (Stout, 1991).

4.0 Internal Dose

Air monitoring data were found in the Site Research database relating to occupational internal dose during the five days of AEC work (Baker-Perkins 1991). 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.

For exposure estimates, each claim will be evaluated to determine the most appropriate job category to utilize for the internal dose estimation. The "operator" job category consists of personnel that were directly involved in the testing of the uranium trioxide mixing activities. The "laborer" job category consists of personnel that supported the testing of the uranium trioxide mixing activities. The "Supervisor" job category consists of personnel that were in the operations area but were not routinely involved in hands on activities during the testing. The "Clerical" job category consists of personnel that did not routinely enter the testing area.

Of the 14 BZ samples, five were taken while uranium was being hand scooped from a drum and dumped into a hopper. Respirators were worn during these activities. The remaining nine samples were all taken during various aspects of decontaminating the equipment. Respirators were worn for the activities associated with four of these samples including the two highest. The five samples taken while scooping material represent the five highest of the 14 BZ samples.

The GA samples were taken while the machines were running but they were also taken in the vicinity of the scooping and the decontamination work. Furthermore, the average GA concentration was 351 dpm/m^3 while the average of the BZs samples not associated with respirators was 539 dpm/m^3. This is approximately 1.5 times the GA average. Since the highest BZ samples were associated with short duration operations and included respirator use, it is considered a bounding estimate to assume 50% of the time the operators were exposed to air concentrations represented by BZs samples. That concentration includes all 14 BZs samples, not just the non-respirator samples. The average air concentration for these 14 samples is 3325 dpm/m^3. The remaining 50% of the time, operators are assumed to be exposed to air concentrations represented by the GA air sample.

Similarly, an estimate for laborers will assume 25% BZ and 75% GA. Supervisors will be estimated using 100% GA concentration since they would presumably be in the vicinity often but not routinely performing hands on work. Other personnel will be assumed to be exposed to 10% of the supervisor exposure.

The two distributions are lognormal with different geometric standard deviations. As such, they cannot be directly combined. Therefore, the average value of each data set was determined and used in combining these distributions. The average value of the BZ samples was 3325 dpm/m^3 while the average value for the GA samples was 351 dpm/m^3. The appropriate fractions discussed above were then applied to these average values to determine an overall exposure average for operators and laborers. Since Supervisors and others use only the GA samples, the lognormal distribution of that data set was used directly. For operators and laborers, the larger of the two geometric standard deviations was assumed (5.5 from the GA samples) and a geometric

mean was determined using this average and GSD based on equations in Battele-TIB-5000 (Battelle 2007). This produced geometric mean concentrations of 430 dpm/m^3 and 256 dpm/m^3 respectively. The air concentrations estimates were also used to estimate ingestion intakes per the requirements of OCAS-TIB-0009 (NIOSH 2004).

Table 1 below presents these internal dose estimates in pCi per calendar day to be used for each day of operation (May 14, 1956 through May 18, 1956). The uranium was in the form of uranium trioxide. Therefore, for internal dose estimates, the uranium will be considered for type M solubility.

Table 1: Daily Intakes of Uranium

Job Category	Year	Operation Phase	Nuclide	Inhalation dpm/day	Ingestion dpm/day	GSD
Operators	May 14-18 1956	Operations	U-234	4126.1	86.0	5.5
Laborers				2456.9	51.2	
Supervisor				883.0	18.4	
Clerical				88.3	1.8	

5.0 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 at Baker-Perkins. 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" (Baker-Perkins 1991). The material utilized for the test had been previously refined and thus the radioisotopes of concern include U-234, U-238 and the short lived decay products of U-238 (Th-234 and Pa-234m). The uranium is assumed to be of natural enrichments with the decay products in 100% equilibrium. The highest external exposure potential existed when the uranium was contained in a drum. The remainder of the time the uranium was contained inside machines. These machines would provide additional shielding as well as spread the uranium over a larger area thus reducing the dose rate at one foot. For a bounding estimate, all personnel will be assumed to spend their entire day one foot (30 cm) from a drum of uranium.

MCNPX (version 2.5.0) was used to determine the dose rate per curie of ^{238}U regardless of the actual activity in the drum. This was later adjusted for actual source activity to compare actual dose rates. All radionuclides were ratioed with respect to ^{238}U to determine the number of photons and electrons per decay of ^{238}U. Anderson and Hertel (Anderson and Hertel 2005) showed that the short lived nuclides (^{234}Th, ^{234m}Pa, ^{234}Pa, and ^{231}Th) are very close to equilibrium (adjusted for branching ratios) at 100 days. For the purposes of this evaluation, branching ratio adjusted equilibrium was assumed. ICRP Publication 74 Table A.1 was used to convert the photon flux to units of air kerma using the conversion factors in Table 2 below (ICRP 1996; Stabin and da Luz 2002).

Table 2: Activity of aged uranium following separation and 100 day ingrowth.

	Activity Concentration in aged Uranium Metal (Bq/g)	Relative activity concentration (normalized to ^{238}U)
^{238}U	12200	1
^{234}Th	12200	1
^{234m}Pa	12200	1
^{234}Pa	19.52	0.0016
^{234}U	12200	1
^{235}U	555	0.045492
^{231}Th	555	0.045492

The dose rate was determined at 77.9 cm above the ground, 30 cm from the edge of the drum for both the photon and beta emissions of natural uranium and its progeny. Results of these are provided in Table 3.

Table 3: Uranium dose rates from drums of uranium oxide.

Density of U_3O_8 (g cm^{-3})	Activity of U in drum (Ci)	Photon emission dose(rad/hr)	Bremsstrahlung dose (rad/hr)	Total dose rate at 30 cm (rad/hr)
0.5*	3.121E-02	3.96E-04	3.20E-4	7.16E-4
1	6.242E-02	5.00E-04	3.60E-04	8.60E-04
2	1.248E-01	5.54E-04	3.76E-04	9.30E-04
4	2.497E-01	5.84E-04	3.84E-04	9.69E-04
6	3.745E-01	5.84E-04	3.64E-04	9.48E-04
6.7	4.182E-01	5.81E-04	3.74E-4	9.56E-4

*The drum begins to noticeably impact the dose rates at low material concentration.

The effect of density of the drummed uranium on the modeled dose rate was evaluated. The effective density of the drummed material was assumed to be variable up to 6.7 g cm^{-3}.

Based on these results, the effective density of drummed uranium makes little difference in the calculated dose rates from 1 to 6.7 g cm^{-3}. The introduction of significant quantities of additional materials essentially will provide additional shielding and reduce the effective Z of the material, both of which will reduce the dose rate. Furthermore, as is evidenced by the drop at 0.5 g cm^{-3}, the steel shell of the drum makes a bigger impact on the dose results for low density uranium. This dose rate compares well with the result obtained by Anderson et al. (2005) from a bare, cylindrical uranium ingot at 30.48 cm (16.51 cm radius, 50.8 cm height) for a total of 1.15 mrem/hour. Differences arise from changes to geometry and shielding from the drum walls.

Based on the calculated values, a value of 1.0E-3 rad/hr will be used in this dose estimate. The photon dose will be assumed to be 100% 30 keV to 250 keV photons. Since the estimate assumes an individual is exposed at a distance of one foot 100% of the time, the estimate will be considered bounding and the dose entered into IREP as a constant distribution.

For exposure to the skin, it is important to also consider beta dose rate. Beta dose rate from U-238 daughters is negligible in uranium compounds just after separation, but rises steadily until Pa-234m and Th-234 reach equilibrium concentrations. After a few months, the contact beta dose rate is about 150 mrem/hr (NRC 2002a). Figure 2 shows the rise in beta dose rate during 100 days after separation from ore.

Figure 2. Beta dose rate on the surface of yellowcake. [Reproduced from NRC 2002a]

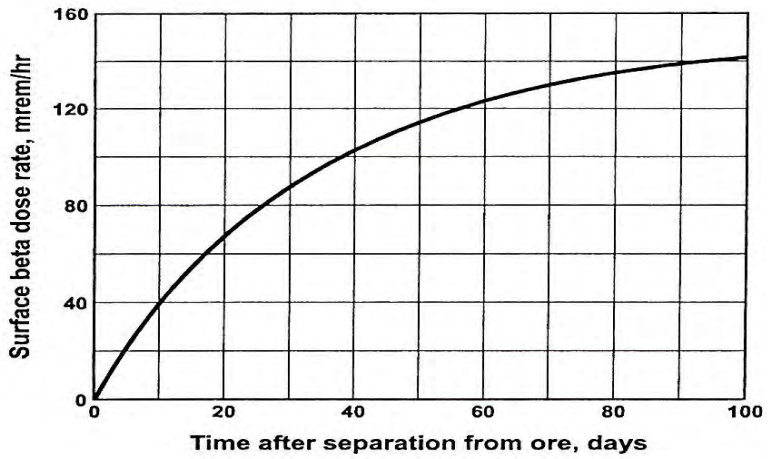
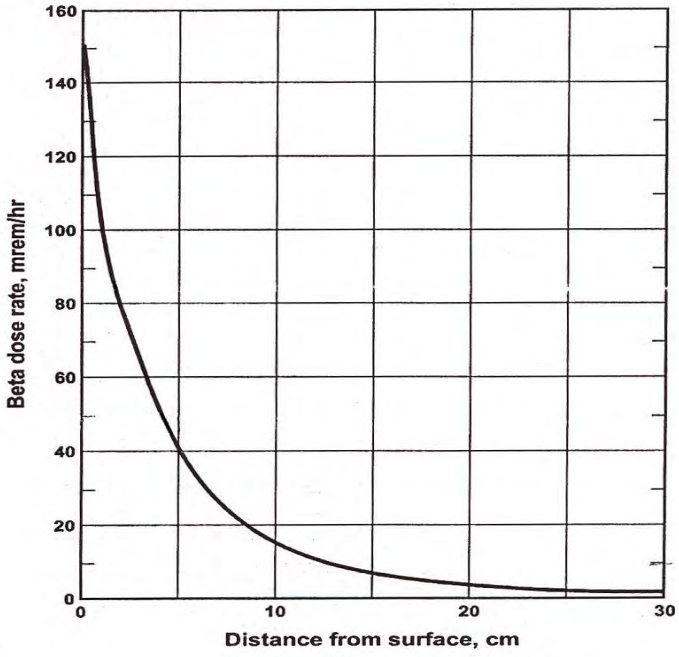


Figure 3. Beta dose rate from yellowcake separated from ore for more than 100 days as a function of distance from the surface. [Reproduced from US NRC 2002a]



There was a potential to receive a shallow dose from exposure to open drums of uranium during drum unloading and loading as well as cleaning the equipment. According to Figure 3 the dose rate at 1 foot from the surface of aged yellowcake is between 1 and 2 mrem/hour. It is assumed that the production workers spent 100% of their time one foot from an open drum of uranium and that the shallow dose rate was 2 mrem/hour or 16 mrem during an 8 hour day.

The skin of the hands and forearms could realistically be closer than the skin of the rest of the body. In order to estimate the shallow dose to the skin of the hands and forearms, it is assumed that the hands are in contact with the uranium 1 hour per work day. This is considered favorable since the purpose of the work was to test equipment. The hands on work would occur only while unloading the drum and while cleaning the equipment. Hands on work during the cleaning could conceivably exceed 1 hour per day but no bulk uranium would be involved. The uranium being handled at that point would be uranium contamination on the surfaces of the equipment. As such, the dose rate would be considerably lower. The estimate for the hands and forearms assumes 1 hour per day at 150 mrem/hr and the remaining 7 hours per day at 2 mrem/hour. The daily dose would then be 164 mrem/day.

The shallow dose estimate is considered bounding and the dose should be entered into IREP as a constant distribution. The shallow dose should be considered to be 100% >15 keV electrons.

Table 4: Daily External Dose

Job Category	Year	Operation Phase	Daily Dose Rate[a] (mrem/day)	Total Dose[a] (mrem)
All workers – **Photon**	1956	Operations	8.0	40
All workers – **Other Skin**	1956	Operations	16	80
All workers –**Hands and Forearms**	1956	Operations	164	820

a) In this table, mrem, mR and mrad are used interchangeably

The dose in Table 4 is a daily dose to be applied for employment between May 14, 1956 and May 18, 1956 inclusive. If the individual was employed during the entire five days, the values in the last column can be used.

6.0 Occupational Medical Dose

No documentation regarding occupational medical dose specific to Baker-Perkins was found. Information to be used in dose reconstructions, for which no specific information is available, is provided in ORAUT-OTIB-0006, Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures (ORAUT 2005). The assumed frequency is one PA Chest X-ray for the year 1956. Annual organ doses are entered into the NIOSH-IREP program as the annual dose due to an acute exposure to photons (E=30-250 keV). The distribution is assumed to be normal with a standard deviation of 30%.

7.0 References

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