

<b>Division of Compensation Analysis and Support</b> Technical Basis Document for the Baker-Perkins Company Saginaw, Michigan		Document Number: DCAS-TKBS-0005 Effective Date: 05/01/2012 Revision No.: 01  Page 1 of 14
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ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
2/17/2011	2/17/2011	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.
4/2/2012	5/01/2012	1	Revises internal dose model. Provides more detail description of quantity of uranium and time line of events. Incorporate review comments.

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## **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.

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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.

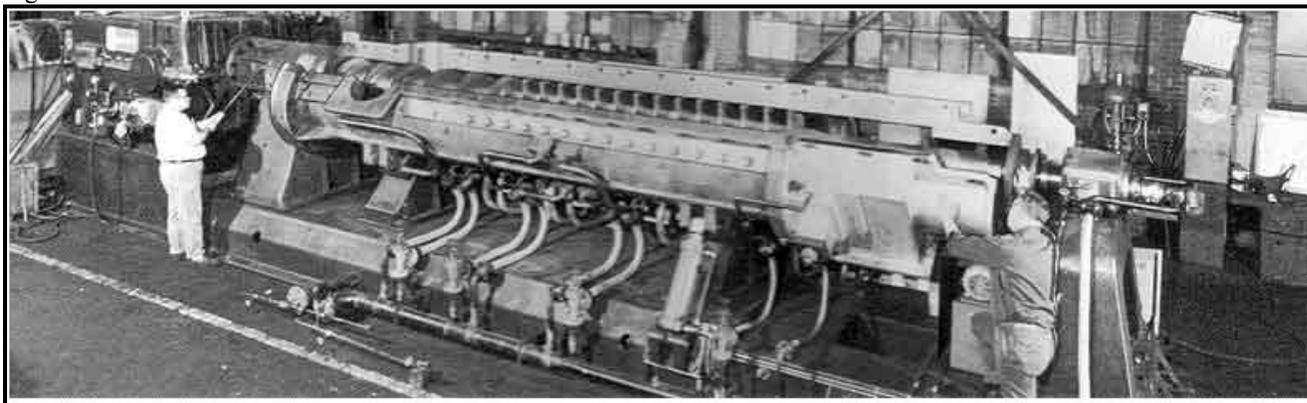
## **2.0 Site Description and Operational History**

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 straightforward, 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).

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Figure 1: Baker-Perkins Ko-Kneader



Source: Baker Perkins Historical Society, 2009a

### 3.0 Process Description

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 15, 1956) and then in their “K” Ko-Kneader (on May 16, 1956). The Baker-Perkins equipment used during the test included the P-100 Ko-Kneader, K-100 Ko-Kneader, Omega feeder, Proportioners 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 Proportioners 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).

Logs from the Ko-Kneader tests included the start and stop times of the uranium feed as well as the rates at which uranium was feed into the machine (Baumann, 1956). This information was used to determine that up to 1478 pounds of  $UO_3$  were feed into the two Ko-Kneaders. It was also determined that this amount of uranium would easily fit into a single 55 gallon drum. 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).

Air sample data sheets included sample times and descriptions of the work. These sheets were combined with the test logs to develop a detailed account of the test and associated work.

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5/14/1956

**1:28 pm** – Background air sample taken prior to opening or processing any material

**3:00 pm** – Began scooping UO<sub>3</sub> into Omega Feeder began.

**3:32pm** – Scooping ended and calibration of the Omega Feeder

**4:30pm** – Work ended for the day

5/15/1956

**8:30 am** – Test #1 of the “P” type Ko-Kneader began

**9:19 am** – Began scooping additional UO<sub>3</sub> into Omega Feeder

**10:35 am** – Test #1 of the “P” type Ko-Kneader ended

**10:42 am** – Test #2 of the “P” type Ko-Kneader began

**11:19 am** – Last of the UO<sub>3</sub> emptied into the Omega Feeder

**11:19 am** – Test #2 ended, “P” type machine determined unsatisfactory for material

**1:04 pm** – Decontamination of Ko-Kneader started

**4:30 pm** – Work ended for the day

5/16/1956

**8:30 am** – Decontamination of “P” Ko-Kneader continued

**11:19 am** – Decontamination of the “P” Ko-Kneader finished

**11:19 am** – Test #3 of the “K” type Ko-Kneader began

**4:24 pm** – Test #3 ended

**4:30 pm** – Work ended for the day

5/17/1956

**9:03 am** – Decontamination of “K” Ko-Kneader and Omega feeder started

**4:30 pm** – Work ended for the day

5/18/1956

**8:30 am** – Decontamination of “K” Ko-Kneader continued

**2:17 pm** – Decontamination ended with steam cleaning of Omega Feeder

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#### **4.0 Internal Dose**

Air monitoring data are available for each phase of the work performed at Baker Perkins (Baker-Perkins 1991). Results of both breathing zone (BZ) and general area (GA) monitoring for alpha radiation (alpha scintillation) were reported. The three key tasks resulting in different degrees of airborne uranium were scooping the uranium from the drum to the Feeder, decontaminating the equipment and all other tasks including operating the Ko-Kneader. There are several air samples available for each task and it is credible that each task was performed by the same workers for the duration of that task. Therefore, the air samples represent a variation in the air concentrations with time, not a variation of exposures to different people. It would therefore be appropriate to use the distribution of air sample results to estimate the intake for each individual rather than applying a bounding constant value.

The first two tasks result in localized high airborne activity that dissipates into lower general area concentrations. Therefore exposures associated with the first two tasks are estimated with BZ air samples for those people actually performing the task. For those that may have been in the vicinity but not actively involved in hands on work, the GA samples are used. The remaining tasks, including operating the Ko-Kneader, do not have a single localized area of release but rather multiple points of release resulting in a dust level dispersed throughout the area. Therefore, GA samples taken during those tasks will be used to estimate the intakes for everyone involved in those tasks.

For exposure estimates, each claim will be evaluated to determine the most appropriate job category to utilize for the internal dose estimation. Scooping the uranium and decontaminating the equipment could have been performed by an operator, a laborer or even maintenance personnel. Therefore, one category of workers will be designated for this hands-on work. It is likely some sort of supervision was in the vicinity but not working in a hands-on fashion. Therefore, the "Supervisor" job category will be estimated using GA air samples and include any type of worker that could perform observation or other ancillary type duties (supervisor, health and safety, security, etc.). The "others" category is intended to account for those not likely to be routinely in the area but who could have entered the area infrequently during the tests. For these people, the estimate will be 10% of the Supervisors intake.

From the time line shown in section 3.0, it can be seen that the duration of the "scooping" task totaled 2 hours and 32 minutes over two days. Likewise, the duration of the decontamination task totaled 19.5 hours. The total duration of the work with radioactive materials at Baker Perkins started at 3 pm on 5/14/1956 and ended at 2:17 pm on 5/18/1956 for a total of 31 hours and 14 minutes in the work area. Therefore, the time associated with the actual testing and ancillary work is 9.2 hours.

Table 1 provides the geometric mean (GM) and the 95<sup>th</sup> percentile of each type of air sample for the given operation. The duration of the operation combined with a breathing rate of 1.2 m<sup>3</sup>/hr was used to determine the overall intake. A geometric standard deviation (GSD) was determined from the GM and the 95<sup>th</sup> percentile of the overall intake assuming a lognormal distribution.

**Table 1: Airborne Concentrations and Intakes**

Operation	GM (dpm/m <sup>3</sup> )	95 <sup>th</sup> (dpm/m <sup>3</sup> )	Duration (hrs)	Intake (GM) (dpm)	Intake (95th) (dpm)
Operators					
Scooping	6135	26338	2.533	18650	80066
Decontamination	491	2888	19.5	11494	67585
Testing and other	43.7	447	9.2	482	4935
Total intake 30626 dpm (GM); 152587 dpm (95 <sup>th</sup> ); GSD = 2.65					
Supervisors					
Scooping	879	12098	2.533	2674	36778
Decontamination	128	1873	19.5	3002	43822
Testing and other	43.7	447	9.2	482	4935
Total intake 6158 dpm (GM); 85536 dpm (95 <sup>th</sup> ); GSD = 4.95					

From the total intakes, the daily intake rates were calculated and presented in Table 2. Ingestion intakes were assigned based on OCAS-TIB-009. For dose reconstructions, these rates should be used to calculate organ dose and assigned as a lognormal distribution. The intakes should only be assigned for each day of work between 5/14/1956 and 5/18/1956.

**Table 2: Intake Comparison**

	Inhalation (GM) (dpm/day)	Ingestion (GM) (dpm/day)	GSD
Operator/laborer	6125	128	2.65
Supervisor	1232	26	4.95
Other	123.2	2.6	4.95

## 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 workers will be assumed to spend their entire day one foot (30 cm) from a drum of uranium. This means the three worker categories in the internal dose section, operators, supervisors and others, will all receive the same external dose estimate.

MCNPX (version 2.5.0) was used to determine the dose rate per curie of  $^{238}\text{U}$  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  $^{238}\text{U}$  to determine the number of photons and electrons per decay of  $^{238}\text{U}$ . Anderson and Hertel (Anderson and Hertel 2005) showed that the short lived nuclides ( $^{234}\text{Th}$ ,  $^{234\text{m}}\text{Pa}$ ,  $^{234}\text{Pa}$ , and  $^{231}\text{Th}$ ) 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 3 below (ICRP 1996; Stabin and da Luz 2002).

**Table 3: Activity of aged uranium following separation and 100 day ingrowth.**

	Activity Concentration in aged Uranium Metal (Bq/g)	Relative activity concentration (normalized to $^{238}\text{U}$ )
$^{238}\text{U}$	12200	1
$^{234}\text{Th}$	12200	1
$^{234\text{m}}\text{Pa}$	12200	1
$^{234}\text{Pa}$	19.52	0.0016
$^{234}\text{U}$	12200	1
$^{235}\text{U}$	555	0.045492
$^{231}\text{Th}$	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 4.

**Table 4: Uranium dose rates from drums of uranium oxide.**

Density of U <sub>3</sub> O <sub>8</sub> (g cm <sup>-3</sup> )	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-04

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

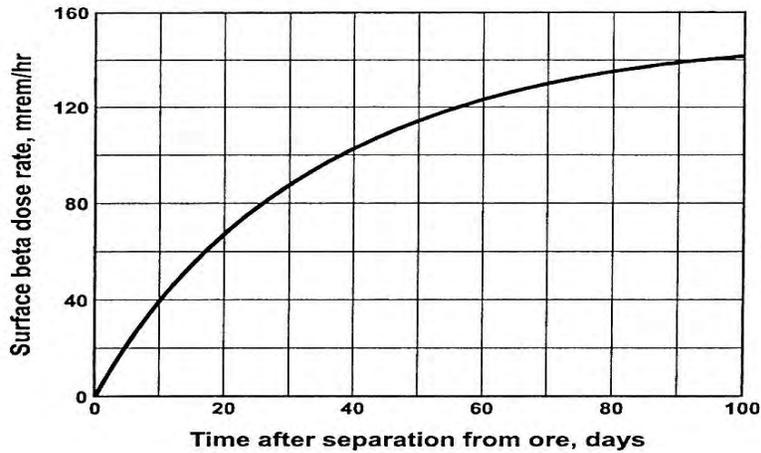
The effect of density of the drummed uranium on the modeled dose rate was evaluated. The effective density of the drummed material was assumed to be variable up to 6.7 g cm<sup>-3</sup>.

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<sup>-3</sup>. 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<sup>-3</sup>, 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.

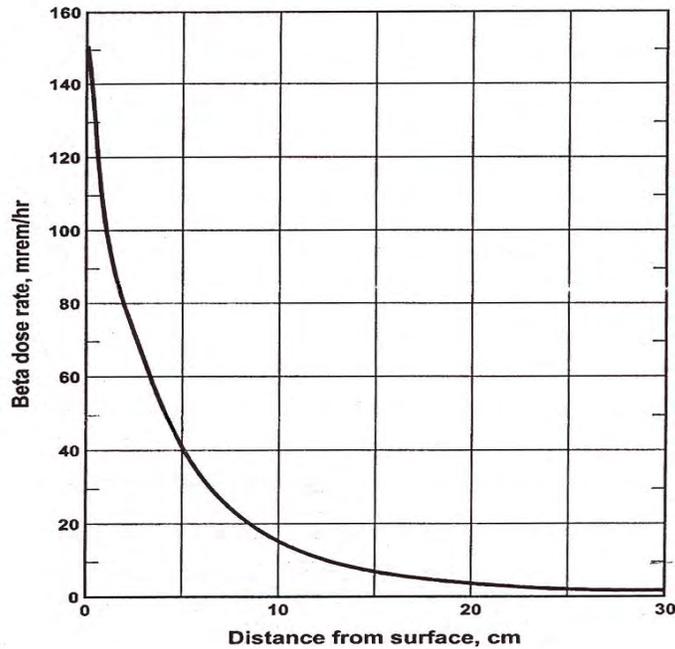
Based on the calculated values, a value of 1.0E-3 rad/hr will be used in this dose estimate. The photon dose will be assumed to be 100% 30 keV to 250 keV photons. Since the estimate assumes an individual is exposed at a distance of one foot 100% of the time, the estimate will be considered bounding and 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. The hands could have been in close proximity to bulk uranium when the uranium was being scooped out of the drums. From section 3.0 it can be seen that this occurred for approximately 2 hours and 32 minutes during the 5 days or approximately ½ hour per day on average. Packaging of the mixed product appears to have occurred automatically as the Ko-Kneader emptied into a drum. However, if some hands on work were necessary, it should have taken no more time to package the material than it took to unload the drums. Therefore, the ½ hour per day is doubled and the hands are assumed to be in contact with bulk uranium for 1 hour per work day.

Hands on work would also occur 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 5: Daily External Dose**

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

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

The dose in Table 5 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%.

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