## RECORD OF ISSUE/REVISIONS

<table>
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<th>EFFECTIVE DATE</th>
<th>REV. NO.</th>
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<td>00-B</td>
<td>Incorporates comments from internal and NIOSH review. Initiated by Jeri L. Anderson.</td>
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<td>Incorporates comments from NIOSH review received on redline/strikeout version of TIB dated 11/12/2003. Initiated by Jeri L. Anderson.</td>
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<tr>
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<td>01-A</td>
<td>Incorporates changes to correct errors on pgs. 4 and 10. TIB incorrectly referred to Absorption Type in ingestion discussion. Initiated by Jeri L. Anderson.</td>
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<td>02-A</td>
<td>Adds remainder dose to Table 4. Initiated by Jeri L. Anderson.</td>
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1.0 SCOPE

The purpose of this document is to provide guidance for estimating the maximum plausible dose to workers at Atomic Weapons Employers (AWEs). This document describes an efficiency process that may be used to expedite the processing of claims requiring dose reconstruction under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA). The exposure matrix in this document is designed for estimating the maximum plausible annual dose in all organs with the exception of lung, skin, breast, eye, and testes except when the testes dose is used as an analog for the prostate. Because the current ICRP model does not calculate a dose to the prostate, the dose to the testes is reconstructed and used to determine the probability of causation for prostate cancer. This is considered a claimant-favorable approach.

There were approximately 109 AWE facilities that handled only natural uranium in support of the atomic weapons program. Of these facilities, 88% operated for 10 years or less and 72% operated for 5 years or less (see Figure 1). The maximum time operated was twenty-three years and the minimum time was less than a year.

The processes at these facilities included reduction and recasting, rolling, machining, and extruding of uranium, fuel element fabrication, scrap recovery, and recovery of uranium from phosphoric acid. A large number of the facilities handled uranium metal. The facilities relevant to this document were privately-owned and the AEC work was done on a part-time basis or in addition to their normal commercial operations.

This document applies only to facilities that handled uranium metal and is not to be used for facilities that processed thorium, radium, or uranium ores. The intake and dose rates in this exposure matrix are to be used in conjunction with the individual worker’s covered employment dates, date of birth, and date of cancer diagnosis. If it is necessary to pro-rate intake and dose rates, it is acceptable to
use values for a full year as this is an over-estimation and, thus, claimant-favorable. Because worker bioassay and dosimetry data cannot be ignored, the worker’s data, if available, should be reviewed and it should be ensured that a dose reconstruction based on this exposure matrix is an overestimate and is, therefore, a claimant-favorable approach.

2.0 ESTIMATION OF INTERNAL DOSE

During World War II and the time of the Manhattan Engineer District, the permissible level for uranium air dust concentration was set at 500 $\mu$g/m$^3$ for insoluble uranium compounds and 150 $\mu$g/m$^3$ for soluble uranium compounds. After the war, the University of Rochester (Rochester, NY) recommended lowering the permissible level to 50 $\mu$g/m$^3$ for all uranium compounds on the basis of chemical toxicity. This level is equivalent to 70 disintegrations per minute per cubic meter (70 dpm/m$^3$) and is based primarily on animal studies. The Medical Division of the AEC New York Operations Office (NYOO) thought that the “maximum permissible level” should be based on human data and was thus unknown. Therefore, the level of 50 $\mu$g/m$^3$ was generally referred to as the “preferred level” (US AEC 1949). Oftentimes the contractors of the Atomic Energy Commission (AEC) used the term “Maximum Allowable (air) Concentration” or “MAC” interchangeably with the “preferred level” and reported air-sampling results as multiples of the MAC (NLO 1952, US AEC 1953).

In 1949, the Medical Division of the NYOO published a report on the health hazards at seven facilities that produced and/or processed uranium for the AEC. These facilities included Mallinckrodt Chemical Works, Harshaw Chemical Company, Linde Air Products, Electrometallurgical Company, Simonds Saw and Steel Company, Vulcan Crucible Company, and Vitro Manufacturing Company. These facilities were the earliest of those constructed by the Manhattan Engineer District and, with the exception of Vulcan Crucible, were very large operations in comparison to the facilities for which this document is relevant. Up until the time of this report, surveys by the NYOO indicated that out of 648 exposed workers at these plants, 9% were exposed to uranium air concentrations greater than 125 MAC (> 6250 $\mu$g/m$^3$), 9% were exposed at 25-125 MAC (1250-6250 $\mu$g/m$^3$), and 82% were exposed to less than 25 MAC (< 1250 $\mu$g/m$^3$). As a result of this report, significant improvements were made in the operational conditions such as re-design of ventilation systems, enclosing some operations, and using remote control (US AEC 1949). By the end of 1949, exposure levels were significantly reduced at these larger plants even though production levels increased (Mason 1958).

Vulcan Crucible (Aliquippa Forge) was a steel mill that contracted with the AEC to roll uranium billets into rods on a part-time basis from 1948 to 1949. The contract (AEC Contract No. AT-(30-1)-407) stated that the plant was to arrange to spend “at least two consecutive weeks out of every five consecutive weeks” performing the AEC contract work. Four of the most exposed workers in the 1949 study were from this plant and the report stated that discussions were under way to shut down this operation (US AEC 1949). Operations were shut down in late 1949 and the plant was decontaminated to 1950 standards (Adams and Payne 1992).

It is important to note that these early exposure studies were not very selective in terms of particle size (Stannard 1988). Also, the air concentration measurements represented the amount uranium in the air where the workers were located but not necessarily what was taken into the lung or the body.

For the purpose of estimating maximum plausible dose, it is assumed that a worker receives a constant exposure to a maximum level of 5000 $\mu$g/m$^3$ (100 MAC) during the entire period of operation. This means that it is assumed that the worker is exposed at this level for eight hours per day, five days per week, 50 weeks per year, whereas time-weighted average studies of even the larger plants like Mallinckrodt show that the majority of time workers were exposed at lower levels this. It is assumed the worker is exposed at this level during lunches, breaks, and when working at tasks that...
are not AEC-related. This is considered claimant-favorable because the operations at the facilities for which this document is applicable were smaller, mostly part-time operations. This maximum exposure level is converted to pCi/m$^3$ by multiplying by 0.677 pCi/$\mu$g, which is the specific activity of natural uranium.

The annual amount inhaled due to chronic exposure is determined by multiplying the maximum air concentration of 3400 pCi/m$^3$ (5000 $\mu$g/m$^3$) by the ICRP 66 recommended breathing rate of 1.2 m$^3$/h and by an assumed 2000-hour work year. This results in an annual intake of 8.1E+06 pCi (1.2E+07 $\mu$g). This value for the cumulative annual intake is assumed to result from a chronic exposure and is used to determine the annual internal organ dose by applying the current ICRP models. The Absorption Type is assigned to Type M as recommended by the ICRP in Publication 71 (ICRP 1995b) for uranium compounds for which there is no specific information on solubility and absorption. Although human and animal studies have indicated that uranium oxides can be relatively insoluble, the selection of Type M results in greater organ uptake and is thus considered claimant favorable. ICRP Publication 66 default values (ICRP 1994) should be selected for particle deposition parameters. The annual organ doses are entered into the NIOSH IREP program assuming a chronic exposure and a constant distribution. The dose is attributed to alpha radiation.

Internal exposure can also be caused by individuals ingesting material by smoking or eating while their hands are contaminated with uranium. To estimate the quantity of this ingested material, several claimant favorable assumptions have been made.

1. The individual’s hands have become contaminated from contact with the most highly contaminated surfaces in the facility, the floor. The individual’s hand is assumed to become contaminated at a level equal to 10% of the level of contamination on the floor.

2. A study was done at the Oak Ridge Gaseous Diffusion Plant (ORGDP) to determine the intake of uranium from hand contamination. The study indicated that the amount of uranium that is transferred from the hand to the cigarette while smoking was approximately 1% of the material on the surface of the hand (Bailey 1958). For this estimate, 10% was used as a bounding estimate to include all forms of consumption.

3. The individual’s hand is to be approximated by an area of 4” by 6” and is evenly contaminated. When the estimated surface contamination level of 8.1E+7 pCi/m$^2$ (see section 3.0 below) is multiplied by the surface area of the hand (0.0155 m$^2$) and the 10% transfer factor is applied, the total activity on the individual’s hand is equal to 1.26E+5 pCi. If 10% of this is ingested on a daily basis, 5 days per week for 50 weeks, the total annual ingestion of uranium can be calculated to be 3.14E+6 pCi annually.

The cumulative annual ingestion intake is assumed to result from a chronic exposure for the entire time the individual was employed at the facility during the uranium contract period and is used to calculate the annual internal organ doses by applying the current ICRP models. The f1 value is assigned to 0.02 in Publication 69 (ICRP 1995a) for uranium compounds for which there is no specific information on solubility. The annual organ doses are entered into the NIOSH IREP program assuming a chronic exposure and a constant distribution. The dose is attributed to alpha radiation.

If eating or drinking occurred in the production portions of a facility, airborne radioactivity can settle out on food or drink. This causes an ingestion mode that is not specifically associated with transferring the material from the hand. A realistic estimate of this would have to involve the settling rate of the airborne contamination onto the food or drink. The surface contamination estimate (see
section 3.0) used this settling rate and accumulated material over the course of a year with no removal mechanisms factored in. Since the surface contamination level was the starting point for the ingestion estimate, it inherently accounts for an entire years worth of settling. Assuming food and drink are consumed at some point during the day that they are brought into the area, the amount of material ingested would be a fraction of one days worth of settling. Since a fraction of one years worth of settling is already accounted for, it is believed that this ingestion estimate accounts for ingestion from all modes.

3.0 ESTIMATION OF EXTERNAL DOSE

The maximum size of the uranium ingots used in the atomic weapons program was used to estimate external exposure during processing. The dimensions of the two larger ingots are shown below in Table 1.

It was assumed that the most exposed workers were the machinists and general laborers so the exposure geometry was assumed to be 75% anterior-posterior (AP) and 25% isotropic (ISO) as recommended in the NIOSH External Dose Reconstruction Implementation Guideline (US DHHS 2002a). The workers were assumed to spend 7 hours per day performing their duties and 1 hour per day at lunch and on breaks. Although during performance of the job, the worker could have been any distance from the source (the ingots), to be claimant-favorable, it was assumed the worker spent the entire 7 hours 1 foot from the source. Also, to be claimant-favorable, it was assumed that the worker spent his/her lunch and breaks in close proximity to an ingot.

For the calculations of exposure rate, it was assumed that the ingots were composed entirely of natural uranium metal that had been allowed to decay for 100 days resulting in significant dose contribution from the Bremsstrahlung radiations created by the Pa-234m and Th-234 beta emissions. A large percentage of the exposure is from Bremsstrahlung photons with energy between 0.8 and 1 MeV. The exposure rate at various distances from the ingots was calculated using MicroShield™ (Grove Engineering 2003) and MCNP (LANL 2003). The calculated values are shown in Table 2.

Table 1. Most probable dimensions of the uranium ingots used in processing (Bonfer 2003).

<table>
<thead>
<tr>
<th>Shape</th>
<th>Dimensions (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular</td>
<td>24 L × 16 W × 4 H</td>
</tr>
<tr>
<td>Cylindrical</td>
<td>20 L × 13 Dia.</td>
</tr>
</tbody>
</table>

Table 2. Calculated exposure rates from uranium metal ingots.

<table>
<thead>
<tr>
<th>Shape of ingot</th>
<th>Distance from surface</th>
<th>MicroShield™ exposure rate (mR/hr)</th>
<th>MCNP dose rate (mrem/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular</td>
<td>1 cm</td>
<td>7.90</td>
<td>8.18</td>
</tr>
<tr>
<td></td>
<td>1 ft</td>
<td>1.91</td>
<td>2.04</td>
</tr>
<tr>
<td></td>
<td>1 m</td>
<td>0.29</td>
<td>0.36</td>
</tr>
<tr>
<td>Cylindrical</td>
<td>1 cm</td>
<td>8.27</td>
<td>8.30</td>
</tr>
<tr>
<td></td>
<td>1 ft</td>
<td>1.13</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>1 m</td>
<td>0.17</td>
<td>0.18</td>
</tr>
</tbody>
</table>

The MCNP calculated dose rates were higher than the MicroShield dose rates for both the rectangular and the cylindrical ingot. It was assumed that the majority of the worker’s time was spent at 1 foot from the surface of the ingot. The calculated dose rates at 1 foot and 1 meter from the rectangular ingot were the highest so those values were used in the dose estimation. The MCNP-calculated dose rate was multiplied by the number of hours spent in the appropriate exposure geometry, and then multiplied by 250 days per year (8 hours per day for a total of 2000 hours per year). The organ doses were calculated by multiplying the calculated annual dose rate by the “Ambient Dose Equivalent
(H*(10)) to Organ Dose (Hr) photon dose conversion factors found in Appendix B of the NIOSH
External Dose Reconstruction Implementation Guideline (DHHS 2002a). The annual dose rate was
divided evenly between the photons with energy between 30 and 250 keV and photons with energy
greater than 250 keV. Table 3 shows the calculated annual organ doses due to exposure to a natural
uranium ingot.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Photons with E=30-250 keV</th>
<th>Photons with E&gt;250 keV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urinary bladder</td>
<td>1.9</td>
<td>2.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Bone (red marrow)</td>
<td>1.6</td>
<td>2.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Bone (surfaces)</td>
<td>2.6</td>
<td>2.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Colon</td>
<td>1.8</td>
<td>2.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Esophagus</td>
<td>1.5</td>
<td>2.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Gonads (ovaries)</td>
<td>1.8</td>
<td>2.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Gonads (testes)</td>
<td>2.1</td>
<td>2.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Liver</td>
<td>1.9</td>
<td>2.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Remainder</td>
<td>1.8</td>
<td>2.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Stomach</td>
<td>1.9</td>
<td>2.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Thymus</td>
<td>1.9</td>
<td>2.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Thyroid</td>
<td>2.0</td>
<td>2.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Uterus</td>
<td>1.8</td>
<td>2.1</td>
<td>3.9</td>
</tr>
</tbody>
</table>

The doses in Table 3 are entered into the NIOSH IREP program assuming a chronic exposure and a
constant distribution. The doses in the second column of Table 3 are attributed to photons with
energy between 30 and 250 keV and the doses in the third column are attributed to photons with
energy greater than 250 keV.

It was also assumed that workers were exposed to contaminated surfaces during their entire work
period. The level of surface contamination was determined by first calculating a terminal settling
velocity for 5-µm activity mean aerodynamic diameter (AMAD) particles. The calculated terminal
settling velocity of 0.00075 meters per second is multiplied by the assumed maximum air
concentration of 3400 pCi/m³. It was assumed that due to the constant air concentration, the surface
contamination level was due to 365 days of constant deposition. This is considered claimant-
favorable as facility housekeeping practices most likely kept levels lower than this. At the assumed air
concentration level with the calculated terminal settling velocity, a 365-day buildup will result in a
contamination level of 8.1E+07 pCi/m². The annual organ dose due to exposure to contaminated
surfaces was determined by multiplying the surface contamination level by the dose coefficients for
contaminated ground surfaces for U-238 and daughters Pa-234m and Th-234 from Federal Guidance
Report No. 12 (US EPA 1993). These dose conversion factors were modeled using an
anthropomorphic phantom standing on an isotropic plane source in air. Table 4 shows the annual
external organ dose estimates.

The doses in Table 4 are entered into the NIOSH IREP program assuming a chronic exposure and a
constant distribution. The dose is divided equally between photons with energy between 30 and 250
keV and photons with energy greater than 250 keV.

The assumption was also made that workers received an annual occupationally related diagnostic x-
ray. The exposure geometry was assumed to be posterior-anterior (PA) (DHHS 2002). The air kerma
at skin entrance for the diagnostic chest x-ray was estimated to be 0.108 R (Scalsky 2003). The
Table 4. Annual organ doses due to external exposure to ground surfaces contaminated with natural uranium dust.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Annual dose (rem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenals</td>
<td>4.0E-02</td>
</tr>
<tr>
<td>Urinary bladder</td>
<td>4.4E-02</td>
</tr>
<tr>
<td>Bone surface</td>
<td>1.1E-01</td>
</tr>
<tr>
<td>Brain</td>
<td>4.2E-02</td>
</tr>
<tr>
<td>Esophagus</td>
<td>3.7E-02</td>
</tr>
<tr>
<td>Stomach wall</td>
<td>4.4E-02</td>
</tr>
<tr>
<td>Small intestine wall</td>
<td>4.1E-02</td>
</tr>
<tr>
<td>Upper large intestine wall</td>
<td>4.2E-02</td>
</tr>
<tr>
<td>Lower large intestine wall</td>
<td>4.3E-02</td>
</tr>
<tr>
<td>Kidney</td>
<td>4.4E-02</td>
</tr>
<tr>
<td>Liver</td>
<td>4.4E-02</td>
</tr>
<tr>
<td>Muscle</td>
<td>5.4E-02</td>
</tr>
<tr>
<td>Ovaries</td>
<td>4.1E-02</td>
</tr>
<tr>
<td>Pancreas</td>
<td>3.9E-02</td>
</tr>
<tr>
<td>Red Marrow</td>
<td>4.5E-02</td>
</tr>
<tr>
<td>Remainder</td>
<td>4.3E-02</td>
</tr>
<tr>
<td>Spleen</td>
<td>4.4E-02</td>
</tr>
<tr>
<td>Testes</td>
<td>5.6E-02</td>
</tr>
<tr>
<td>Thymus</td>
<td>4.3E-02</td>
</tr>
<tr>
<td>Thyroid</td>
<td>4.8E-02</td>
</tr>
<tr>
<td>Uterus</td>
<td>4.1E-02</td>
</tr>
</tbody>
</table>

organ doses were calculated by multiplying the air kerma by the “Kerma (K_a) to Organ Dose (H_T)” photon dose conversion factors for 30-250 keV photons found in Appendix B of the NIOSH External Dose Reconstruction Implementation Guideline (DHHS 2002). Table 5 below shows the annual organ doses due to the assumed annual diagnostic chest x-ray. The values in Table 5 are entered into the NIOSH-IREP program as the annual dose due to an acute exposure to photons (E=30-250 keV) and a constant distribution is assumed.

Table 5. Annual organ doses due to the assumed annual diagnostic chest x-ray.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Annual dose (rem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bladder</td>
<td>0.074</td>
</tr>
<tr>
<td>Red bone marrow</td>
<td>0.124</td>
</tr>
<tr>
<td>Bone Surface</td>
<td>0.178</td>
</tr>
<tr>
<td>Breast</td>
<td>0.059</td>
</tr>
<tr>
<td>Colon</td>
<td>0.095</td>
</tr>
<tr>
<td>Esophagus</td>
<td>0.105</td>
</tr>
<tr>
<td>Eye</td>
<td>0.022</td>
</tr>
<tr>
<td>Ovaries</td>
<td>0.110</td>
</tr>
<tr>
<td>Testes</td>
<td>0.061</td>
</tr>
<tr>
<td>Liver</td>
<td>0.101</td>
</tr>
<tr>
<td>Lung</td>
<td>0.133</td>
</tr>
<tr>
<td>Remainder organs</td>
<td>0.110</td>
</tr>
<tr>
<td>Skin</td>
<td>0.110</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.077</td>
</tr>
<tr>
<td>Thymus</td>
<td>0.048</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.052</td>
</tr>
<tr>
<td>Uterus</td>
<td>0.096</td>
</tr>
</tbody>
</table>
4.0 **ESTIMATION OF EXPOSURE TO RESIDUAL RADIOACTIVITY**

During operations with uranium, airborne contamination can be caused directly from operations with uranium bearing materials as well as by the resuspension of surface contamination. This airborne contamination can be removed by settling on floors or other surfaces or by ventilation (both engineered and natural building ventilation). The surface contamination levels can be increased by the airborne contamination settling or directly by operations with uranium. This level is decreased by various incidental means such as general housekeeping or tracking of contamination out of the area on equipment or personnel.

For the purpose of estimating the airborne contamination from residual contamination, it is assumed that during uranium operations, these factors reached an equilibrium that caused the airborne concentration and surface contamination to remain at a constant level. Once the generation source from uranium operation was removed, the other factors then caused the over mass of uranium to decrease at some rate due to the remaining removal factors.

This analysis assumes that 1) uranium operations directly accounted for half the airborne concentration in the facility during operations and 2) all the remaining removal mechanisms eliminated only 1% of the uranium mass per day. With these assumptions in place, an equation can be written for the airborne concentration as a function of time.

\[ A(t) = 50MAC \times e^{-0.01t} \]

Where:

- \( A(t) \) = Airborne activity at time \( t \) (pCi/m³)
- \( t \) = time since uranium operations ended (days)
- \( MAC \) = Maximum Allowed Concentration (34 pCi/m³)

When this is multiplied by the breathing rate of 9.6 m³ per day, the daily intake is calculated. This equation can then be integrated from the end of uranium operations to infinity to determine the total amount of uranium that could be inhaled from residual contamination. This integration results in:

\[ I = 9.6 \times 50MAC / 0.01 \]

Where:

- \( I \) = total intake from inhalation of residual activity (pCi)
- \( MAC \) = Maximum allowed concentration (34 pCi/m³)
- 9.6 = daily breathing rate (m³/day)
- 0.01 = fraction of material removed per day

The results of this equation indicate a total of 1.63x10⁶ pCi would be inhaled. This equates to approximately 20% of the 8.1x10⁶ pCi annual intake during operations. Therefore, the total inhalation intake from residual contamination can be overestimated by assuming one additional year of inhalation exposure at the operational level of 100 MAC.

The external radiation caused by residual contamination can be overestimated by assuming the contamination levels that existed during operations continued to exist after operations ceased. The annual dose from this source of radiation has already been estimated and can be found in Table 4.
This dose should be added to an individual's estimate for each year the individual worked at the facility following the end of uranium operations.

Ingestion of material is most closely related to removable surface contamination rather than fixed surface contamination. Airborne concentrations are also related to removable surface contamination. Therefore, the removable contamination levels are assumed to decrease at the same rate as the airborne concentrations. For this reason, the same approach will be taken for ingestion estimates following periods of operations. That is, the ingestion intakes from residual contamination will be estimated by assuming one additional year of ingestion at the same rate it occurred during operation.

5.0 REFERENCES


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International Commission on Radiological Protection (ICRP), “Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 3 Ingestion Dose Coefficients, ICRP Publication 69, pg. 65, 1995a


Scalsky, E.D., Technical Basis Document for the Savannah River Site To be Used for EEOICPA Dose Reconstructions, ORAUT-TKBS-003, Effective Date August 21, 2003


### Appendix

#### List of Applicable Facilities

<table>
<thead>
<tr>
<th>Site name</th>
<th>Years of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ajax Magnethermic Corp.</td>
<td>1958–1962</td>
</tr>
<tr>
<td>Alba Craft</td>
<td>1952–1957</td>
</tr>
<tr>
<td>Aliquippa Forge</td>
<td>1947–1950</td>
</tr>
<tr>
<td>Allegheny-Ludlum Steel</td>
<td>1950–1952</td>
</tr>
<tr>
<td>Allied Chemical and Dye Corp.</td>
<td>1951–1969</td>
</tr>
<tr>
<td>Allis-Chalmers Co.</td>
<td>1943–1944</td>
</tr>
<tr>
<td>Aluminum Co. of America (NJ)</td>
<td>1944</td>
</tr>
<tr>
<td>Aluminum Co. of America (PA)</td>
<td>1944–1945</td>
</tr>
<tr>
<td>AMCOT</td>
<td>1961–1962</td>
</tr>
<tr>
<td>American Bearing Corp.</td>
<td>1954–1959</td>
</tr>
<tr>
<td>American Chain and Cable Co.</td>
<td>1944</td>
</tr>
<tr>
<td>American Peddinghaus Corp.</td>
<td>1978</td>
</tr>
<tr>
<td>American Potash &amp; Chemical</td>
<td>1959–1961</td>
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<tr>
<td>Anaconda Co.</td>
<td>1942, 1956–1959</td>
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<tr>
<td>Armco-Rustless Iron &amp; Steel</td>
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<tr>
<td>Armour Fertilizer Works</td>
<td>1951–1955</td>
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<tr>
<td>Associated Aircraft Tool and Manufacturing</td>
<td>1956</td>
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<td>B&amp;T Metals</td>
<td>1943</td>
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<tr>
<td>Baker and Williams Co.</td>
<td>1957–1962</td>
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<td>Baker and Williams Warehouses</td>
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<td>Baker Brothers</td>
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<td>Baker-Perkins Co.</td>
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<td>Bell Telephone Laboratories</td>
<td>1943–1944</td>
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<td>Bendix Aviation (Pioneer Division)</td>
<td>1960</td>
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<td>Besley-Wells</td>
<td>1953</td>
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<td>Bethlehem Steel</td>
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<td>Bliss &amp; Laughlin Steel</td>
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<td>Blockson Chemical Co. (Bldg. 55)</td>
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<td>Bloomfield Tool Co.</td>
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<td>Bridgeport Brass Co., Havens Laboratory</td>
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<td>Brush Beryllium Co. (Detroit)</td>
<td>1940–1955</td>
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<td>C.H. Schnoor</td>
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<td>C.I. Hayes, Inc.</td>
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<td>Callite Tungsten Co.</td>
<td>1944</td>
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<td>Carboloy Co.</td>
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<td>Carpenter Steel Co.</td>
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<td>Chambersburg Engineering Co.</td>
<td>1957</td>
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<td>Chapman Valve</td>
<td>1948–1949</td>
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<td>Cincinnati Milling Machine Co.</td>
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<td>Combustion Engineering</td>
<td>1965–1972</td>
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<td>Copperweld Steel</td>
<td>1943–1946</td>
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<tr>
<td>Dow Chemical Co. (Madison Site)</td>
<td>1957–1960</td>
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<tr>
<td>Electro Circuits, Inc.</td>
<td>1952–1953</td>
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<tr>
<td>Fenn Machinery Co.</td>
<td>1950</td>
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## List of Applicable Facilities (Continued)

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<tr>
<th>Site name</th>
<th>Years of operation</th>
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<tr>
<td><strong>Fenwal, Inc.</strong></td>
<td>1967–1968</td>
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<tr>
<td><strong>Frankford Arsenal</strong></td>
<td>1952–1954</td>
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<td><strong>Granite City Steel</strong></td>
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<td><strong>Gruen Watch</strong></td>
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<td><strong>Heald Machine Co.</strong></td>
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<td><strong>Heppenstall Co.</strong></td>
<td>1955</td>
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<td><strong>Herring-Hall Marvin Safe Co.</strong></td>
<td>1943–1951</td>
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<td><strong>Hunter Douglas Aluminum Corp.</strong></td>
<td>1959–1963</td>
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<td><strong>Huntington Pilot Plant</strong></td>
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<td><strong>International Minerals and Chemical Corp.</strong></td>
<td>1951–1961</td>
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<td><strong>International Nickel Co., Bayonne Laboratories</strong></td>
<td>1951–1952</td>
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<td><strong>International Register</strong></td>
<td>1943</td>
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<td><strong>Ithaca Gun Co.</strong></td>
<td>1961–1962</td>
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<td><strong>J.T. Baker Chemical Co.</strong></td>
<td>1948, 1957–1958</td>
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<td><strong>Jessop Steel Co.</strong></td>
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<td><strong>Joslyn Manufacturing and Supply Co.</strong></td>
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<td><strong>Kaiser Aluminum Corp.</strong></td>
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<td><strong>Kerr-McGee</strong></td>
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<td><strong>La Pointe Machine and Tool Co.</strong></td>
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<td><strong>Landis Machine Tool Co.</strong></td>
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<td><strong>Magnus Brass Co.</strong></td>
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<td><strong>Mathieson Chemical Co.</strong></td>
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<td><strong>Medart Co.</strong></td>
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<td><strong>Metals and Controls Corp.</strong></td>
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<td><strong>Mitchell Steel Co.</strong></td>
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<td><strong>National Research Corp.</strong></td>
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<td><strong>New England Lime Co.</strong></td>
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<td><strong>New York University</strong></td>
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<td><strong>Picatinny Arsenal</strong></td>
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<td><strong>Podbeliniac Corp.</strong></td>
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<td><strong>Precision Extrusion Co.</strong></td>
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<td><strong>Quality Hardware and Machine Co.</strong></td>
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<td><strong>R.W. Leblond Machine Tool Co.</strong></td>
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<td><strong>Revere Copper and Brass</strong></td>
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<td><strong>Sciaky Brothers, Inc.</strong></td>
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<td><strong>Seymour Specialty Wire</strong></td>
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<td><strong>Spencer Chemical Co., Jayhawks Works</strong></td>
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<td><strong>Sperry Products, Inc.</strong></td>
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<td><strong>Star Cutter Corp.</strong></td>
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<td><strong>Stauffer Metals, Inc.</strong></td>
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<td><strong>Superior Steel Co.</strong></td>
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<td><strong>Tennessee Valley Authority</strong></td>
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<td><strong>Texas City Chemicals</strong></td>
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<td><strong>Titus Metals</strong></td>
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<td>Tocco Induction Heating Div.</td>
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<td>Torrington Co.</td>
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<td>Tube Reducing Co.</td>
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<td>U.S. Steel Co., National Tube Division</td>
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<td>United Nuclear Corp.</td>
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<td>University of Michigan</td>
<td>1944</td>
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<td>Ventron Corporation</td>
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<td>Virginia-Carolina Chemical Corp.</td>
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<td>Vulcan Tool Co.</td>
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<td>W.E. Pratt Manufacturing Co.</td>
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<td>W.R. Grace Co., Agricultural Chemical Div.</td>
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<td>Westinghouse Atomic Power Development Plant</td>
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<td>Wyckoff Drawn Steel Co.</td>
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