Draft

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RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

DRAFT REVIEW OF BLOCKSON CHEMICAL COMPANY RESIDUAL PERIOD SEC-00225

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation Worker Health (the Board)
AEC	Atomic Energy Commission
ANL	Argonne National Laboratory
AWE	Atomic Weapons Employer
Bi	bismuth
bkgd	background
Bq	becquerel
CATI	computer-assisted telephone interview
cm^2	square centimeters
d	day
D&D	decontamination and decommissioning
DCF	dose conversion factor
dpm	disintegrations per minute
dpm/m^2	disintegrations per minute per square meter
dps	disintegrations per second
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
EE	energy employee
FGR	Federal Guidance Report
ft	foot/feet
FUSRAP	Formerly Utilized Sites Remedial Action Program
GM	geometric mean
GSD	geometric standard deviation
hr/yr	hours per year
IRPA	International Radiation Protection Association
kBq/kg	kilobecquerel per kilogram
keV	kiloelectron volts
kg	kilogram
L	liter
m	meter
m/s	meter per second

m^2-s	square meter per second
m^3	cubic meter
µR/hr	microroentgen per hour
µrem/hr	microrem per hour
MDA	minimum detectable activity
MDL	minimum detectable level
MeV	mega-electron volt
mg/m^3	milligrams per cubic meter
mR/hr	milliroentgen per hour
mR/yr	milliroentgen per year
mrad	millirad
mrad/hr	millirad per hour
mrem/yr	millirem per year
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH OCAS Claims Tracking System
OCAS	Office of Compensation Analysis and Support
Pa	protactinium
Pb	lead
pCi/day	picocurie per day
pCi/g	picocurie per gram
pCi/L	picocurie per liter
pCi/m^2	picocurie per square meter
pCi/m^2-s	picocurie per square meter per second
pCi/m^3	picocurie per cubic meter
PER	Petition Evaluation Report
Po	polonium
R	Roentgen
Ra	radium
rad	radiation absorbed dose
rem	Roentgen equivalent man
SEC	Special Exposure Cohort
sec	second

SRDB	Site Research Database
Sv	sievert
Sv/Bq	sieverts per becquerel
TBD	technical basis document
TCC	Texas City Chemicals, Inc.
Th	thorium
U	uranium
U_3O_8	uranium oxide
USACE	United States Army Corps of Engineers
WL	working level

EXECUTIVE SUMMARY

During the November 2015 meeting of the Advisory Board on Radiation and Worker Health (ABRWH or the Board), SC&A, Inc. was directed to perform a review of the National Institute for Occupational Safety and Health (NIOSH) Special Exposure Cohort (SEC) Petition Evaluation Report (PER) for Blockson Chemical Company (NIOSH 2015). This draft report is provided in response to the Board's direction.

Blockson Chemical Company (Blockson) was a commercial producer of various forms of phosphate products that made use of what is referred to as the "wet process," in which crushed phosphate rock was digested in sulfuric acid. This digestion process produced phosphoric acid, which was further processed to produce various phosphate products. One of the byproducts of the digestion process was a solid, phosphogypsum, which was collected and stored outdoors in large volumes.

It has long been recognized that phosphate ore often contains elevated levels of naturally occurring uranium, at about 0.01 % by weight of the ore. Given the value and scarcity of uranium, especially in the early years of the weapons complex, the Atomic Energy Commission (AEC) contracted with Blockson to develop and implement a process to separate the uranium from the ore. The uranium, and also the thorium associated with the ore, reports to (i.e., follows) the phosphoric acid, but the radium226 (Ra-226) reports to the phosphogypsum during ore digestion. In order to capture the uranium, Blockson built a separate building, Building 55, next to the building that processed the ore and produced phosphoric acid, phosphate product, and phosphogypsum (Building 40). The phosphoric acid that was produced in Building 40 was sent to Building 55, where the uranium was separated out (along with the thorium), collected in 55-gallon drums, and sent to the AEC. As the uranium was removed, the phosphoric acid was returned to Building 40 to resume its processing to produce phosphate product.

These Atomic Weapons Employer (AWE) activities were performed at Blockson from 1951 through June 1960. During this time, workers had the potential to experience both external and internal exposures to uranium, thorium, and its progeny, not only in Building 55, but also in Building 40 and in the vicinity of the outdoor phosphogypsum stacks. Many Blockson workers who were employed during this time period and subsequently were diagnosed with cancer submitted claims for compensation under the Energy Employee Occupational Illness Compensation Program Act (42 CFR Part 83). However, the Board determined that the doses to workers at Blockson could not be reconstructed with sufficient accuracy because of the inability to reconstruct radon exposures in Building 40 during the AWE operational period, and an SEC was granted for this time period.

Subsequently, Blockson workers submitted an SEC petition claiming that workers who were employed at Blockson producing phosphate products after the termination of AWE operations were exposed to residual levels of radioactive material, and that those workers should also be designated as an SEC class. NIOSH performed a review of the SEC petition and issued SEC Petition Evaluation Report No. 00225 (NIOSH 2015), concluding that exposures experienced by workers after the termination of AWE operations (referred to as the residual period) could be reconstructed with sufficient accuracy, even though external dosimetry and bioassay data were not available.

SC&A reviewed SEC Petition Evaluation Report No. 00225 (NIOSH 2015) and has five findings and one observation, as follows:

Finding 1. The approach used to assign external exposures to workers at Blockson, though reasonable, is not consistent with the method used to assign external exposures at Simonds Saw and Steel, nor is it consistent with reported working hours characterized in claimant computer-assisted telephone interview (CATI) reports.

In order to reconstruct external photon exposures during the residual period, NIOSH used extensive external radiation surveys that were performed in Building 55 in 1978 (DOE 1983) as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP) site characterization program. Finding 1 has to do with a consistency issue. In the case of Blockson, a full distribution of the data was assigned to plant workers and a work year of 2,000 hours was applied, this despite the fact that 90 percent of Blockson claimants who answered the question concerning typical working hours reported working overtime in their CATI interviews. In contrast, at Simonds Saw and Steel, the 95th percentile value and 2,500 hours per year were used [ORAUT-TKBS-0032, Revision 02 (2014); also referred to as the site profile or technical basis document (TBD) for Simonds Saw and Steel].

Section 3.2 of *Draft Criteria for the Evaluation and Use of Coworker Datasets*, Version 4.1.1, July 2015 (Neton 2015), states:

> *For workers that are considered to have worked in environments with a potential for elevated exposure, the 95th percentile of the distribution should be used as an upper bound of their exposure during the modeled time period. Although it could be argued that the job categories that fall under this criterion should be listed, any attempt to do so might be artificially restrictive. This decision is most accurately made using the information available in the site profiles, the claimant interview and other documents that might be in the worker's records. For workers who were less likely to be highly exposed and/or were intermittently exposed in the workplace, the full distribution (i.e., the geometric mean and its associated standard distribution if a lognormal fit is used) should be used as representative of their potential for exposure during the modeled period.*

SC&A understands that the primary purpose of Neton (2015) is to provide generalized guidance for analyzing coworker datasets. Nonetheless, the question of implementation (i.e., determining the relative exposure potential of "production" versus "administrative" personnel) would appear applicable to Blockson. While SC&A recognizes that there will always be some degree of professional judgment involved in determining which workers had elevated exposure potential at any particular site and time period, we believe that NIOSH has not sufficiently explained their reasoning is choosing to assign the full distribution instead of the 95th percentile to workers at Blockson during the residual period.

Finding 2. The Blockson TBD (DCAS-TKBS-0002, Revision 04) should address the potential radiological exposures associated with the phosphogypsum stacks, including the relatively small volumes of scale and sediment containing elevated levels of Ra-226 that are often present in phosphogypsum stacks.

In considering the potential external exposures experienced by workers during the residual period, NIOSH limited its investigations to Building 55. Workers could have also experienced elevated exposures from the phosphogypsum stacks. SC&A checked these potential exposures and found that the exposures in Building 55 were likely limiting, but we believe it would have been appropriate for the site profile to have investigated this potential issue, including the potential for elevated exposures due to the presence of scale and sediments in the phosphogypsum stacks and its associated elevated levels of Ra-226.

Finding 3: Beta dose associated with residual contamination in Building 55 should be included in the site profile.

The site profile appears to have dismissed external beta exposures to the skin during the residual period as insignificant. SC&A's investigations reveal that the potential beta exposures to skin to workers in Building 55 during the residual period were not insignificant and should be addressed.

Finding 4. The doses associated with the inhalation of resuspended particulates in the vicinity of the phosphogypsum piles should be explicitly addressed in the site profile.

The site profile explicitly evaluated the potential exposures to resuspended particulates in Building 55 during the residual period. However, no consideration is given to the potential inhalation exposures associated with resuspended particulates in the vicinity of the phosphogypsum stacks. SC&A investigated this exposure scenario and found that inhalation exposures in Building 55 during the residual period, as derived in the site profile, appear to be limiting. However, for completeness, this exposure scenario should be investigated.

Finding 5. The radon concentration in the vicinity of the phosphogypsum stacks should remain at the elevated level of 2.1 picocuries per liter (pCi/L) up until 1991, the time when the piles actually became inactive.

The site profile estimates radon exposures in the vicinity of phosphogypsum stacks using surrogate data and making corrections to account for the fact that aged stacks have lower radon emanation rates than active piles. However, the methods used to make these adjustments do not appear to be claimant favorable because the stack remained active until 1991, and DCAS-TKBS-0002, Revision 04, applied a reduction factor of 5 as if the pile became inactive in June 1960. We acknowledge that AWE operations ceased in June 1960, but NIOSH elected to assume that the entire pile, including the phosphogypsum produced after June 1960, is to be treated as if it was contributing to AWE exposures during the residual period. Given this assumption, the aging process should have been assumed to begin in 1991, not in June 1960.

Observation 1: Radon exposures to workers in the vicinity of phosphogypsum stacks during the residual period appear to have been substantially overestimated.

The site profile takes the position that the radon exposures associated with the phosphogypsum piles cannot be distinguished between the phosphogypsum produced during AWE operations that took place from 1951 through June 1960 and the phosphogypsum produced during commercial operations that extended to 1991. This assumption results in implausibly high estimates of AWE-related radon exposures for time periods when the phosphogypsum produced during AWE operations was covered with large volumes of phosphogypsum produced during commercial operations and would have been largely attenuated by the commercially produced phosphogypsum overburden.

1.0 INTRODUCTION AND BACKGROUND

On February 24, 2015, NIOSH received an SEC petition for the Blockson Chemical Co. (SEC-00225). The petitioner-requested class was as follows:

> *All maintenance and operations personnel who worked in any area at Blockson Chemical Co. in Joliet, Illinois, from July 1, 1960 through December 31, 1991.* [NIOSH 2015]

The SEC qualified for evaluation on May 5, 2015, with the class definition amended as follows:

> ***All employees*** *who worked in any area at the Blockson Chemical Co. site in Joliet, Illinois, during the period from July 1, 1960 through December 31, 1991.* [NIOSH 2015; emphasis added]

One of the main functions at the Blockson Chemical Company was the manufacture of phosphoric acid from phosphate rock that originated in Florida. The facility used a wet acid process to produce the phosphoric acid, which was then used to manufacture other chemicals at the site. In the early 1950s, the AEC approached Blockson about recovering uranium from the phosphate rock being processed at the site. Feasibility studies of recovering uranium were undertaken at Blockson beginning in 1951, and it was determined that the material could be recovered using a by-product process with existing plant operations. Building 55 was specifically constructed to house this process, which was performed under contract with the AEC up until June 30, 1960, which constitutes the end of the designated AWE "operational period." Therefore, SEC-00225 covers the subsequent residual period for the site.

Previously, the ABRWH had granted an SEC for the operational period of the site under SEC-00058 (ABRWH 2006). The basis for granting the petition was the inability to reconstruct, with sufficient accuracy, the exposure of workers to radon in Building 40, where digestion of the phosphate rock took place. It is important to note that this dose reconstruction feasibility issue is not relevant to SEC-00225, since AEC-contracted activities were no longer occurring during the period of interest. However, residual contamination from the operational period would still have existed in Buildings 40 and 55, and also at the phosphogypsum pile, which contained the waste product from the wet acid processing of phosphate rock. The primary contaminants of concern for Buildings 40 and 55 are uranium, thorium, and relevant progeny. Radium, which was largely separated during the wet acid process, was transferred into the phosphogypsum waste material.

NIOSH completed its petition evaluation report for SEC-00225 (NIOSH 2015) on September 8, 2015, and presented its findings to the Board on November 19, 2015. NIOSH determined that dose reconstruction was feasible for the evaluated period and reached the following findings, as stated in NIOSH 2015:

- *NIOSH finds that it is not applicable to reconstruct occupational medical dose for Blockson Chemical Co. during the period under evaluation. Medical X-rays are not required to be considered during a residual radiation period.*

- *Principal sources of internal radiation for members of the proposed class included exposures to natural uranium and thorium (and their progeny) through inhalation or ingestion of surface or airborne contamination.*
- *NIOSH has obtained personnel bioassay monitoring data from the production period prior to the period under evaluation, and workplace and air monitoring data from the period under evaluation to allow it to reconstruct with sufficient accuracy the internal doses from natural uranium and thorium and their progeny, for Blockson Chemical Co. workers during the period from July 1, 1960 through December 31, 1991.*
- *Principal sources of external radiation for members of the proposed class included exposures to surfaces contaminated with natural uranium and thorium (and their progeny) and submersion in resuspended surface contamination.*
- *NIOSH has found no external personnel monitoring data for the period under evaluation. NIOSH has obtained workplace radiological survey data and site source-term information to allow it to reconstruct with sufficient accuracy the external doses from natural uranium and thorium and their progeny, for Blockson Chemical Co. workers during the period from July 1, 1960 through December 31, 1991.*

During the Advisory Board meeting on November 19, 2015, the Board tasked SC&A to review the petition evaluation report and the determination that dose reconstruction is feasible with sufficient accuracy. This report presents the results of that review.

As a preface to this report, note that, in addition to the SEC PER (NIOSH 2015) and DCAS-TKBS-0002, Revision 04, there are a number of other source documents that serve as the underpinning to radiological issues addressed in this report. These include ORAUT-OTIB-0043, Revision 00, *Characterization of Occupational Exposure to Radium and Radon Progeny during Recovery from Phosphate Materials* (2006); the Florida Institute of Phosphate Research's (FIPR), *Evaluation of Exposure to Technically Enhanced Naturally Occurring Radioactive Materials (TENORM) in the Phosphate Industry* (FIPR 1998); and U.S. Environmental Protection Agency (EPA) 520/5-85-029, *Radon Flux Measurements on Gardinier and Royster Phosphogypsum Piles Near Tampa and Mulberry, Florida* (EPA 1986).

2.0 RECONSTRUCTION OF EXTERNAL DOSES

2.1 OVERVIEW OF PROPOSED NIOSH METHODOLOGY

As stated in NIOSH 2015 and reproduced in Section 1 of this report, NIOSH was unable to find any external dosimetry data associated with the residual period at Blockson (in fact, external dosimetry data are also unavailable for the operational period). However, the Blockson site (and Building 55 in particular) was surveyed in 1978 by the Argonne National Laboratory (ANL) under the United States Army Corps of Engineers (USACE) FUSRAP (see Appendix A). The survey took both contact readings and readings at 1 meter. In total, 70 measurements were reported at 1 meter, with 7 that were reported as above background exposure levels.[1] The seven survey results above background ranged from 0.04 milliroentgen per hour (mR/hr) to 0.2 mR/hr (DOE 1983). NIOSH has elected to utilize the upper-end background exposure rate (0.03 mR/hr) as the median exposure rate, with the upper-end 95th percentile as the maximum reading at 1 meter (0.2 mR/hr). This results in a geometric standard deviation (GSD) of 3.2 and will be applied as a lognormal distribution assuming a 2,000 hours per year (hr/yr) exposure. This exposure distribution is assumed to be 10% 30–250 kiloelectron volts (keV) and 90% >250 keV photons.

Beta dose was considered in NIOSH 2015, and it was determined that there was no need to assign a beta dose during the residual period. NIOSH modeled the potential exposure to beta or non-penetrating radiation by modeling the dose from fixed residues and submersion in resuspended materials. Using the maximum fixed and removable contamination values in DOE 1983, and assuming 2,000 hr/yr and a resuspension factor of 10^{-6} per meter, NIOSH calculated the penetrating photon exposure as 0.5 millirem per year (mrem/yr) and the beta exposure to the skin as 25.1 mrem/yr. NIOSH 2015 concludes the following:

> *These values are much less than the bounding 0.060 rem per year assumed for photon exposure.*
>
> *Beta dose is bounded within the 0.060 rem per year assigned as photon dose…. Beta dose is not reconstructed separately for the period under evaluation from July 1, 1960 through December 31, 1991.*

The SEC PER (NIOSH 2015) notes most of the residues identified by ANL were in locations that were relatively inaccessible, such as on overhead beams and overhead pipes. Additionally, interviews with former workers indicated that work areas were washed down on a daily basis.

2.2 SC&A'S REVIEW OF PROPOSED EXTERNAL DOSE RECONSTRUCTION METHOD

This section is divided into two subsections. Section 2.2.1 reviews the individual claimant records to confirm that no external dosimetry data are available for Blockson workers during the residual period. Section 2.2.2 evaluates the methods used in the SEC PER (NIOSH 2015) and DCAS-TKBS-0002, Revision 04 to reconstruct external doses during the residual period.

[1] The background levels reported in FUSRAP 1978 ranged between 0.02-0.03 mR/hr.

2.2.1 Review of Claimant Records

SC&A examined the NIOSH OCAS Claims Tracking System (NOCTS) records of 143 energy employees (EEs) that were available at the time of this review for evidence of external monitoring and any other related information about radiological conditions at Blockson during the residual period. Specifically, the records included the CATI, U.S. Department of Energy (DOE) response, and U.S. Department of Labor (DOL) case files.

Eleven of the 143 EEs were not employed at Blockson during the residual period and were not evaluated further. Fifteen EEs were solely employed during the residual period. Anecdotal information available in the CATI statements for these EEs is summarized in Table 1.

Table 1. Summary of Relevant CATI Information for 15 EEs Solely Employed during the Residual Period

Number of EEs	Comments and/or Statements in CATI
9	Stated that no radiological monitoring occurred during the covered employment. Seven of 9 were conducted with the energy employee; the other two were conducted with a survivor.
2	Were unavailable either because the claim had been pulled prior to the CATI being performed or the CATI was declined.
3	Were conducted with survivors who were unsure if there was radiological monitoring. Case 1: "[The EE] *wore a picture badge and also a separate badge*." Case 2: Survivor stated the EE had a "regular badge" but doesn't know if it was a dosimetry badge.
1	One survivor stated the following: "*He was the Safety* [redacted]. *He was* [redacted] *of radiation exposure and general worker safety…not sure if* [the EE] *wore a radiation monitor, but he did carry a Geiger Counter around with him*." No other evidence related to the use of a Geiger counter could be located in the claimant's files.

Of the remaining EEs who had employment in both the operational/residual period, only 22 claims contained CATI reports directly with the EE. Of these 22 claims for which the CATI was with the EE, the following was reported:

- Eighteen (~82%) reported that no external monitoring took place.
- Two (~9%) were unsure if they were monitored externally.
- Two (~9%) stated that they wore a dosimetry badge.

No additional evidence existed in the DOE or DOL files indicating that external monitoring was conducted for the two EEs who reported wearing dosimeters.

SC&A also examined available documentation in the Site Research Database (SRDB) to attempt to identify any indication that EEs may have been individually monitored either during the residual period or toward the end of the operational period. SC&A did not find significant evidence to indicate that energy employees could have been monitored externally either in the residual period or the operational period; therefore, an alternate modeling approach was needed to assign external exposures.

2.2.2 Review of External Photon Dose Reconstruction Data and Procedures

External exposures at Blockson during the residual period could have included exposures to residual levels of uranium and progeny, and relatively smaller amounts of thorium-232 (Th-232) and progeny that may have been deposited on surfaces and equipment as residue in Building 55. In addition, residue from crushed ore and phosphogypsum residue associated with AWE operations in Building 40 could have resulted in some external exposures during the residual period. Finally, workers outdoors in the vicinity of the phosphogypsum stacks could also have experienced external exposures from radium and its progeny from the phosphogypsum produced during the AWE period and remained onsite well after the termination of AWE operations in June 1960.

In theory, any of the workers present on site during the residual period could have experienced external exposures from these sources. However, since it is not plausible to determine which workers might have been exposed to any one or combination of these sources of exposure, DCAS-TKBS-0032, Revision 04, investigated the limiting exposure scenarios and developed methods to reconstruct those exposures, taking advantage of available data.

Sections 5 and 6 of DCAS-TKBS-0002, Revision 04, describe the methods NIOSH used to reconstruct worker doses during the residual period. For external exposures, page 41 of the TBD explains that the limiting external dose is believed to be associated with residual radioactivity in Building 55. Hence, NIOSH developed a method to reconstruct these exposures and applied them to all workers at the site during the residual period. Table 11 of the TBD presents those doses, which are applied for every year and to every worker during the residual period.

The data and methods used to derive these doses are described in Section 4.2.3 of DCAS-TKBS-0002, Revision 04 (also referred to as "the TBD"). The data used in the TBD as the starting point for developing the external exposure rates provided in Table 11 of the TBD are from surveys performed in 1978 by ANL as part of the FUSRAP remediation program. External exposure rate measurements were made on 95% of the floors and 90% of the walls at contact and at 1 meter (see page 30 of DCAS-TKBS-0002, Revision 04). The key findings of these surveys are stated in the TBD, as follows:

> *The dose rates at 1 meter on 7 of the 63 "hot" spots ranged from 0.04 mR/hr to 0.2 mR/hr. The other 56 spots had 1 meter dose rates indistinguishable from background. The reported background dose rate on the instrument used was between 0.02 mR/hr and 0.03 mR/hr. The results of the 7 spots with measurable 1 meter dose rates included the background dose rates. From a review of the survey map and results it seems improbable that a worker could be significantly exposed above the background rate of 0.03 mR/hr for significant time. However,*

> *in the absence of individual dosimeter data, whole body dose rates are modeled by a lognormal distribution by assuming a worker was exposed to the 0.03 mR/hr rate for 2,000 hours per year, which results in an annual exposure of 60 mR, or 0.06 R. To allow for uncertainty this value is applied as the median of a lognormal distribution. The geometric standard deviation is 3.2, which was determined by assuming that the 95th percentile dose rate is equal to the maximum observed result of 0.2 mR/hr.*

On this basis, an external penetrating exposure rate of 60 milliroentgen per year (mR/yr) was assigned as the geometric mean (GM) of a distribution with a GSD of 3.2. These exposure rates were converted to organ effective doses, as provided in Table 11 of the TBD, using Appendix A of OCAS-IG-001 (2007). SC&A confirmed that these dose conversion factors are correct.

A review of the data collected by ANL revealed that the above summary is an accurate characterization of the data. The 1978 FUSRAP survey (DOE 1983, SRDB 23615) for Blockson contains dose rate measurements made within Building 55, both at contact and at 1 meter. Of the 70 1-meter measurements, 7 locations had dose rates that were measurable above background. Of these seven locations, one was located on a stainless steel Kelly, one was located inside of a steel pipe, and the remaining five were located on the concrete floor. The highest reading of 0.2 mR/hr corresponded to an area of the floor.

DOE 1983 also investigated the potential maximum exposure from the measured contamination, which was found to be 340 mrem/yr (page 26). Appendix 7 of DOE 1983 details this calculation, as follows:

A = 40 hr/week × 50 weeks/year × (0.2 mR/h – 0.03 mR/h background)

= 2000 hours/yr × 0.17 mR/h above background

= 340 mR/yr

= 340 mrem/yr

Given these data, it is appropriate to raise a number of questions about the data and the strategy that DCAS-TKBS-0002, Revision 04 adopted for assigning external penetrating doses to workers at Blockson during the residual period.

<u>Question 1 – Is it reasonable to select 60 mR/yr above background as a default exposure for workers in Building 55 in 1978 based on these data?</u>

The data indicate that the vast majority of the readings were below the minimum detectable level (MDL), which is cited as a maximum of 30 micro-Roentgen per hour (µR/hr). However, 7 of the 119 readings gave results of 40 µR/hr to a maximum of 200 µR/hr. The source documents for these data summary clearly reveal that most of the readings were below the maximum MDL of 30 µR/hr, which, in itself, is a generous MDL, especially considering that the background exposure rates were likely on the order of 10–20 µR/hr (based on general knowledge of background exposure rates). However, a more claimant-favorable value would be to use the data that were observed to be above the MDL. For example, taking the GM of the 40 µR/hr and 200 µR/hr (i.e., 89 µR/hr) would yield an annual exposure of 178 mR/yr above background. This would be a more favorable, but perhaps implausible, annual exposure, since only 7 of 119 measurements were above 30 µR/hr, and a worker would had to have spent the entire 2,000 hours per year in this radiation field. In addition, a GSD of 3.2 was used, which corresponds to 60 mR/yr × 3.2 = 192 mR/yr, and which certainly captures the possible high-end exposures. On this basis, an annual GM exposure rate of 60 mR/yr above background, with a GSD of 3.2, appears to be a reasonably bounding value for all workers who might have been in Building 55 <u>in 1978</u>, the year the measurements were made.

<u>Question 2 – Is the strategy for assigning external exposures at Blockson for the residual period consistent with the approach used at other AWE facilities?</u>

SC&A is concerned that the approach used at Blockson for assigning external exposures may not be consistent with the approaches used at other AWE facilities. Specifically, the strategy used in DCAS-TKBS-0002, Revision 04, for Blockson is inconsistent with the approach used at Simonds Saw and Steel Co. (ORAUT-TKBS-0032, Revision 02). In ORAUT-TKBS-0032, Revision 02, NIOSH states that a total of 37 external dose rate measurements from four different surveys between 1957 and 1999 were ranked and fit to a lognormal distribution. NIOSH calculated the annual penetrating dose for workers during the residual period by assuming 2,500 hours of exposure per year at 80 µR/hr, resulting in an annual exposure of 200 mR/yr. The 95th percentile of the distribution for Simonds Saw and Steel Co. was 75 µR/hr, yet NIOSH used an even higher exposure rate of 80 µR/hr in its calculation of annual external dose (page 43 of ORAUT-TKBS-0032, Revision 02). For Blockson, NIOSH used what is more reflective of a lognormal distribution with a GM and GSD, instead of the 95th percentile dose rate, as was used at Simonds Saw and Steel (which was actually set to the maximum measured dose rate). Another difference is that, for Simonds Saw and Steel Co., NIOSH used 2,500 hours per year to determine annual exposures, whereas for Blockson, NIOSH assumed an exposure duration of 2,000 hours per year. Based on SC&A's review of the relevant claimant population employed during the residual period, more than 90% of the cases reported working more than 40 hours per week. Specifically, as of the time of the preparation of this report, there were 131 Blockson claimants, of whom 121 provided information concerning typical work-hour practices. (The remaining 10 claimants did not have CATI reports available, the CATI was declined, or the interviewee did not have information on the number of hours worked in a typical work-week.) Of the 121 who reported typical work-hour practices, 109 reported working at least some overtime.

Finding 1. The approach used to assign external exposures to workers at Blockson, though reasonable, is not consistent with the method used to assign external exposures at Simonds Saw and Steel, nor is it consistent with reported working hours characterized in claimant CATI reports.

<u>Question 3 – Is it possible that the exposure rates in Building 55 immediately following the termination operations in June 1960 could have been substantially higher than the 60 mR/yr value, which is based on data collected in 1978?</u>

In theory, external exposures measured in 1978 could be used to back-calculate the exposures at the beginning of the residual period (June 1960) by applying the basic strategy adopted in ORAUT-OTIB-0070, Revision 00, *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (2012). The ORAUT-OTIB-0070 approach would involve estimating the average uranium airborne dust loading observed in Building 55 toward the end of AWE operations, and then deriving the accumulated concentration of uranium that might have been deposited on surfaces during this time period. This surface contamination level would then be used to estimate external exposure rates as a function of time after the end of AWE operations using well-established protocols, such as those described in Battelle-TBD-6000 (also referred to as TBD-6000) and ORAUT-OTIB-0070.

Unfortunately, as described in DCAS-TKBS-0002, Revision 04, there were no airborne dust loading or surface contamination data collected during AWE operations. However, there are uranium bioassay data for Building 55 workers during AWE operations that can be used to back-calculate the airborne dust loadings in Building 55, which, in turn, can be used to estimate the amount of uranium that might have deposited on surfaces toward the end of the AWE operations period. Page 20 of the TBD states that, based on the bioassay data,

> *Daily intake rates ranged from 6 to 76 pCi/day. The intake rate results fit well to a lognormal distribution having a median value of 25 pCi/day with a geometric standard deviation of 2.1.*

The airborne dust loading associated with a daily median intake rate of 25 picocuries per day (pCi/day) would be 2.6 picocuries per cubic meter (pCi/m^3). However, apparently, for the purpose of deriving external exposure rates from direct deposition, NIOSH used an upper end airborne dust loading of 4.3 pCi/m^3, as follows (page 29):

> *Estimates of external dose from surfaces contaminated with uranium have been performed. The 95th percentile intake rates from inhalation were used to derive a U-238 airborne concentration of 4.3 pCi/m^3. A terminal settling velocity of 0.00075 m/s was used as an estimate of the velocity of deposition to surfaces in the building. The value is within the range of deposition velocities measured in various studies (NRC 2002b). It was assumed that uranium settled on plant surfaces at a steady state 24 hours per day for 365 consecutive days with no cleanup or removal of contamination.*

The accumulated dust loading on surfaces could be estimated assuming a deposition velocity of 0.00075 meters per second (m/s) for an entire year, or 4.3 pCi/m^3 × 0.00075 m/s × 3.15E7 seconds per year = 101,588 picocuries per square meter (pCi/m^2). This value could be assumed to be the uranium contamination level on surfaces in Building 55 at the beginning of the residual period, assuming no cleanup after AWE operations ceased. The external exposure rate from uranium and its short-lived progeny at this time would be:

101,588 pCi/m^2 × 3.94E-10 mR/hr per dpm/m^2 ÷ (1 dps/60 dpm × 1 Bq/dps × 27 pCi/Bq) = 8.89E-5 mR/hr = 8.89E-2 µR/hr

The dose conversion factor of 3.94E-10 mR/hr per disintegrations per minute per square meter (dpm/m^2) is from Table 3.10 of TBD-6000, which was previously reviewed by SC&A as part of its review of TBD-6000 and found to be scientifically sound.

This exposure rate is based on the assumption that all the activity is due to natural uranium, including 100-day ingrowth of its short-lived progeny, Th-234 (100% abundance), protactinium-234m (Pa-234m) (100% abundance), and Pa-234 (with an abundance of <1%). The source of the photon exposures would be primarily low-energy photons and one strong photon [1.9 mega-electron volt (MeV)] from Pa-234, but with a very low abundance (1.3E-3).

However, radionuclides other than natural uranium and its short-lived progeny would have also reported to Building 55. Table 1 of DCAS-TKBS-0002, Revision 04, reproduced here as Table 2, provides the relative amounts of the various radionuclides that reported to Building 55 and likely represent the source of the gamma activities in the radiation surveys and the alpha activity in the swipe samples collected in Building 55 during the residual period:

Table 2. Reproduction of Table 1 of DCAS-TKBS-0002, Revision 04, "Building 55 Relative Radionuclide Concentrations"

Radionuclide	Relative Ratio[1]	Notes	Normalized to U-238[a]
U-238	85	Progeny in equilibrium through Th-230	1
U-235	3.87	Progeny in equilibrium	0.0455
Ra-226	4	Progeny in equilibrium	0.047
Pb-210	85	Equal to U-238	1
Bi-210	85	Equal to U-238	1
Po-210	85	Equal to U-238	1
Th-232	2.8	Progeny in equilibrium	0.033

[a] Ratios given for the progeny without consideration of branching ratios, where applicable.

Since these other radionuclides, which include photon emitters, also reported to Building 55, they also would contribute to the photon radiation field observed in 1978. This table requires a little discussion. Uranium-235 (U-235) would not contribute to the photon field, but Ra-226 and its progeny would. As discussed in DCAS-TKBS-0002, Revision 04 and its supporting literature, though most of the Ra-226 reports to the phosphogypsum, some (4%) report to the phosphoric acid and would contribute to the residual radioactivity in Building 55 in 1978. Table 3 provides the external dose conversion factors for an infinite plane contamination of Ra-226 and its progeny and also for Th-232, as given in Table III.3 of Federal Guidance Report (FGR) No. 12 (EPA 1993):

Table 3. External Dose Conversion Factors for an Infinite Plane of Contamination (from EPA 1993)

Isotope	Fraction*	DCF (Sv/s per Bq/m^2)	Skin
Ra-226	0.047	6.44E-18	8.12E-18
Bi-214	0.047	1.41E-15	8.48E-15
Pb-210	1	2.48E-18	1.98E-17
Th-232	0.033	5.51E-19	6.86E-18

*Normalized to U-238.

Table 3 indicates that, even though Ra-226 [and by association, bismuth-214 (Bi-214)] contributes only 4.5% of the total activity relative to U-238, the dose conversion factor associated with Bi-214 is so large that it cannot be ignored for the purposes of this analysis. The following calculation demonstrates this point.

Assuming that the activity of Bi-214 on surfaces in Building 55 is 0.047 of that of U-238, the additional external exposure rate from Bi-214 can be estimated as follows:

101,588 pCi/m^2 × 0.047 × 1.41E-15 Sv/s m^2/Bq × 1.0E5 mrem/Sv × 3,600 s/hr × 1 Bq//27 pCi = 8.98E-5 mrem/hr = 8.89E-2 µrem/hr

This value is appropriately compared to the exposure rate for uranium of 8.89E-2 µR/hr. Hence, the contribution of radionuclides other than U-238 and its progeny to the external exposure rate cannot be ignored. In fact, one could conclude that the relatively small amount of Bi-214 is responsible for approximately half of the external exposure associated with residual uranium in Building 55.

Notwithstanding these results, this external photon exposure rate, as derived from estimates of surface contamination immediately following the termination of AWE operations, are a very small fraction of the 0.03 mR/hr (30 µR/hr) exposure rate used in DCAS-TKBS-0002, Revision 04 for the entire residual period, and it appears to be claimant favorable to assign external exposures using the 1978 survey data as opposed to using the conventional ORAUT-OTIB-0070 approach.

<u>Question 4 – DCAS-TKBS-0002, Revision 04, could have also used swipe data to derive external exposure rates. If those data were used, would the derived exposure rates have been substantially different than those obtained using the 1978 exposure rate data?</u>

As a check on the external dose rate of 60 mR/yr employed in the TBD for the residual period, SC&A used the maximum alpha swipe contamination level of 640 disintegrations per minute (dpm) per 100 square centimeters (cm^2) cited on page 33 of DCAS-TKBS-0002, Revision 04. Appendix A presents a tabulation of the data from DOE 1983. This value is cited as the maximum swipe level observed in a survey performed in 1978. The value is used in DCAS-TKBS-0002, Revision 04, to derive inhalation exposures from resuspension, but it could also be used to bound external exposure rates, as follows:

Uranium: 640 dpm/100 cm^2 × 3.9E-10 mR/hr per dpm/m^2 × 1E4 cm^2/m^2 = 2.5E-5 mR/hr

Bi-214: 640 dpm/100 cm^2 × 0.047 × 1.41E-15 Sv/s per Bq/m^2 × 1 dps/60 dpm × 1 Bq/dps × 1E5 mrem/Sv × 1E4 cm^2/m × 3,600 s/hr = 2.54E-5 mrem/hr

The factor of 3.9E-10 mR gamma per hour per alpha dpm/m^2 was obtained from TBD-6000, Table 3.10, page 26, reproduced here as Figure 1. These values were previously reviewed by SC&A as part of its review of TBD-6000 and found to be scientifically sound.

Figure 1. Table 3.10 from TBD-6000

Table 3.10 Dose conversion factors from natural uranium surface contamination

Surface contamination dose conversion factors		
Time since separation	Photon Exposure Rate (mR/h per dpm(α)/m²)	Beta dose rate (mRad/h per dpm(α)/m²)
100 d	3.94E-10	3.82E-08

Assuming an exposure duration of 2,000 hours per year, the annual dose to workers at that time would be about 0.1 mrem/yr in 1978. In one respect, this estimate is an overestimate because it is based on the maximum, as opposed to the average, smear level. However, conversely, it is based on smear results, which only pick up the removable contamination. Based on Regulatory Guide 1.86 (NRC 1974), a smear is likely to represent about one fifth of the total deposited contamination.

Assuming that 0.1 mrem/yr is a reasonable estimate of the external dose in 1978, based on swipe data, it is likely that the external exposure rate would be higher in June 1960, the time when AWE operations ceased. Using a natural attenuation rate of 0.00067/day recommended in ORAUT-OTIB-0070, the exposure rate in 1960 would be about 8 mrem/yr.

This last calculation indicates that the value of 60 mR/yr for every year during the residual period is claimant favorable, even if one considers that the contamination level immediately following AWE operations in June 1960 might be substantially higher than the surface contamination levels observed in 1978.

It is noteworthy that, using the ORAUT-OTIB-0070 approach, in what we can refer to as the reverse mode, provides external exposure rates at the end of AWE operations (i.e., June 1960) that are about 1 order of magnitude smaller than the actual measured values as used in DCAS-TKBS-0002, Revision 04, obtained from survey data collected in 1978. One of the likely reasons for this is that the "forward" calculation as used in ORAUT-OTIB-0070 was selected to be a gradual decline and, therefore, claimant favorable. However, in the reverse mode (i.e., going backward in time), the gradual upward slope is not claimant favorable.

The lesson learned from this discussion is that using the ORAUT-OTIB-0070 protocols to perform reverse calculations could result in substantial underestimates of the surface contamination levels at the beginning of the residual period. NIOSH wisely used exposure rate measurements made in 1978, which resulted in more claimant-favorable estimates of external doses from residual uranium than would have been derived using OTIB-0070 in the reverse direction. This exercise reveals that the OTIB-0070 natural attenuation rate of 0.00067/day should not be used in the reverse direction, because it is likely to be non-claimant favorable.

Question 5 – Are the external exposures associated with Building 55 limiting as compared to other locations at the site? For example, another location at the site where the external exposure rates could have been elevated is in the vicinity of the phosphogypsum stacks.

Section 4.1 of DCAS-TKBS-0002, Revision 04, summarizes external dosimetry data from FIPR 1998. FIPR 1998 presents a detailed series of investigations of the radiation exposures experienced by workers at all stages and locations of the phosphate industry. Estimates of the annual exposures of workers in the industry are provided in Appendix C of the FIPR report based on external dosimetry measurements adjusted for dosimeter type. The data are sorted according to a very large numbers of different job categories and locations, and it is not self-evident which categories are best representative of workers who might have worked in close proximity to phosphogypsum stacks during and following the termination of phosphate production. The reported annual exposures ranged from a high of 141.3 mrem/yr for assistant operators and 184.4 mrem/yr for paint yard personnel to a low of 5–10 mrem/yr for most other categories of workers.

In order to obtain additional information on how to best interpret the data provided in Appendix C of FIPR 1998, SC&A contacted [redacted] on January 13, 2016, to discuss his personal experience with respect to external gamma exposures in the vicinity of phosphogypsum stacks ([redacted] 2016a). [redacted] explained that it is difficult to identify which of the various categories of workers and locations best represent workers that may have spent extended periods of time in the vicinity of the stacks, because most workers move around the site. However, he indicated that the Payload Operator would likely have spent a substantial amount of time in the vicinity of the stacks, and that category of exposure is estimated to have experienced external photon doses of about 5 mrem/yr above background (a value difficult to discern above natural background).

Tables C-1, C-2, and C-3 in Appendix C of FIPR 1998 provide doses from three deployments of aluminum oxide dosimeters for the “payloader operator” that range from 4.5 to 6.5 mrem/yr. Table C-4 shows 17.4 mrem/yr from a 3-month lithium fluoride badge deployment (FIPR 1998).

Based on this information and analysis, it appears that the external exposure dose rate of 60 mR/yr used in DCAS-TKBS-0002, Revision 04, to place a plausible upper bound on worker exposures during the residual period in 1978 (which is derived from survey data applicable to Building 55) is likely higher than that experienced by workers who may have spent extended periods of time in the vicinity of phosphogypsum stacks.

NIOSH also addresses this issue in ORAUT-OTIB-0043, Revision 00.[2] Table 4-1 of ORAUT-OTIB-0043 cites NCRP Report No. 118 (1993), which reports exposures for a 2,000 hr/yr occupancy at phosphogypsum stacks as 70 mrem, and Laiche and Scott (1991) estimated a range of doses for that occupancy of 48 to 68 mrem. A review of these source documents [see page 93 of National Council on Radiation Protection and Measurements (NCRP) Report No. 118 and Laiche and Scott (1991)] confirms the values cited by NIOSH in ORAUT-OTIB-0043, Revision 00. This annual exposure rate assumes a worker spends 2,000 hours per year 1 meter from the surface of a large phosphogypsum pile.

Roessler (1987) points out that phosphogypsum stacks might also become a repository of other radioactivity-bearing material from phosphate plants. The author specifically mentions scales and sediments associated with digestion, filtration, cooling, and acid-receiving systems of wet process phosphoric acid plants. Radium concentrations in these materials were cited as hundreds of kilobecquerels per kilogram (kBq/kg) of solids [thousands of picocuries per gram (pCi/g)] as

[2] At the time of the preparation of this report, ORAUT-OTIB-0043 was undergoing review by the Procedures Subcommittee.

compared to about 30 pCi/g in phosphogypsum. DCAS-TKBS-0002, Revision 04, is silent regarding the potential radiological implications of these relatively small volume but highly concentrated sources of Ra-226 that are often present in phosphogypsum stacks.

Finding 2. The Blockson TBD (DCAS-TKBS-0002, Revision 04) should address the potential radiological exposures associated with the phosphogypsum stacks, including the relatively small volume of scale and sediment containing elevated levels of Ra-226 that are often present in phosphogypsum stacks.

Summary of External Gamma Exposure Data

The implications of this review are that NIOSH's use of an external exposure rate with a GM of 60 mR/yr and a GSD of 3.2 is generally claimant favorable as applied not only to workers in Building 55 in 1978, but also for workers who may have worked in the vicinity of the phosphogypsum stacks and also at the beginning of the residual period on July 1, 1960. DCAS-TKBS-0002, Revision 04, is silent regarding the potential radiological implications of the relatively small volume but highly concentrated sources of Ra-226 in scale and sediment that are often present in phosphogypsum stacks. However, it is appropriate not to lose sight of the fact that, for the exposures to the phosphogypsum stack, it is likely that the portion of the stack that is associated with AWE operations was probably quickly covered by commercially produced phosphogypsum beginning at the termination of AWE operations in June 1960. Hence, the approach used in DCAS-TKBS-0002, Revision 04, is likely quite conservative as applied to the phosphogypsum stacks.

SC&A concludes that the external exposures rate of 60 mR/yr used in DCAS-TKBS-0002, Revision 04, to reconstruct annual external dose to workers to penetrating radiation during the residual period is generally reasonable for Building 55 for 1978 and can also apply to time periods shortly after the termination of AWE operations in June 1960, based on the series of analyses provided above.

SC&A's analyses also provides a level of assurance that the 60 µR/yr exposure rate is also generally bounding for workers who may have been in the vicinity of the phosphogypsum stacks shortly after the termination of AWE operations. One qualifier to this conclusion is that some discussion and analysis of exposures associated with scale and sediment present in the phosphogypsum at relative low volumes but with high Ra-226 concentrations would further reinforce this conclusion.

2.2.3 Review of External Beta Dose Reconstruction Data and Procedures

Section 4.2.4 of DCAS-TKBS-0002, Revision 04, addresses beta dose but is limited to AWE operations and the exposures from drums of yellowcake, clothing contaminated with uranium, direct contact of skin and forearms with yellowcake, and direct deposition of uranium dust on skin. As discussed above, DCAS-TKBS-0002, Revision 04, does not assign skin doses from beta exposures during the residual period, because it judges that the 60 mR/yr adequately covers skin exposures.

In order to evaluate the potential beta exposures during the residual period, we used the maximum smear contamination of 640 dpm/100 cm^2 for gross alpha emitters (assumed to be entirely uranium and its short-lived progeny) cited on page 33 of DCAS-TKBS-0002, Revision 04, adjusted by a factor of 5 to account for total contamination versus removable contamination, as described above from NRC Regulatory Guide 1.86 (NRC 1974), and an external beta dose conversion factor of 3.82E-8 millirads per hour (mrad/h) per dpm (alpha) per square meter (m^2) from Table 3-10 of TBD 6000, as follows:

640 dpm/100 cm^2 × 5 × 3.82E-8 mrad/hr per dpm/m^2 × 1E4 cm^2/m^2 = 0.012 mrad/hr

The factor of 3.82E-8 mrad/hr beta per alpha dpm/m^2 was obtained from TBD-6000, Table 3.10, page 26.

This beta exposure rate corresponds to 24 mrad per year skin dose from beta emitters from residual U-238 at the time of the 1978 survey. This is as compared to the 60 mR/yr photon exposure assigned for every year of the residual period. It appears that beta dose should be added to the photon dose for the purpose of reconstructing skin doses.

Finding 3: Beta dose associated with residual contamination in Building 55 should be included in the site profile.

3.0 REVIEW OF INTERNAL DOSE RECONSTRUCTION DATA AND PROCEDURES (NOT INCLUDING RADON)

Not including radon and its progeny, internal exposure of Blockson workers during the residual period includes inhalation and ingestion of residual radioactive materials in Building 55 due to resuspension of residual levels of uranium and thorium on surfaces and also inhalation and ingestion of primarily Ra-226 and its progeny (not including radon) resuspended from phosphogypsum stacks as particulates. There is evidence that polonium-210 (Po-210) reports to phosphogypsum and some question whether lead-210 (Pb-210) reports to phosphogypsum or to phosphoric acid (see Roessler 1987)

3.1 RESIDUAL URANIUM AND THORIUM IN BUILDING 55

Page 33 of DCAS-TKBS-0002, Revision 04 states the following:

> *the derived median U-238 inhalation rate of 13 pCi/day is used as the inhalation intake rate of U-238 at the start of the residual contamination period on July 1, 1960. Thereafter, airborne radioactivity from resuspension of contamination in the facility and corresponding intakes are assumed to decrease according to an exponential model.*

DCAS-TKBS-0002, Revision 04, explains (page 33) that this inhalation rate was based on the assumption that the "*facility was uniformly contaminated at the level of the maximum alpha smear result of 640 dpm/100 cm^2 as reported in the 1978 survey (DOE 1983)*"; see Appendix A for a summary of the data provided in the DOE 1983 report. The assumptions and calculations that we believe were used in DCAS-TKBS-0002, Revision 04, to derive the U-238 inhalation rate of 13 pCi/day at the start of the residual period are as follows:

640 dpm/100 cm^2 × 1 min/60 s × 1E4 cm^2/m^2 × 1E-6/m × 1 Bq per dis/s × 27 pCi/Bq = 0.029 pCi/m^3

0.029 pCi/m^3 × 9.6 m^2/day = 0.28 pCi/day inhalation rate of alpha emitters.

The 0.28 pCi/day of alpha emitters likely consists of equal amounts of U-238, U-234, and Th-230. This is consistent with the intake rate reported on page 33 of DCAS-TKBS-0002, Revision 04. Hence, the U-238 intake rate in 1978 should be about one third this value, or about 0.09 pCi/day.

At the beginning of the residual period in June 1960, the residual level of contamination and the associated airborne alpha activity and intake rate are likely to be higher due to natural attenuation between June 1960 and 1978. Using the natural attenuation rate of 0.00067/day, as recommended in ORAUT-OTIB-0070, the intake rate of U-238 in June 1960 can be estimated as follows:

$I_0 = I_t (\exp \lambda t)$ = 0.092 pCi/day × exp (0.00067/d × 6570 d) = 0.092 × 81.5 = 7.5 pCi/day

This value differs somewhat from the value of 13 pCi/day cited on page 33 of DCAS-TKBS-0002, Revision 04. Page 34 of the TBD states that an attenuation rate of 0.000764 per day was used, with a duration of 6,483 days. Using these values, we derive the following U-238 intake rate in June 1960:

0.092 × exp (0.000764/d × 6483 d) = 0.092 × 141 = 13 pCi/day

An inhalation rate of 13 pCi/day of U-238 Type M is associated with an effective dose of 34 mrem/yr. The intake rate from U-234 and the associated dose would be similar to that of U-238. The effective dose from the inhalation of 13 pCi/day of Type S Th-230 would be about 172 mrem/yr. These doses are based on the adult inhalation effective dose conversion factors (e50) in FGR No. 13 (EPA 1999) and its supporting CD [i.e., 2.86E-6 sieverts per becquerel (Sv/Bq) for Type M U-238 and 1.45E-5 Sv/Bq for Type S Th-230].

We are not quite sure why an attenuation rate of 0.000764/day was used in DCAS-TKBS-0002, Revision 04, as opposed to the value recommended in ORAUT-OTIB-0070 of 0.00067/day. This is a minor difference that we can certainly resolve. However, other matters related to this calculation need to be discussed. The use of 640 dpm/100 cm^2 is extremely conservative, because it is the maximum swipe level observed. A more appropriate contamination level would be an estimate of the average contamination level on surfaces in 1978, because the airborne activity in a building due to resuspension would reflect the average and not the high-end contamination deposited on surfaces. From this perspective, the strategy adopted in DCAS-TKBS-0002, Revision 04, is extremely claimant-favorable.

Also, a natural attenuation rate of 0.00067/day (or 0.000764/day), in combination with a relatively low resuspension factor of 1.0E-6 per meter, is reasonable when performing the forward calculation, as employed in ORAUT-OTIB-0070, because it tends to place an upper bound on the time-integrated exposure when the starting point is the beginning of the residual period. However, when going backward in time, as we are doing here, such an approach is not necessarily claimant favorable (see discussion in Section 2.2.2). In defense of the approach used in DCAS-TKBS-0002, Revision 04, a slow attenuation rate is consistent with a low resuspension factor (i.e., 1E-6/m), and, in this case, a low resuspension factor might be reasonable because there is some evidence that the site was routinely cleaned up (see pages 18 and 30 of the TBD).[3] Taking all these matters into consideration, and the fact that the highest observed contamination level in 1978 was used as the starting point in this calculation (i.e., 640 dpm/100 cm^2), as opposed to a more central tendency value, we concur with the overall approach adopted in DCAS-TKBS-0002, Revision 04, to derive alpha inhalation rates during the residual period.

3.2 INHALATION OF PARTICULATES RESUSPENDED FROM PHOSPHOGYPSUM STACKS

Before leaving this topic, it is appropriate to confirm that the inhalation of Ra-226, and perhaps some of its progeny, resuspended from phosphogypsum stacks is not limiting when compared to the 13 pCi/day uranium inhalation rate derived for workers in Building 55 during the residual period. Appendix C of EPA 1986 indicates that the concentration of Ra-226 measured at several

[3] Section 6.3.1 of NRC 1992 discusses indoor resuspension factors, indicating that in locations where the room has been cleaned up, a resuspension factor of 1E-6/m is reasonable. However, if there is tracked-in dirt on the floors, a resuspension factor of 5E-5/m is more appropriate. However, Sehmel (1980) cites indoor resuspension factors ranging from 1.5E-2/m to 1E-6/m. This subject is also extensively discussed in NRC 2002a.

phosphogypsum stacks in Florida was consistently about 28 to 38 pCi/g. Moisset (1980) found that the Ra-226 in phosphogypsum is associated with relatively small particles, on the order of 1–8 micron. Pb-210 and Po-210 are also present in the phosphogypsum stacks at equilibrium with Ra-226.[4] Though we were unable to find literature citing dust loadings or Ra-226 concentrations in the atmosphere in the vicinity of phosphogypsum stacks, a considerable amount of data has been compiled on short-term and long term average outdoor dust loadings under a wide range of natural conditions and occupational/industrial activities. Page 110 of ANL 1993 provides a convenient overview of the literature on this subject. Inspection of these reports reveals that a fairly bounding chronic airborne outdoor dust load in industrial settings is about 1 milligram per cubic meter (mg/m^3). On this basis, SC&A derived the following inhalation exposures:

Table 4. Dose Project from Exposure to 1 mg/m^3 of Dust Loading

Isotope	Estimated Airborne Concentration (Bq/m^3)	Inhalation Rate (Bq/yr)	DCF (Sv/Bq) Effective Dose Commitment Type M	DCF (Sv/Bq) Dose Commitment Equivalent Lung	Effective Dose (mrem/yr)	Lung Dose Equivalent (mrem/yr)
Ra-226	1.1E-3	2.64	3.46E-6 (Type M)	2.75E-5 (Type M)	0.91	7.26
Pb-210	1.1E-3	2.64	1.1E-6 (Type M) 5.61E-6 (Type S)	5.55E-6 (Type M) 4.62E-5 (Type S)	0.29 (Type M) 1.48 (Type S)	1.66 (Type M 12.2 (Type S)
Po-210	1.1E-3	2.64	3.27E-6 (Type M)	2.60E-5 (Type M)	0.86 (Type M)	6.9
Total	—	—	—	—	—	15.82 (if Pb-10 is Type M) 26.36 (if Pb-210 is Type S)

These doses are relatively small compared to the doses associated with an intake rate of 13 pCi/day of U-234, U-238, and Th-230 associated with Building 55. Accordingly, we concur that DCAS-TKBS-0002, Revision 04, has assigned a limiting inhalation dose. However, DCAS-TKBS-0002, Revision 04, would benefit from a discussion of this matter.

Finding 4. The doses associated with the inhalation of resuspended particulates in the vicinity of the phosphogypsum piles should be explicitly addressed in the site profile.

[4] Roessler (1987) states that Po-210 reports to phosphogypsum, but Pb-210 stays with the phosphoric acid. However, Pb-210 will eventually grow in from the Ra-226 in the phosphogypsum, but ingrowth will take decades given the half-life of Pb-210 is 22 years. In addition, an e-mail from [redacted] to John Mauro on January 20, 2016, stated: "*Pb definitely goes with the phosphogypsum*," citing Saueia et al. 2005 ([redacted] 2016b). A review of this paper reveals that Pb-210 goes to the phosphogypsum stacks.

3.3 RADON

SC&A summarized the radon air sampling data from the 1978 FUSRAP (DOE 1983) survey data of Building 55 as shown in Table 5.

Table 5. Radon Air Sampling Data Associated with Building 55

Location of Sample	Working Level	pCi/L*
First Floor – Main Room – Near Center of Room (Grid #8 in Figure 1)	0.0061	0.61
First Floor – Main Room – Near Southwest Corner (Grid #17 in Figure 1)	0.0026	0.26
Second Floor Laboratory	0.0047	0.47
Third Floor – Near Stairwell and Soundproof Booth	0.0025	0.25
Roof – Near Center	0.0014	0.14

*Typically, a radon equilibrium factor of 0.4–0.5 would be appropriate for indoor areas; however, it appears DOE 1983 derived the reported working level values assuming an equilibrium factor of 1.

Page 38 of DCAS-TKBS-0002, Revision 04 provides a brief summary of the radon and working level (WL) concentrations measured in Building 55 in 1978. Notwithstanding these results, NIOSH elected to use the radon concentration and flux measurements performed in the vicinity of the phosphogypsum stacks for Texas City Chemicals, Inc. (TCC) as a surrogate for the radon exposures for workers at Blockson. As indicated on pages 39 and 40 of DCAS-TKBS-0002, Revision 04, a radon concentration of 2.1 pCi/L, with a 0.4 equilibrium factor for radon progeny, has been adopted for use at Blockson beginning at the start of the residual period on July 1, 1960. This concentration is assumed to decline to 0.42 pCi/L (a factor of 5) by September 1993. Since the radon exposures assigned to Blockson workers during the residual period are based on surrogate data, a detailed review of these data and the approach adopted by NIOSH is discussed in Section 4, which is dedicated to reviewing these exposures against the five surrogate data criteria developed by the Board.

4.0 EVALUATION OF THE SURROGATE DATA USED FOR BLOCKSON CHEMICAL COMPANY DOSE RECONSTRUCTION AGAINST THE SURROGATE DATA CRITERIA DEVELOPED BY THE BOARD

Section 2.4 of DCAS-TKBS-0002, Revision 04, describes the radiological data that are available to reconstruct doses to workers. For the AWE operational period, the radiological data that are known to exist are bioassay results for uranium from 1954 through 1958. For the residual period, DCAS-TKBS-0002, Revision 04, describes the following sources of data:

- In 1978, as part of the FUSRAP program, extensive radiological monitoring was performed in Building 55, the location where yellowcake was separated from the phosphoric acid solution, dried, and then deposited into 55-gallon drums. During the residual period, it is likely that workers in Building 55 might have experienced both external and internal exposures to yellowcake (and any associated progeny and Th-232 and its progeny) that were deposited on surfaces and in equipment that remained in Building 55 as residual contamination after AWE operations ceased. These data are useful in reconstructing doses to workers in Building 55 during the residual period.

- For 1983, data consist of total dust measurements, airborne alpha radioactivity measurements, and radon WL measurements, none of which were collected from Building 55. These data are useful for reconstructing exposures to workers on site at locations other than Building 55 during the residual period. This would include primarily workers in Building 40, where there could have been residual levels of Ra-226 and its progeny associated with AWE operations. It was in, or in the vicinity of, Building 40 where the phosphate ore was received by barge from Florida phosphate mines, stored, calcined, crushed, and dissolved in sulfuric acid, and the solid residue remaining after dissolution transferred to the outdoor phosphogypsum stacks.

- In 1993, radon flux measurements were performed on the outdoor phosphogypsum stacks. These flux measurements are useful in assessing worker exposures to radon and its progeny at locations close to or on the phosphogypsum stacks. These measurements would include contributions from phosphogypsum that was produced by both AWE operations and also commercial phosphate production over the lifetime of the facility up to the time that the measurements were made.

- In 1996, radiological measurements were made in support of the demolition of Building 55. The surveys are useful in the reconstruction of doses to decontamination and decommissioning (D&D) workers and other workers in the vicinity of Building 55 during D&D. These data complement and supplement the data collected at Building 55 in 1978; i.e., following the termination of AWE operations, but prior to the start of D&D operations.

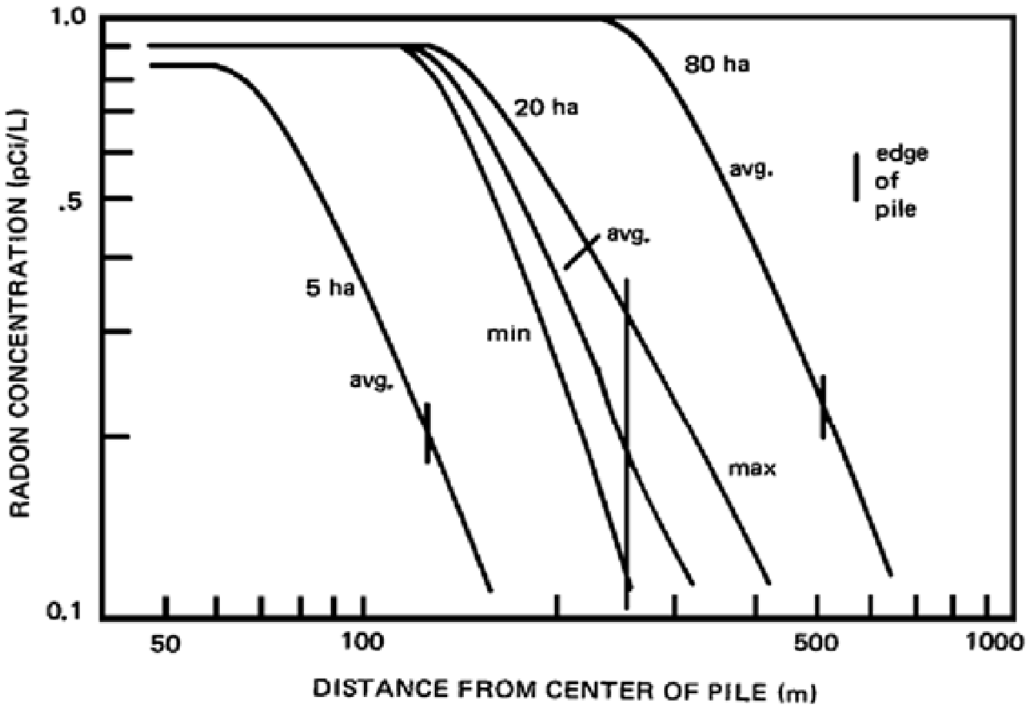
These data are somewhat incomplete, and it was necessary for NIOSH to make use of a number of models, assumptions, and, to a limited extent, surrogate data to reconstruct external and internal doses to workers who might have been exposed during the residual period, including workers in Buildings 40 and 55, workers outdoors in the vicinity of the phosphogypsum stacks, and D&D workers. Among the various internal and external exposure pathways evaluated in DCAS-TKBS-0002, Revision 04, and the SEC PER (NIOSH 2015) for the residual period, only outdoor internal exposures to radon and its progeny from the phosphogypsum stacks made use of surrogate data.

Page 38 of DCAS-TKBS-0002, Revision 04, explains that, in September 1993, after the plant was permanently closed in 1991, 300 radon flux measurements were made on the phosphogypsum stacks during varying weather conditions and at various locations. The measurements were made in order to assess whether the radon emanation rates from the stacks complied with the EPA acceptance criteria for the stabilization of inactive phosphogypsum stacks of 20 pCi/m^2-s. The results of these measurements, as described on page 38 of DCAS-TKBS-0002, Revision 04, are as follows:

> *The weighted mean radon flux for the total stack area was reported to be 4.4 pCi/m^2-s, with the sides of the stack having the highest mean value of 10.1 pCi/m^2-s. The values were compared to flux and radon gas measurements reported from phosphogypsum stacks at phosphate plants in Texas and in Florida.*

In theory, these results could be used to reconstruct the internal doses to workers in the vicinity of the stacks during the residual period. However, there are a number of limitations associated with these data. First, radon emanation rate data can be used to reconstruct radon exposures to workers, but the flux measurements must be converted to airborne radon and radon progeny concentrations in the vicinity of the workers. This can be done, but it requires atmospheric transport modeling, which is associated with considerable uncertainty, in order to estimate the concentrations and associated exposures at worker locations. For example, the following figure (shown here as Figure 2), excerpted from EPA (1982), presents the airborne concentration of radon as a function of distance from the center of various sizes of uranium mill tailings stacks, assuming the average radon flux at the surface of the stacks is 20 pCi/sec-m^2. As can be seen, the radon concentrations vary considerably depending on the size of the stack and distance of the receptor from the center of the stack. The EPA report also provides substantial information on how the radon concentrations vary with wind speed and also the degree to which radon progeny grow in as a function of wind speed and the distance of the receptor from the location of the stack. Clearly, the relationship between radon flux and airborne radon concentration and its progeny is complex and can be highly site specific.

Figure 2. Radon Concentration Versus Wind Speed and Distance (EPA 1982)



Source: EPA 520/4-82-013-1, Figure 4-1

In addition to the complexities associated with deriving radon concentrations based on radon flux data, the radon flux measurements collected at Blockson could result in substantial overestimates of the radon exposures to the phosphogypsum from AWE activities, because most of the phosphogypsum stacks were created as a result of commercial activities, which extended from the beginning of operations (believed to be in the early 1950s) until June 1991 (see page 5 of DCAS-TKBS-0002, Revision 04). However, the AWE activities only extended from August 1952 through June 1960 (see pages 5 and 7 of the TBD). Accordingly, only a very small fraction of the volume of the phosphogypsum stacks in 1993, the time when the flux data were collected, were due to AWE operations. In addition, it is likely that the portion of the phosphogypsum stacks that were produced as a result of AWE operations were buried under huge volumes of phosphogypsum generated from commercial operations following the termination of AWE operations in June 1960. Hence, little, if any, of the radon flux data obtained in 1993 were likely due to radon emanated from phosphogypsum <u>associated with AWE operations</u>.

On this basis, one could argue that the radon flux measurements made in 1993 would likely result in an overestimate of the radon exposures to workers during at least part of the residual time period (i.e., time periods well after June 1960, when AWE operations ceased), because only a very small fraction of the phosphogypsum at the site in 1993 was due to AWE operations. However, it can also be argued that the phosphogypsum stacks in 1993 were aged, and the flux from these stacks, as measured in 1993, was quite low as compared to the flux from the stacks during and following AWE operations (which ended in June 1960). DCAS-TKBS-0002, Revision 04, explains that aged stacks develop a surficial crust that reduces the radon flux.

Hence, the radon flux from the phosphogypsum stacks in 1960, and for some time period thereafter, might have been substantially higher than the flux measured in 1993.

These limitations in the radon flux measurements made in 1993 diminish their usefulness for reconstructing radon exposures during the early part of the residual period. As one means to help validate and supplement the Blockson data, DCAS-TKBS-0002, Revision 04, investigated radon flux and concentration data collected from a similar facility, TCC. In researching these data, NIOSH determined that the radon exposure data set from TCC was preferable to the data set from Blockson, because it included both radon flux <u>and concentration data</u>. Page 41 of the TCC SEC PER (NIOSH 2010) provides the following information on the measured outdoor radon concentrations in the vicinity of its phosphogypsum stacks:

> *Radon gas concentrations at TCC were also measured on top of the phosphogypsum stack and near the Administration Building some 200 to 300 yards from the stack; radon concentrations above background (0.14 pCi/L), were reported to be 0.42 pCi/L and 0.32 pCi/L, respectively. Radon concentrations at other locations on the TCC property were lower.*

These measured radon concentrations were used as the starting point for deriving the radon concentrations used to reconstruct radon exposures in the vicinity of the Blockson phosphogypsum stacks during the residual period. As explained on page 41 of the TCC SEC PER, the radon flux and airborne concentration data were collected from February 1983 through September 1984, about 7 years after the TCC stacks became inactive in 1970. Page 41 further explains that, as phosphogypsum stacks age, a crust forms on the surface of the stacks, which reduces the radon flux by about a factor of 5 as compared to the flux from active piles. Hence, the dose reconstruction models used to reconstruct radon exposures in the vicinity of the phosphogypsum stacks at TCC incorporate a factor of 5 to account for this phenomenon. Blockson used the same approach.

With respect to this 5-fold adjustment factor, Page 41 of the TCC SEC PER states the following:

> *The highest net radon concentration reported at TCC from the 1980s study was on the pile at 0.42 pCi/L. Assuming the active pile would have been 5 times higher indicates that a concentration of 2.1 pCi/L would have been present when the pile was active. This value compares reasonably well to reports by the Florida Institute for Phosphate Research (FIPR 1998). FIPR reported radon results for some outdoor areas from Florida plants that had detectable elevated radon concentrations, including phosphogypsum stacks (or piles). The results were highly variable and statistics were reported for 5 locations with elevated results. The median radon concentration for the areas ranged from 1.07 to 2.72 pCi/L. The 2.1 pCi/L estimate for TCC during periods in which the pile was active should provide a reasonable bounding estimate for exposure to radon gas from phosphogypsum at TCC, given that workers do not continuously occupy waste piles.*

A similar discussion is provided on page 39 of the Blockson TBD, DCAS-TKBS-0002, Revision 04, indicating that a radon concentration of 2.1 pCi/L (i.e., the concentration used for

TCC) was used to reconstruct the radon exposures to workers in the vicinity of the phosphogypsum stacks at Blockson at the beginning of the residual period, and that this concentration declined exponentially to 0.42 pCi/L in 1993 (i.e., a 5-fold reduction, which corresponds to an exponential attenuation rate of 0.000133/day from 1960 through 1993.) SC&A has a concern with this approach for dealing with a reduction in the radon flux from an inactive pile. NIOSH has elected to assume that the entire pile, right up to the termination of commercial operations in 1991, should be treated as if it were entirely an AWE pile. We acknowledge that this is an extremely (if not implausible) claimant-favorable assumption. But, if this assumption is used, the pile should be treated as active up through 1991. Hence, a radon concentration of 2.1 pCi/L should remain at this level right up to 1991 and not begin to decline in 1960.

Finding 5. The radon concentration in the vicinity of the phosphogypsum stacks should remain at the elevated level of 2.1 pCi/L up until 1991, the time when the piles actually became inactive.

Another issue associated with using TCC radon concentration measurements as a surrogate for the radon exposures at Blockson is, as discussed above, for the same flux, the concentration of radon in the vicinity of a stack depends on the size of the stack. DCAS-TKBS-0002, Revision 04, provides information that the throughput of ore at Blockson was about 6,000 tons per week, which may have continued from about 1950 to 1991. However, it appears that the throughput of ore at TCC might have been substantially lower. For example, Section 7.2.5.2 of the TCC SEC PER states the following:

> *At capacity TCC could have processed over 8,000 tons phosphate rock per month, although the plant was not operating at capacity due to equipment problems. They were operating at less than capacity as late as February 1955 (date of last known AEC documented site visit) because new equipment had not yet arrived (AEC 1955).*

In addition, these operations might have extended from the early 1950s until 1970. Therefore, it is likely that the volume of phosphogypsum at TCC was substantially lower than at Blockson, and one might conclude that the measured concentration of radon at TCC may underestimate the radon concentrations at Blockson. However, outdoors, the radon concentration close to a pile would be expected to be comparable for both large and relatively smaller piles <u>for piles with a comparable radon flux (see Figure 2 above)</u>. The reason is that, as long as the distance to the receptor is small relative to the size of the pile, the size of the pile would not be expected to affect the airborne radon concentrations at the locations of the receptors.

Because of this possible limitation of the TCC data as applied to Blockson (i.e., 2.1 pCi/L), SC&A reviewed the data provided in FIPR 1998. Table 8 (page 21) of FIPR 1998 indicates that the concentration of radon in the vicinity of the gypsum stacks in Florida had a mean of 9.51 pCi/L, a median of 1.25 pCi/L, a 95th confidence level of 5.36 pCi/L, and a maximum level of 78.72 pCi/L. The implications are that the TCC data appear to be a reasonable surrogate for Blockson, when consideration is also given to the large body of data provided in FIPR 1998.

One last point needs to be discussed before we move on to an assessment of the surrogate data against the Board's surrogate data criteria. This issue has to do with the ingrowth of radon progeny. As described in considerable detail in FIPR 1998, the radon that emanates from a phosphogypsum stack does not include any of its progeny, which are of a particulate nature and stay behind in the stack. As a result, it takes some time for the short-lived progeny of radon to grow in after radon emanates from the surface of a phosphogypsum stack. For example, the short-lived progeny have an approximate 30-minute half-life. Hence, it takes about 30 minutes for the progeny to achieve 50% equilibrium with radon. The Blockson TBD assumes 40% equilibrium (see page 40 of DCAS-TKBS-0002, Revision 04), which is a reasonably conservative assumption considering that, in the outdoor environment, naturally occurring progeny is at about 40% equilibrium (see UNSCEAR 1993, page 54).

With this as background information, and using the Board surrogate data criteria (reproduced in Appendix B), the following subsections discuss the strengths and limitations of using the TCC radon data as a surrogate for exposures of workers to radon in the vicinity of the phosphogypsum stacks during the residual period at Blockson. The quotations that head each subsection are reproduced from the Board's surrogate data criteria reproduced in Appendix B.

4.1 CRITERION 1 – HIERARCHY OF DATA

> *It should be assumed that the usual hierarchy of data would apply to dose reconstructions for that site (Individual worker monitoring data followed by coworker data followed by workplace monitoring data such as area sampling followed by process and source term data.) This hierarchy should be considered when evaluating the potential use of surrogate data. Surrogate data should only be used to replace data if the surrogate data have some distinct advantages over the available data and then only after the appropriate adjustments have been made to reflect the uncertainty inherent in this substitution.*

The concept of the hierarchy of data for internal exposures is concerned with whether the data are direct measurements of the exposures experienced by a worker, such as bioassay or chest count data, which are highest on the hierarchy when reconstructing internal inhalation doses. However, in the case of exposure to radon and its progeny, bioassay and chest count data are not plausible, and the highest quality data are measurements of radon and its progeny at the locations where workers may have been located. These are, in fact, the surrogate data that were used, and, therefore, DCAS-TKBS-0002, Revision 04, meets this criterion.

4.2 CRITERION 2 – EXCLUSIVITY CONSTRAINTS

> *In many cases, surrogate data are used to supplement the available monitoring data from a site. In those cases, the surrogate data is usually used to justify certain assumptions about the distribution or range of possible exposures or assumptions about the source terms. In those cases, no special justification is necessary beyond the usual scientific evaluation. This is akin to the Type II use described above. However, in other situations, there are no or very little monitoring data available. In those cases, the use of the surrogate data as the basis for individual dose reconstruction would need to be stringently justified. This judgment needs to take into account not only the amount of surrogate data*

> *being relied on relative to data from the site but also the quality and completeness of that surrogate data.*

The above quote, which refers to Type I and Type II surrogate data, requires some explanation. The Board's surrogate data criteria refer to Type I and Type II surrogate data, and reference is made to "as described above." Type I data refer to actual dose calculations, measured radiation fields, and measured radionuclide concentrations in urine samples and in air and soil and on surfaces. Type II surrogate data refer to various constants or parameters that are used in a dose calculation, such as airborne dust loadings, deposition velocities, or resuspension factors. In theory, these parameters can be site specific or obtained from the literature, which, in turn are often obtained from a number of sites or experiments. In this respect, these types of data can be considered a type of surrogate data. However, for the purpose of evaluating the use of the surrogate data criteria cited here, such evaluations are limited to Type I data.

This criterion states that, in cases where little or no monitoring data are available, the use of surrogate data "would need to be stringently justified." In this case, we are in the fortunate position that we have considerable radon flux data from Blockson and also radon flux and airborne radon concentration data from TCC. As a result, we are not in an "exclusive" situation. We have data from Blockson that can be used to help supplement and validate the data from TCC as a reasonable source of surrogate data. We also have radon flux and radon concentration data from other phosphogypsum stacks that are also useful in helping to ensure that the surrogate data meet the exclusivity criterion. However, the discussion of Criterion 3 probes this issue a little further.

4.3 CRITERION 3 – SITE OR PROCESS SIMILARITIES

> *One of the key criteria for judging the appropriateness of the use of surrogate data would be the similarities between the site (or sites) where the data were generated and the site where the surrogate data are being utilized. The application of any surrogate data to an individual dose reconstruction at a site should include a careful review of the rationale for utilizing that source of data. Factors that could be considered include, but are not limited to, similarity of the production processes, presence or absence of conditions that might affect exposure, and monitoring methods employed at the site(s). The potential availability of other sources of surrogate data needs to be considered and the selection of the surrogate data used for dose reconstruction justified. Some of the questions to be considered where appropriate are:*
>
> - *Are there other sources of surrogate data that were not used?*
> - *Do these other potential sources contradict or undermine the application of the data from the selected site?*
> - *Are there adequate data characterizing the site being used that would help support its application to other sites?*
> - *Do the surrogate data reflect the type of operations and work practices in use at the facilities in question?*

- *Surrogate data should not be used if the equivalence of working conditions, source terms, and processes of the surrogate facility to the one for which dose reconstructions are being done cannot be established with reasonable scientific or technical certainty as outlined here.*

This criterion is concerned with the degree to which the characteristics of the facility and operations and the processes used at the surrogate facility are applicable to the facility of concern. Several aspects of the operations at Blockson and TCC need to be investigated in order to ensure that the TCC radon concentration data can be reasonably used as a surrogate for Blockson.

Both Blockson and TCC obtained their ore from similar locations in Florida, and the ore likely had similar concentrations of uranium and thorium and their progeny. In addition, both facilities manufactured wet process phosphoric acid; i.e., they both digested the ore using sulfuric acid. Section 5.3 of the TCC SEC PER states that the uranium concentration in the TCC ore was about 0.2 pounds per ton of ore or about 0.01% uranium oxide (U_3O_8). The same section states the following:

> *Blockson reported the average uranium content of the central Florida phosphate rock it used in the 1950s was between 0.01% and 0.014% U_3O_8 (Lopker, 1951; Stoltz, 1958). Mills, et al. (1977) reported that the marketable rock from central Florida had 41 pCi/gm of U-238, which is equivalent to about 0.012% uranium. These values are all similar and the differences likely represent the variation that is seen in various batches of phosphate rock. A total uranium concentration of 0.014% will be used to bound the average concentration in phosphate rock at TCC.*

In this respect, the ore and ore processing activities at Blockson and TCC were similar.

In addition, as described above, the weighted mean radon flux for the total Blockson stack area in 1993 was reported to be 4.4 pCi/m^2-s, with the sides of the stack having the highest mean value of 10.1 pCi/m^2-s. For TCC, the combined average flux from those measurements was 10.5 pCi/m^2-s. In addition, the flux measurements from similar inactive stacks in Florida and another unidentified plant were 4.5 and 4.4 pCi/m^2-s, respectively. Hence, the range of the flux values at TCC and other similar facilities are nearly identical to the range of the mean total stack and highest mean stack areas at Blockson. In this respect, there is considerable evidence that the processes and the resulting radon emanation rates (i.e., flux) are similar at both facilities. However, it is important not to lose sight of the fact that we are concerned with the <u>concentrations</u> of radon and its progeny at worker locations close to the stacks. These concentrations are affected not only by radon flux but also by the size and age of the stacks and the locations of the workers relative to the stacks. The following discussion probes these potential surrogate data issues.

The total amount of ore processed determines the volume of the phosphogypsum stack, which, in turn, can affect the concentration of radon in the vicinity of the stacks. Hence, it would be desirable for the ore throughput at TCC to be comparable to that at Blockson. The throughput rate of phosphate ore at Blockson was reported as about 6,000 tons per week and continued up until the termination of phosphate production operations in 1991. TCC began to produce animal feed and fertilizer in 1952 and ceased operations in 1956 because of difficulties in its uranium operations. However, TCC resumed phosphate commercial operations shortly thereafter and continued these operations until 1977 (see page 14 of the TCC SEC PER). Hence, like Blockson, TCC performed phosphate production operations for many years and likely also compiled a very large volume of phosphogypsum. However, as discussed above, the throughput of ore, and therefore the amount of phosphogypsum at TCC, appears to have been smaller than that at Blockson. However, investigations of radon concentrations in the vicinity of phosphogypsum stacks in Florida appear to support the applicability of the TCC radon concentrations used as surrogate data for Blockson.

The above discussion provides a compelling argument for using the TCC data, as adjusted by a factor of 5, as a claimant-favorable surrogate for similar worker exposures at Blockson. However, since the volumes of phosphogypsum produced as a result of AWE activities at Blockson are only a very small fraction of the total volume of phosphogypsum associated with commercial phosphate production, the radon exposures, as derived using the method described above, might be considered to be implausibly high as applied to workers at the site many years after the end of AWE operations in June 1960.

Observation 1: Radon exposures to workers in the vicinity of phosphogypsum stacks during the residual period appear to have been substantially overestimated.

As described above in support of Finding 5, SC&A is also concerned that the radon concentration should not begin to decline in June 1960 but remain at the elevated level until 1991 when commercial operations ceased. Of course, this issue is only applicable if the radon emitted from both the AWE and commercial operations are considered indistinguishable.

4.4 CRITERION 4 – TEMPORAL CONSIDERATIONS

> *Consideration also needs to be given to the period in question, since working conditions and processes varied in different periods. Surrogate data should belong in the same general period as the period for which doses are sought to be reconstructed unless it can be demonstrated that the working conditions, procedures, monitoring methods, and (perhaps) legal requirements were comparable to the period in question.*

This criterion is mainly concerned with the evolution of engineered systems, such as heating, ventilation, and air conditioning systems and other modifications to operations and health and safety systems and controls that may have matured over the years and possibly have significance with respect to the use of surrogate data. The issue is not entirely applicable to radon exposures to phosphogypsum stacks. The use of the wet sulfuric acid process for the production of phosphate and the production and management of phosphogypsum stacks has remained fundamentally the same since its inception. Nevertheless, it is noteworthy that both Blockson and TCC used the wet sulfuric process to produce phosphate during the same time periods; beginning in the 1950 and, in the case of Blockson, ending in 1991, and, for TCC, ending in 1970. Hence, we believe that Blockson meets this criterion.

4.5 CRITERION 5 – PLAUSIBILITY

The manner in which the surrogate data are to be used must be "plausible" with regard to the reasonableness of the assumptions made. The plausibility determination should address issues of:

- *Scientific plausibility. Are the assumed models (e.g., bioassay, concentration gradients) scientifically appropriate? Have the models been validated (where feasible) using actual monitoring data collected in a similar situation?*

- *Workplace plausibility. Are the assumed processes and procedures (including monitoring) plausible for the facility in question? Have all of the factors that could significantly impact exposure been taken into account? Is adequate information available about the facility in order to be able to make a fair assessment?*

The plausibility criterion was originally conceived with the intent to ensure that there was parity in the operating conditions associated with the workplace of interest and its surrogate. The discussion and assessment of the previous four surrogate criteria reveal that the types of activities and the workplace, and the types of radon measurement as representative of the surrogate facility (i.e., TCC), apply to the facility of interest (i.e., Blockson) <u>for issues related to exposures to radon from phosphogypsum stacks</u>. It is noteworthy that uranium bioassay data from TCC would not apply to Blockson, because of the enormous differences in the amounts of yellowcake produced at each facility. However, the amounts and types of phosphogypsum associated with the two facilities, and the associated outdoor radon concentrations, were sufficiently comparable to allow TCC to serve as a plausible surrogate for Blockson. Notwithstanding these conclusions regarding compliance with the surrogate data criteria, SC&A does have a number of findings that pertain to how exposures associated with the phosphogypsum stacks were derived, as described in this report.

5.0 REFERENCES AND BIBLIOGRAPHY

42 CFR Part 83. *Code of Federal Regulations*, Title 42, "Public Health," Part 83, "Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort Under the Energy Employees Occupational Illness Compensation Program Act of 2000." May 28, 2005.

ABRWH 2006. *Report of the Working Group on Special Exposure Cohort Petition Review* [Draft], National Institute for Occupational Safety and Health, Advisory Board on Radiation and Worker Health. January 16, 2006.

ABRWH 2010. Final Draft Criteria for the Use of Surrogate Data, National Institute for Occupational Safety and Health, ABRWH Work Group on Use of Surrogate Data. May 14, 2010. Available at www.cdc.gov/niosh/ocas/pdfs/abrwh/proc/abrwh-proc-sd-r0.pdf

AEC 1955. *Monthly Report on Activities of Domestic Production Phosphates, Division of Raw Materials During December 1955*, U.S. Army Environmental Command, Division of Raw Materials, Domestic Production Phosphates, Office of Domestic Procurement. December 1955. [SRDB Ref. ID 22264]

ANL 1993. "Data Collection Handbook to Support Modeling the Impacts of Radionuclides in Soil," ANL/SAIS-8, Argonne National Laboratory, Environmental Assessment and Information Sciences Division. April 1993. [SRDB Ref. ID 93081]

Battelle-TBD-6000. 2011. *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals,* Revision No. 1. June 17, 2011.

[redacted] 2016a. Telephone conversation between [redacted] and John Mauro, SC&A, Inc. January 13, 2016.

[redacted] 2016b. Email from [redacted] to John Mauro, SC&A, Inc. January 20, 2016.

DCAS-TKBS-0002. 2014. *Technical Basis Document for Atomic Energy Operations at Blockson Chemical Company, Joliet Illinois*, Revision 04, Oak Ridge Associated Universities Team, Cincinnati, Ohio. May 19, 2014.

DOE 1983. *Formerly Used MED/AEC Sites Remedial Action Program: Radiological Survey of Chemicals Group, Olin Corporation (Formerly Blockson Chemical Company), Joliet, Illinois, March 27–November 28, 1978,* DOE/EV-0005/35, ANL-OHS/HP-83-103, Argonne National Laboratory, U.S. Department of Energy. May 1983. [SRDB Ref. ID 23615]

EPA 1978. *Radiological Surveys of Idaho Phosphate Ore Processing – The Wet Process Plant,* U.S. Environmental Protection Agency. April 1978. [SRDB Ref. ID 30886]

EPA 1982. *Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192),* Volume I, EPA 520/4/82/013-1, U.S. Environmental Protection Agency, Office of Radiation Programs. October 1982. [SRDB Ref. ID 95489]

EPA 1986. *Radon Flux Measurements on Gardinier and Royster Phosphogypsum Piles Near Tampa and Mulberry, Florida*, EPA 520/5-85-029, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC. 1986. [SRDB Ref. ID 18080]

EPA 1993. *Federal Guidance Report No.12: External Exposure to Radionuclides in Air, Water, and Soil*. EPA 402-R-93-081, U.S. Environmental Protection Agency. September 1993. [SRDB Ref. ID 11997]

EPA 1999. *Federal Guidance Report No.13: Cancer Risk Coefficients for Environmental Exposure to Radionuclides,* EPA 402-R-99-001, U.S. Environmental Protection Agency. September 1999. [SRDB Ref. ID 13719]

EPA 2011. *Exposure Factors Handbook 2011 Edition (Final),* EPA/600/R-09/052F, U.S. Environmental Protection Agency, Washington, DC. 2011. [SRDB Ref. ID 22413]

FIPR 1995. *Microbiology and Radiochemistry of Phosphogypsum*, Publication No. 05-035-114, Florida State University, Florida Institute of Phosphate Research. May 1995. [SRDB Ref. ID 30136]

FIPR 1998. *Evaluation of Exposure to Technically Enhanced Naturally Occurring Radioactive Materials (TENORM) in the Phosphate Industry*, Florida Institute of Phosphate Research. July 1998. [SRDB Ref. ID 18076]

Laiche and Scott 1991. T. P. Laiche and L. Max Scott, "A Radiological Evaluation of Phosphogypsum," *Health Physics*, 60(5): 691–693. May 1991. [SRDB Ref. ID 18074]

Lopker 1951. E. B. Lopker, Director of Engineering, Blockson Chemical Co., correspondence to Sheldon Wimpfen, Raw Materials Division, Atomic Energy Commission. July 31, 1951. [SRDB Ref. ID 9558]

Mills et al. 1977. W. A. Mills, R. J. Guimond, and S. T. Windham, "Radiation Exposures in the Florida Phosphate Industry," International Radiation Protection Association (IRPA), *IRPA 4 Proceedings*, P3-78, Paris, France. 1977. [SRDB Ref. ID 18065]

Moisset 1980. J. Moisset, "Radium Removal from Phosphogypsum," In *Proceedings of the International Symposium on Phosphogypsum, Lake Buena Vista, Florida* (eds. D. P. Borris and P. W. Boody), Florida Institute of Phosphate Research, pp. 442–457. 1980.

NCRP 1993. *Radiation Protection in the Mineral Extraction Industry*, NCRP Report No. 118, National Council on Radiation Protection and Measurements, Bethesda, Maryland. November 1993.

Neton 2015. *Draft Criteria for the Evaluation and Use of Coworker Datasets, Version 4.1.1,* James Neton, Division of Compensation Analysis and Support, National Institute for Occupational Safety and Health. July 2015.

NIOSH 2010. *SEC Petition Evaluation Report – Petition SEC-00088 (Pertaining to Texas City Chemicals, Inc.),* National Institute for Occupational Safety and Health. October 18, 2010.

NIOSH 2015. *SEC Petition Evaluation Report, Petition SEC-00225, Blockson Chemical Co. (Building 55 and Related Activities)*, National Institute for Occupational Safety and Health. September 8, 2015.

NRC 1974. *Termination of Operating Licenses for Nuclear Reactors*, Regulatory Guide 1.86, U.S. Nuclear Regulatory Commission. June 1974. [SRDB Ref. ID 23559]

NRC 1992. *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent*, NUREG/CR-5512, PNL-7994, Volume 1, U.S. Nuclear Regulatory Commission. October 1992. [SRDB Ref. ID 23558]

NRC 2002a. *Re-evaluation of the Indoor Resuspension Factor for the Screening Analysis of the Building Occupancy Scenario for NRC's License Termination Rule: Draft Report for Comment*, NUREG-1720, U.S. Nuclear Regulatory Commission. June 2002. [SRDB Ref. ID 22400]

NRC 2002b, *Technical Basis for Calculating Radiation Doses for the Building Occupancy Scenario Using the Probabilistic RESRAD-BUILD 3.0 Code*, NUREG/CR-6755, ANL/EAD/TM/02-1, U.S. Nuclear Regulatory Commission. February 2002. [SRDB Ref. ID 91669]

ORAUT-TKBS-0032. 2014. *Site Profile for Simonds Saw and Steel*, Revision 02, Oak Ridge Associated Universities Team, Cincinnati, Ohio. October 21, 2014.

OCAS-IG-001. 2007. *External Dose Reconstruction Implementation Guideline*, Revision 03, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. November 21, 2007.

ORAUT-OTIB-0043. 2006. *Characterization of Occupational Exposure to Radium and Radon Progeny during Recovery from Phosphate Materials*, Revision 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. January 6, 2006.

ORAUT-OTIB-0070. 2012. *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, Revision 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. March 5, 2012.

[redacted] 1979. [redacted], Letter Regarding Lack of Uranium Recovery Activities. March 22, 1979. [SRDB Ref. ID 16646 (page 126 of 197)]

Roessler 1987. C. E. Roessler, "The Radiological Aspects of Phosphogypsum," Professor, Environmental Engineering and Sciences, University of Florida, Gainesville, Florida 32611. (Also published by the Florida Chapter of the Health Physics Society, December 1987. Proceedings of a Symposium held May 6-8, 1987, Daytona Beach, Florida, Sponsored by the Health Physics Society and Co-Sponsored by the Southeastern Geological Survey. An alternative title is "Natural Radiation and Technologically Enhanced Natural Radiation in Florida.")

Saueia et al. 2005. C. H. Saueia, B. P. Mazzilli, and D. I. T. Favaro, "Natural Radioactivity in Phosphate Rock, Phosphogypsum and Phosphate Fertilizers in Brazil" *Journal of Radioanalytical and Nuclear Chemistry*, 264(2): 445–448. 2005.

SC&A 2007. *Focused Review of the NIOSH Evaluation Report for the Blockson Chemical Company SEC Petition*, S. Cohen and Associates, Vienna, Virginia, and Saliant, Inc., Jefferson, Maryland. January 10, 2007.

Sehmel 1980. G. A. Sehmel, "Particle Resuspension: A Review," *Environ. Int*. 4:107–127. 1980.

Stoltz, Jr. 1958. Emil Stoltz, Jr., *Recovery of Uranium from Phosphate Ores*, July 24, 1958. [SRDB Ref. ID 4026]

UNSCEAR 1993. *Sources and Effects of Ionizing Radiation*. Volume 1, United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly, with Scientific Annexes, United Nations, New York. 1993. [SRDB Ref. ID 22742]

APPENDIX A: SUMMARY OF DATA FROM DOE 1983 (SRDB 23615)

Main Location	Direct readings dis/min-100 cm^2		Smear results dis/min-100 cm^2		Comments
	Beta-gamma	alpha	Beta-gamma	alpha	
First Level of Main Room	1.20E+04	bkgd	No smear taken	No smear taken	Location 1, spot on concrete floor
First Level of Main Room	8.20E+03	bkgd	No smear taken	No smear taken	Location 2, spot on concrete floor
First Level of Main Room	6.90E+02	bkgd	No smear taken	No smear taken	Location 3, spot on concrete floor
First Level of Main Room	4.30E+03	bkgd	bkgd	bkgd	Location 6, spot on concrete floor
First Level of Main Room	4.30E+03	bkgd	bkgd	bkgd	Location 7, spot on concrete floor beneath stairs
First Level of Main Room	2.70E+04	bkgd	bkgd	bkgd	Location 12, area on concrete floor
First Level of Main Room	1.10E+04	bkgd	bkgd	bkgd	Location 13, spot on concrete floor
First Level of Main Room	1.60E+04	bkgd	bkgd	bkgd	Location 14, spot on concrete floor
First Level of Main Room	1.10E+04	bkgd	bkgd	bkgd	Location 15, spot on concrete floor
First Level of Main Room	1.10E+04	bkgd	bkgd	bkgd	Location 16, spot on concrete floor
First Level of Main Room	1.60E+04	bkgd	bkgd	bkgd	Location 20, spot on concrete floor
First Level of Main Room	1.10E+03	bkgd	bkgd	bkgd	Rest of survey, general contamination on floor
First Level of Main Room	2.30E+04	1.20E+03	bkgd	bkgd	Location 22, spot on concrete floor
First Level of Main Room	3.40E+04	1.20E+03	bkgd	bkgd	Location 23, spot on concrete floor
First Level of Main Room	3.40E+04	1.20E+02	bkgd	bkgd	Location 24, spot on concrete floor
First Level of Main Room	1.60E+05	2.90E+03	1.80E+01	6.00E+00	Location 26, spot on concrete floor
First Level of Main Room	2.70E+03	bkgd	bkgd	bkgd	Rest of survey, general contamination on floor
First Level of Main Room	1.60E+05	1.20E+03	2.40E+02	1.35E+02	Location 27, spot on concrete floor
First Level of Main Room	4.90E+04	bkgd	bkgd	bkgd	Location 29, spot on concrete floor
First Level of Main Room	1.50E+04	bkgd	bkgd	bkgd	Location 32, spot on concrete floor
First Level of Main Room	1.00E+03	bkgd	bkgd	bkgd	Location 33, spot on concrete floor
First Level of Main Room	6.80E+05	5.80E+03	8.50E+02	5.10E+02	Location 34, spot of yellow residue on a steel pump valve flange. [SC&A note: It is a small spot and may not represent exposure potential.]
First Level of Main Room	6.80E+05	5.80E+03	8.50E+02	5.10E+02	Location 34, spot of yellow residue on a steel pump valve flange
First Level of Main Room	2.10E+03	bkgd	bkgd	bkgd	Location 35, spot on concrete floor
First Level of Main Room	bkgd	NA	bkgd	bkgd	Rest of survey was bkgd
First Level of Main Room	6.80E+05	bkgd	No smear taken	No smear taken	Location 38, spot on concrete floor
First Level of Main Room	2.40E+05	bkgd	bkgd	bkgd	Location 40, spot on concrete floor
First Level of Main Room	1.00E+05	bkgd	bkgd	bkgd	Location 41, spot on concrete floor
First Level of Main Room	2.60E+04	bkgd	bkgd	bkgd	Location 43, spot on concrete floor
First Level of Main Room	2.60E+04	bkgd	bkgd	bkgd	Rest of survey, general contamination on about 30% of the floor

Main Location	Direct readings dis/min-100 cm^2		Smear results dis/min-100 cm^2		Comments
	Beta-gamma	alpha	Beta-gamma	alpha	
First Level of Main Room	1.70E+03	bkgd	bkgd	bkgd	Location 47, spot on concrete floor
First Level of Main Room	bkgd	NA	bkgd	bkgd	Rest of survey was bkgd
Overheads	1.40E+03	bkgd	bkgd	bkgd	Location 81, spot on steel overhead beam
Overheads	2.10E+03	bkgd	33	10	Location 83, spot on steel overhead beam
Overheads	6.90E+02	bkgd	bkgd	6	Location 84, spot on steel overhead beam
Overheads	bkgd	NA	bkgd	bkgd	Rest of survey was bkgd
Acct. Storage	bkgd	NA	bkgd	bkgd	—
Dock Area	bkgd	NA	bkgd	bkgd	—
Entrance Corridor	bkgd	NA	bkgd	bkgd	—
2nd Level of Main Room	6.60E+04	bkgd	220	56	Location 102, area on top of stainless steel Nitric Acid Tank-1
2nd Level of Main Room	3.40E+05	bkgd	86	25	Location 103, spot on steel floor beam
2nd Level of Main Room	3.40E+05	bkgd	780	640	Location 104, spot on steel floor beam
2nd Level of Main Room	6.80E+04	bkgd	260	130	Location 105, spot on steel floor beam
2nd Level of Main Room	1.60E+04	bkgd	96	28	Location 107, spot on top on steel top of Nitric Acid Tank-1
2nd Level of Main Room	bkgd	NA	bkgd	bkgd	Rest of survey was bkgd
2nd Level Lab	7.90E+04	4.00E+03	bkgd	12	Location 119, area in soapstone sink in lab
2nd Level Lab	bkgd	NA	bkgd	bkgd	Rest of survey was bkgd
2nd Level Change Room	bkgd	NA	bkgd	bkgd	—
3rd Level	6.50E+04	4.00E+03	4.40E+01	bkgd	Location 132, spot on stainless steel Kelly-1
3rd Level	1.40E+06	4.60E+03	bkgd	bkgd	Location 133, spot on stainless steel Kelly-1
3rd Level	3.30E+04	bkgd	bkgd	bkgd	Location 134, spot of steel floor beam
3rd Level	6.80E+05	2.30E+03	1.90E+01	4.20E+01	Location 135, spot on stainless steel Kelly-1
3rd Level	bkgd	NA	bkgd	bkgd	Rest of survey was bkgd
4th Level Catwalk	bkgd	NA	bkgd	bkgd	Walkway over Kellys
Roof	3.40E+04	bkgd	bkgd	bkgd	Location 147, spot on galvanized steel roof vent, equated to Ra-226
Roof	6.03E+03	bkgd	bkgd	bkgd	Location 148, spot on gravel, dirt, and tar roof floor, equated to Ra-226
Roof	1.80E+03	bkgd	bkgd	bkgd	Rest of survey, general contamination equated to Ra-226
Roof	3.40E+05	2.30E+03	bkgd	bkgd	Location 164, spot inside steel crossover pipe
Roof	2.10E+03	bkgd	bkgd	9	Location 157, spot on steel wall
Roof	1.30E+05	bkgd	No smear taken	No smear taken	Ring of contamination along walls, 2 ft below top of tank
Roof	2.10E+03	bkgd	bkgd	bkgd	Rest of survey, general contamination on floor and walls
Roof	3.40E+05	bkgd	bkgd	bkgd	Location 174, spot inside steel inlet pipe
Roof	7.50E+03	1.70E+03	No smear taken	No smear taken	General contamination on steel walls
Roof	6.90E+02	bkgd	bkgd	bkgd	General contamination on steel floor
Roof	3.40E+02	bkgd	bkgd	bkgd	General contamination on center stirrer
Roof	1.70E+03	bkgd	bkgd	27	Location 188, spot steel wall
Roof	1.70E+03	bkgd	bkgd	bkgd	General contamination on rest of walls

Main Location	Direct readings dis/min-100 cm^2		Smear results dis/min-100 cm^2		Comments
	Beta-gamma	alpha	Beta-gamma	alpha	
Roof	6.90E+02	bkgd	No smear taken	No smear taken	General contamination on center stirrer
Roof	5.50E+03	bkgd	bkgd	bkgd	Location 191, spot on steel pipe
Roof	bkgd	NA	bkgd	bkgd	rest of survey (floors) was bkgd

APPENDIX B: FINAL DRAFT CRITERIA FOR THE USE OF SURROGATE DATA

Prepared by the ABRWH Work Group on Use of Surrogate Data

May 14, 2010

For the purposes of this report, the term "surrogate data" will refer to the use of exposure data from one site for individual dose reconstruction for workers at another site. In reviewing this topic for the Work Group SC&A distinguished between "Type I" surrogate data use (as described above) and "Type II" surrogate data where these data are used as part of a scientific effort to develop parameters for use in dose reconstruction activity calculations rather than as a substitute for the lack of adequate data needed for dose reconstruction.

"Surrogate data" are used in the NIOSH dose reconstruction program because of the lack of complete and comprehensive exposure monitoring records for many of the workers at the sites covered by the program (SC&A September 2007). It is more often considered for dose reconstruction during the early years of some DOE and AWE facilities because of the lack of reliable monitoring methods, the urgency of developing production capabilities, and other reasons.

This report will review a number of criteria that need to be considered in determining whether the specific use of surrogate data for individual dose reconstruction is scientifically sound and appropriate for that particular application.

1. Hierarchy of Data – It should be assumed that the usual hierarchy of data would apply to dose reconstructions for that site (Individual worker monitoring data followed by co-worker data followed by workplace monitoring data such as area sampling followed by process and source term data.) This hierarchy should be considered when evaluating the potential use of surrogate data. Surrogate data should only be used to replace data if the surrogate data have some distinct advantages over the available data and then only after the appropriate adjustments have been made to reflect the uncertainty inherent in this substitution.

2. Exclusivity Constraints – In many cases, surrogate data are used to supplement the available monitoring data from a site. In those cases, the surrogate data is usually used to justify certain assumptions about the distribution or range of possible exposures or assumptions about the source terms. In those cases, no special justification is necessary beyond the usual scientific evaluation. This is akin to the Type II use described above. However, in other situations, there are no or very little monitoring data available. In those cases, the use of the surrogate data as the basis for individual dose reconstruction would need to be stringently justified. This judgment needs to take into account not only the amount of surrogate data being relied on relative to data from the site but also the quality and completeness of that surrogate data.

3. Site or Process Similarities – One of the key criteria for judging the appropriateness of the use of surrogate data would be the similarities between the site (or sites) where the data were generated and the site where the surrogate data are being utilized. The application of any surrogate data to an individual dose reconstruction at a site should include a careful review of the rationale for utilizing that source of data. Factors that could be considered include, but are not limited to, similarity of the production processes, presence or absence of conditions that might affect exposure, and monitoring methods employed at the site(s). The potential availability of other sources of surrogate data needs to be considered and the selection of the surrogate data used for dose reconstruction justified. Some of the questions to be considered where appropriate are:

   - Are there other sources of surrogate data that were not used?

   - Do these other potential sources contradict or undermine the application of the data from the selected site?

- Are there adequate data characterizing the site being used that would help support its application to other sites?

- Do the surrogate data reflect the type of operations and work practices in use at the facilities in question?

- Surrogate data should not be used if the equivalence of working conditions, source terms, and processes of the surrogate facility to the one for which dose reconstructions are being done cannot be established with reasonable scientific or technical certainty as outlined here.

4. Temporal Considerations: Consideration also needs to be given to the period in question, since working conditions and processes varied in different periods. Surrogate data should belong in the same general period as the period for which doses are sought to be reconstructed unless it can be demonstrated that the working conditions, procedures, monitoring methods, and (perhaps) legal requirements were comparable to the period in question.

5. Plausibility: The manner in which the surrogate data are to be used must be "plausible" with regard to the reasonableness of the assumptions made. The plausibility determination should address issues of:

    - Scientific plausibility. Are the assumed models (e.g., bioassay, concentration gradients) scientifically appropriate? Have the models been validated (where feasible) using actual monitoring data collected in a similar situation?

    - Workplace plausibility. Are the assumed processes and procedures (including monitoring) plausible for the facility in question? Have all of the factors that could significantly impact exposure been taken into account? Is adequate information available about the facility in order to be able to make a fair assessment?

Claimants will have significant concerns about the credibility of using surrogate data. To the extent that the use of surrogate data for individual dose reconstruction can be avoided, this will help to minimize concerns about the credibility of the individual dose reconstruction process. This is especially important given that the use of surrogate data often relies on information on the operations and characteristics of industrial facilities operated many years ago. Many of the people knowledgeable about the facility have died, and records are usually incomplete (which is the reason for needing to use surrogate data in the first place). Given the difficulties in obtaining the comprehensive information needed for validating the use of surrogate data for individual dose reconstruction and the inherent concerns about its use by claimants, the Work Group recommends that the use of surrogate data be limited to the circumstances where other approaches are not feasible and then only after the rigorous review of the proposed use to determine if the above criteria have been fully met.