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Evaluation of Method for Assessment of Thorium-232 Exposures at the Savannah River Site from 1972 to 1989

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ACRONYMS AND ABBREVIATIONS

d	day
DAC	derived air concentration
DDCP	dibutyl N,N-diethylcarbamylphosphonate
DOE	U.S. Department of Energy
dpm	disintegrations per minute
g	gram
hr	hour
kg	kilogram
mCi	millicurie
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
pCi	picocurie
PEF	Plutonium Experimental Facility
PuFF	$^{238}PuO_2$ Fuel Form Facility
SC&A	S. Cohen & Associates
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
TIOA	triisooctlyamine
TFCT	Thorium Fuel Cycle Technology Program
THOREX	thorium extraction
yr	year
µCi	microcurie

1.0 PURPOSE

In *Addendum 3 to Savannah River Site (SEC-00103) Special Exposure Cohort Evaluation Report*, NIOSH proposed methods to reconstruct potential internal doses from exposure to ^{232}Th (NIOSH 2012) at the Savannah River Site (SRS). These methods are summarized:

- Intakes based on coworker trivalent radionuclide urinalysis results will be used to bound doses for the period from 1973 through 1994 providing chronic intake rates of 0.599 pCi/d for type M material and 8.06 pCi/d for type S material.

- Intakes based on coworker chest count data will be used to bound doses for the period from 1995 through 2007 providing chronic intake rates of 22.67 pCi/d for type M and 3.18 pCi/d for type S material.

Since the publication of NIOSH (2012), NIOSH learned that the method used to analyze urine samples for trivalent radionuclides was changed in 1990 to alpha spectroscopy, which rendered the use of trivalent radionuclide bioassay coworker data impracticable.

After publication of NIOSH 2012, Sanford Cohen and Associates (SC&A) published the draft white paper *SC&A Review of Addendum 3 to the NIOSH Savannah River Site Special Exposure Cohort (SEC-103) Evaluation Report* (SC&A 2013). SC&A questioned:

1. The use of trivalent radionuclide bioassay coworker data as a surrogate for thorium

2. The use of chest count data to bound intakes of thorium.

The National Institute for Occupational Safety and Health (NIOSH) responded to those questions in the Advisory Board SRS Work Group meeting held on February 5, 2014. NIOSH has proposed extending the use of chest count data back to 1990, as discussed in the NIOSH response (NIOSH 2014) to SC&A issue 27. NIOSH also recently published a new coworker study for thorium based on urinalysis results that that were obtained using the triisooctlyamine (TIOA) followed by dibutyl N,N-diethylcarbamylphosphonate (DDCP) technique. This approach is provided in ORAUT-OTIB-0081 (ORAUT 2016). The results of the study are that intakes for type S thorium total alpha was determined to be 67.59 dpm/d at the 50th percentile and 626.2 dpm/d at the 95th percentile. Assuming natural thorium, these represent ^{232}Th intake rates of 33.8 and 313.1 dpm/d, respectively. These coworker intakes are applicable from October 1972 through May 1980. There is no indication that there was any major work with thorium between in the May 1980 through 1989 time period (Steimke 1980).

This document discusses a new method for bounding potential internal doses from thorium for the period from 1981 to 1989 using known inventories and routine air monitoring data.

2.0 WORK WITH THORIUM

NIOSH discussed work at SRS using thorium in NIOSH (2012). Through information from interviews of former scientists (ORAUT 2013a, 2013b) at SRS, NIOSH has updated the history of the use of thorium.

The Alpha Materials Laboratory (in Building 773-A) was placed in operation in 1973; ThO_2 was used as a surrogate for testing in gloveboxes with the ^{238}Pu fuel form program (DuPont 1972). In 1973, gram-quantity ThO_2 was again used as a surrogate for plutonium shards in 773-A hot cells to test chemical vapor deposition of molybdenum (DuPont 1973). The Team has found no documentation of significant production and research activities involving thorium for 1974, 1975, and 1976, although

nominal uses of thorium as a surrogate were possible. In 1977, thorium (oxalate powder prepared in Building 773-A) was used as a surrogate for plutonium in testing of HB-Line exchange columns (DuPont 1978a).

In 1977, SRS began work in Building 773-A as part of the Thorium Fuel Cycle Technology (TFCT) Program to develop processing technology for spent thorium fuel. The scope of the program included broad evaluations to "identify viable thorium/uranium recycle strategies; research and development programs to confirm the feasibility of the selected fuel cycle or cycles; a design integration study to identify development areas and safeguards and proliferation aspects; and the development and testing of key systems, equipment, and components" (DuPont 1984a). By 1978, nine cells in the high-level caves of Building 773-A were prepared for the Alternate Fuel Cycle Technology Program of which TFCT was a part (DuPont 1984b). SRS received 4.5 kg (0.45 mCi) of unirradiated ThO_2 reflector pellets and used them to test the effects of heat treatment on physical characteristics and dissolution (DOE 1978a; ORAUT 2013a, 2013b). This work, in the high-level caves, involved mechanical grinding of ThO_2. Testing of a conceptual thorium extraction (THOREX) process was evaluated using some of that same ThO_2 inventory (DOE 1978a). Testing of the conceptual THOREX flowsheets continued at SRS using irradiated thorium and uranium from spent fuels stored at the Receiving Basin for Offsite Fuel. SRS staff cut sections of irradiated Elk River O_2/UO_2 fuel rods to test off-gas removal characteristics (DOE 1978b).

To test the Plutonium Experimental Facility (PEF, Building 235-F) where ^{238}Pu heat source development was to occur, SRS staff put about 300 g of ThO_2 into the process line in March 1978 to functionally test the facility. The cited reference stated that no health physics problems were encountered (DuPont 1978b). By April 1978, all PEF equipment except for the hot press had been tested using ThO_2 as a surrogate in gloveboxes (DOE 1978b).

In 1979, SRS and Hanford were planning and preparing a small number of 80% ThO_2-20% UO_2 rod assemblies for irradiation in fiscal year 1980 and subsequent postirradiation characterization (DuPont 1984a). While 30 fuel rods (of varying thorium and uranium mixtures) were prepared at Hanford in 1979 and shipped to SRS, the irradiation was canceled in May 1980 (Steimke, J. L., 1980). Laboratory analyses were performed to evaluate alternative chemical reagents in the dissolution of ThO_2 (DOE 1978c; ORAUT 2013b). At CMX (a code designation for a facility), SRS performed long-term flow testing for 6 months using one of the Hanford 100% ThO_2 fuel rods (DOE 1978c; ORAUT 2013b). Thirty rods were prepared by Hanford for SRS flow experiments; 12 of the rods were 100% ThO_2, and the remainder was a mixture of uranium and thorium. Nine of 12 100% ThO_2 rods were used for the long-term flow tests. All 30 rods were stored in a cage in Building 773-A, Room C 070 (Steimke 1980). Work with the Hanford thorium material was canceled in May 1980 (Steimke 1980; DuPont 1984a).

SRS investigated tritium removal and retention processes for ThO_2 fuels including the associated evaluation of other volatile radioisotopes. Four types of mechanically blended ThO_2-UO_2 unirradiated fuel pellets were received from General Electric of Canada for use in ThO_2 experiments (DOE 1978d). Two additional types of ThO_2-UO_2 unirradiated fuel pellets were received from General Electric of Canada (DOE 1978e). Work at SRS on these types of analyses continued through December 1978 (DOE 1978e).

In November 1980, SRS began stocking thorium nitrate crystals in the 773-A "Chem Stores" for use in research and as surrogate material with an inventory of 3.4 kg (0.34 mCi) (Author unknown 2012). The quantity in the material accountability ledgers had decreased to 2.9 kg (0.29 mCi) in March 1982, to 2.7 kg (0.27 mCi) in May 1982, and to 1.2 kg (0.12 mCi) in August 1984. A notation denoted the latter entry as "inventory write-off." The inventory was further decreased to 1.0 kg (0.1 mCi) in February 1986 and remained at that amount until February 1991, after which there were no further entries for thorium for 773-A Chem Stores (Author unknown 2012). SRS continued to use thorium in

laboratory analyses in 1981 as a direct reagent and as a surrogate for other radionuclides (DuPont 1987a, pp. 179, 183; Monson and Hall 1981).

The thorium inventory in 773-A steadily declined from 1981 when the TFCT Program ended through 1987; most of the thorium was sent to the burial grounds. Less than 5 kg (0.5 mCi) thorium remained in 773-A during 1987. In 1988, SRS began acquiring ^{232}Th for use in research of waste glass for the defense waste program. This research, using gram quantities, was likely performed in 1988 and 1989 in laboratory-scale studies. Table 2-1 lists the ^{232}Th inventory of Building 773-A by year from 1973 to 1989.

Table 2-1. ^{232}Th inventory, Building 773-A.

Year	Operation	Inventory (kg)
1973	Storage, surrogate	154.0
1974	Storage, surrogate	104.0
1975	Storage, surrogate	104.0
1976	Dissolution studies, storage, surrogate	89.4
1977	Alternative fuels program, dissolution studies, storage, surrogate	85.4
1978	Alternative fuels program, dissolution studies, storage, surrogate	56.6
1979	Alternative fuels program, tritium studies, storage, surrogate	83.4
1980	Alternative fuels program, tritium studies, storage, surrogate	108.6
1981	Storage	110.9
1982	Storage	85.5
1983	Storage	32.5
1984	Storage	21.6
1985	Storage	17.9
1986	Storage	5.4
1987	Storage	4.9
1988	Storage, surrogate	17.0
1989	Storage, surrogate	41.7

3.0 ANALYSIS OF INVENTORY DATA TO BOUND THORIUM DOSES

3.1 NUREG-1400 APPROACH

NUREG-1400, *Air Sampling in the Workplace* (NRC 1993), provides an approach to evaluate the need for air sampling during work based on the amount of radioactive material included in the work process. The approach is influenced by the type of material, the release potential, and the confinement of the material. Equation 3-1 describes this relationship:

$$I_p = Q \times 10^{-6} \times R \times C \times D \quad (3\text{-}1)$$

where

I_p = *estimated intake.*

Q = estimated quantity of unencapsulated radioactive material available for inhalation by a worker in a room or location. The estimate of the quantity of handled material was determined based on the change in inventory in any given month. If no change of inventory occurred, then it was assumed no work for that period of time was performed.

1×10^{-6} = a combination of the fraction of material that is released to the environment times the fraction of that material that is inhaled.

R = release fraction, based on the physical form of the material (Table 3-1). A release fraction value of 0.01, associated with nonvolatile powders, was assumed.

C = confinement factor, which takes into consideration the engineering controls in place (Table 3-2). During the period of interest it is reasonable to assume that any process associated with radioactive material would have routinely occurred in a fume hood or under some form of capture ventilation. Therefore a confinement factor value of 0.1 was assumed.

D = dispersibility factor, which takes into consideration energy that is added by the work process. This could be from heating, grinding, milling, boiling, or adding chemicals that cause an exothermic chemical reaction to occur (Table 3-3). It is assumed that the handling of this material would have inherently added chemical or mechanical energy. Therefore, a dispersibility factor value of 10 was assumed.

Table 3-1. Values of release fraction *R* (NRC 1993).

Physical form	Release fraction *R*
Gases or volatile material	1.0
Nonvolatile powders	0.01
Solids, (e.g., uranium fuel pellets, cobalt or iridium metal)	0.001
Liquids	0.01
Encapsulated material	0

Table 3-2. Values of confinement factor *C* (NRC 1993).

Work location	Confinement factor *C*
Material handled in a glovebox	0.01
Material handled in a well-ventilated hood	0.1
Material handled in an open work area	1

Table 3-3. Values of dispersibility factor *D* (NRC 1993).

Added energy	Dispersibility factor *D*
Cutting, grinding, heating, or chemical reactions	10
None	1

Based on the assumptions above, the NUREG-1400 approach (NRC 1993) was used to calculate a potential monthly intake based on the change of inventory between months (which represents the amount of processed material). Assuming all of the inventory was associated natural thorium. Therefore, ^{232}Th would only represent 50% of the calculated activity. The estimated monthly intakes were converted to daily intake rates and averaged over the entire inventory data period (Table 3-4). Based on these estimated daily intake rates, an associated average air concentration was calculated. The expected surface contamination levels were calculated by determining that amount of activity that would build up due to the settling of the airborne particulate based on guidance in Battelle-TBD-6000, *Technical Basis Document: Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (NIOSH 2011).

Table 3-4. Average airborne concentrations, surface contamination levels, and intake rate estimates using NUREG-1400.

Location	Average thorium surface contamination estimates (dpm/100 cm^2)	Average thorium airborne concentrations (µCi/cm^3)	Th-232 inhalation intake rate (dpm/calendar day)
Building 773-A	2.1	0.05×10^{-12} (2.4% DAC or 0.1 dpm/m^3)	0.45
Stores	0.2	0.005×10^{-12} (0.2% DAC or 0.01 dpm/m^3)	0.05

3.2 AREA AIR MONITORING DATA

During the 1970s and 1980s, SRS had a routine air monitoring program. These samples were generally collected daily and counted for gross alpha and beta activity. The calculated air concentrations from these air samples were only reported in the air sample data sheets if the air sample concentration was above 1×10^{-12} µCi alpha/cm^3 (2.22 dpm/m^3), or 50% of the plutonium derived air concentration (DAC). Figure A-9 is an example air sample datasheet. These sheets also indicate when respiratory protect were worn in conjunction with the collection of the air sample.

Much of the air monitoring data collected for 773-A was censored (reported) at less than 1×10^{-12} µCi alpha/cm^3. The Team analyzed available air sample data to determine if there was a systematic nature to routine air concentrations that exceeded the censoring level. Due to the large number of air samples SRS collected between 1972 and 1989, it was determined that a random number of samples would be analyzed to estimate the true population percentage of air samples that exceeded the censoring level. The analysis used a sample of results selected from 1975, 1981, 1984, and 1987 to determine if a more detail analysis was needed. For each year, a random list of workdays (weekends and holidays were excluded) were created to provide a means to collect a random sample from the large set of available data. Air sample results were recorded, based on the random list of workdays, until a minimum number of air samples results were compiled.

The Team used a set of gross alpha air monitoring obtained from 1974 through 1977 at the $^{238}PuO_2$ Fuel Form Facility (PuFF) data (ORAUT 2017). The PuFF data was sampled and analyzed for the effect of the number of samples versus the variability in ability to determine the number of samples over a set limit. For each of the years 1974 through 1977, 10,000 PuFF air concentration results were simulated in groups of random 20 days. The sampling was continued in increments of 5 days up to 80 days.

Summary statistics for 1974, 1975, 1976, and 1977 were plotted for each 5-day sample and are provided in Figure 3-1. The dot at 20 days, and subsequent samples, represent the median of the fraction of results over the censoring level for the 10,000 samples (*y*-axis). The error bars are the uncertainty in that fraction (95% confidence interval). The black horizontal line represents the actual median for all of the PuFF data in year. The PuFF data does not contain exactly the same number of rooms sampled each day such that the 10,000 simulations of the number of days drew a variety of actual number of results. The numbers on the top *x*-axis are the median number of results pulled for the 10,000 simulations of 20 days. As the numbers of days and results increase, the uncertainty in the median narrows and the sampled median approaches the population median. The number of random results to pull per year from 773-A air concentration data was determined by visually identifying the point on all of the plots, using the top *x*-axis (number of results), at which there is little change in the sample median. Using this analysis, the Team selected a sample size of 750 randomly selected air concentrations to provide acceptable confidence in the determination that the limit was considered bounding.

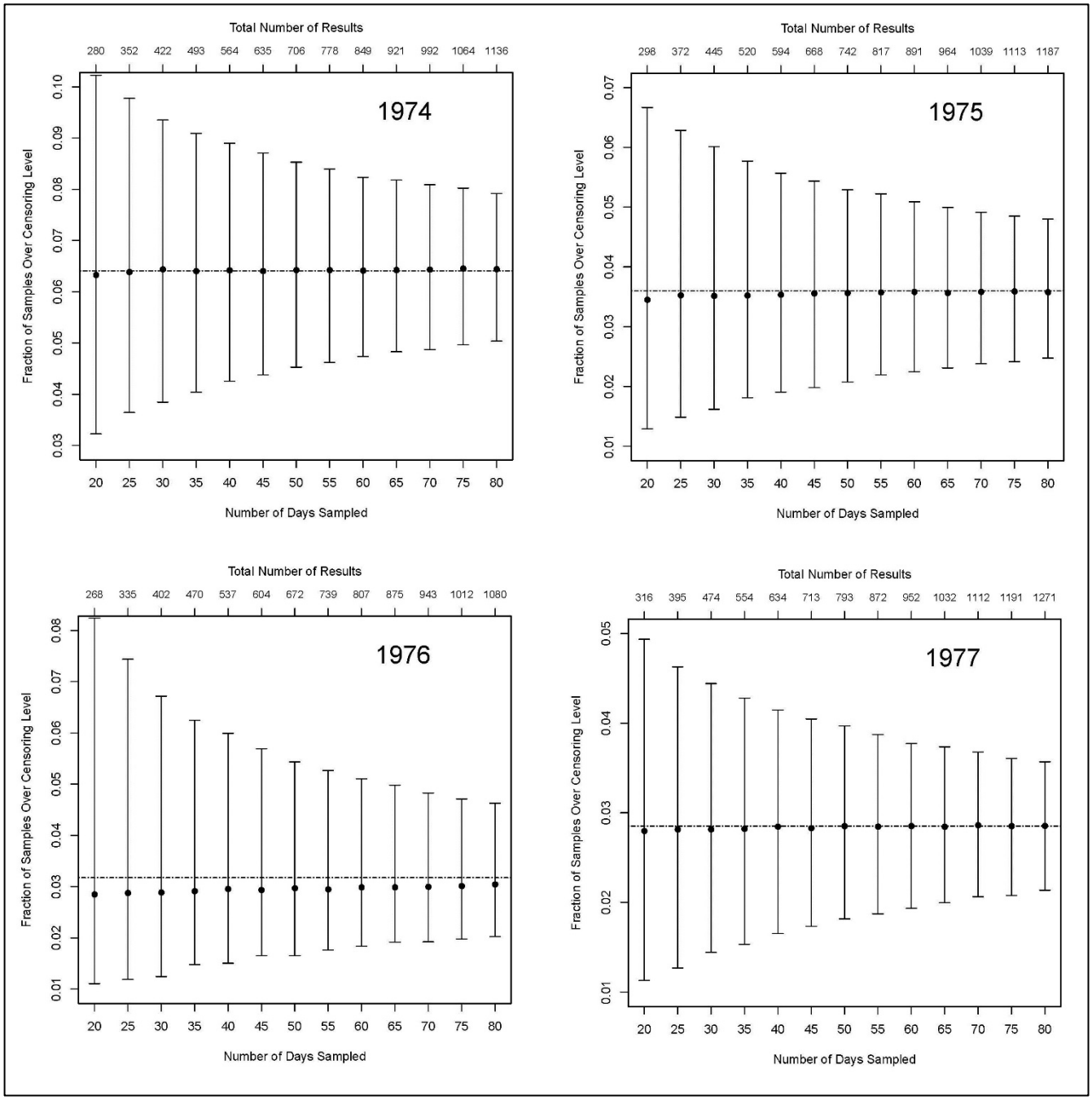

Figure 3-1. Fraction of sample results expected over censoring level. Censoring level for this dataset was 0.1 DAC.

Based on the determinations above, 750 air sample results for each year sampled were compiled and analyzed to determine the percent of the sample group (and its approximate 95% confidence interval) that exceeded the censoring level (50% DAC). Only air concentrations associated with the 773-A laboratories were considered. Each result was categorized as either less than the bounding value or not. All of the reported results were converted to the percentage of total results that are not bounded by censoring level. The intervals were computed using a bootstrapping technique. Figure 3-2 summarizes the results.

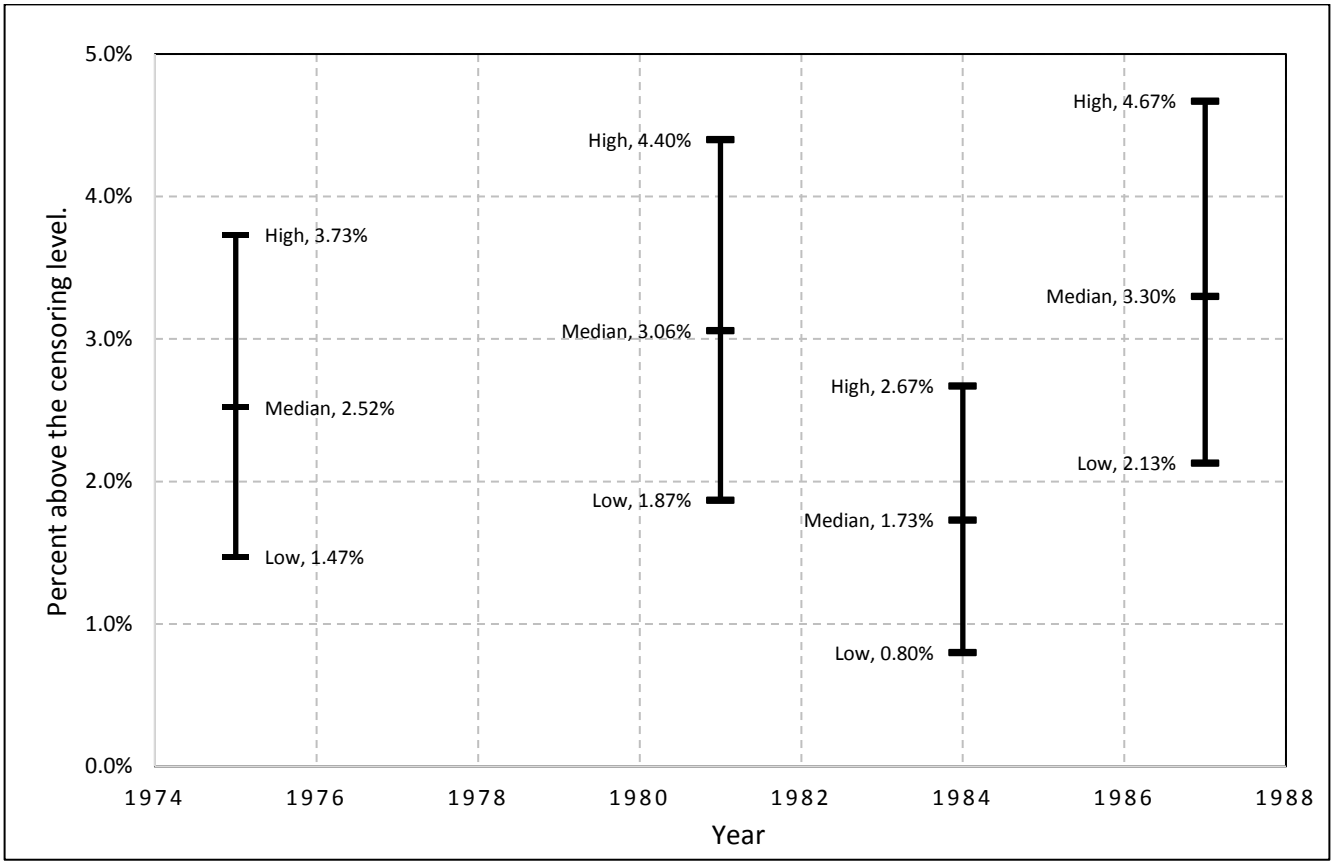

Figure 3-2. Percent of airborne concentration levels above the censoring level. (DuPont 1975a to 1975e, 1981a to 1981f, 1984c to 1984g, 1987b to 1987d).

Based on the statistical confidence intervals themselves and the consistency between them, there is no indication that additional sampling is necessary in order to draw a conclusion from this data. With indications that more than 95% of the air samples SRS collected in thorium work areas were below the censoring level of 1×10^{-12} µCi alpha/cm^3 (2.22 dpm/m^3), the censoring level is considered to be a bounding estimate of the potential airborne concentration to which a worker might have been exposed.

The daily inhalation intake rate associated with an air concentration of 1×10^{-12} µCi alpha/cm^3 was calculated (assuming a breathing rate of 1.2 m^3/hr for 8 hr/workday and 250 workdays/yr) to be 14.6 dpm alpha/calendar day (assuming natural thorium, this results in a ^{232}Th inhalation intake rate of 4.87 dpm/d). Based on guidance in OCAS-TIB-009, *Estimation of Ingestion Intakes* (NIOSH 2004), this air concentration would also be associated with an ingestion intake rate of 0.30 dpm alpha per calendar day (assuming natural thorium, this results in a ^{232}Th ingestion intake rate of 0.1 dpm/d).

4.0 CONCLUSION

Based on a source term analysis, NUREG-1400, the average air concentration that a worker could have been exposed to would likely not exceed 1×10^{-13} µCi/cm^3. However, available air concentration data was censored at a level that could not validate this low level of exposure. In addition, the analysis of the urinalysis data extracted via the TIOA-DDCP technique could not validate this low level of exposure. Figure 4-1 is a comparison of the intake rates using the three different approaches.

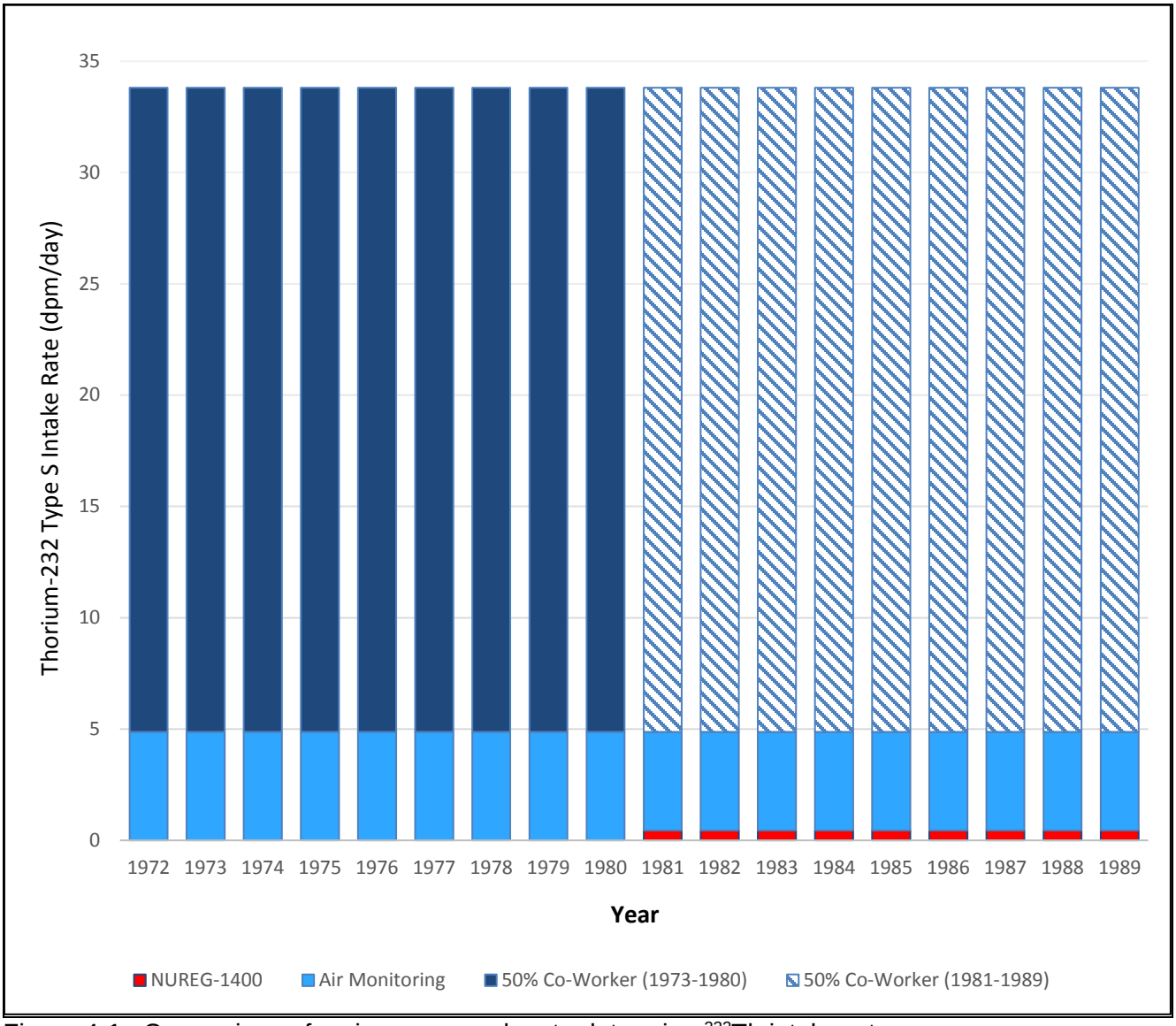

Figure 4-1. Comparison of various approaches to determine ^{232}Th intake rate.

In addition, a comparison of the 50-year organ dose was made for a chronic 1-year exposure to each of four target organs (lung, bone surface, colon, and prostate). This comparison is provided in Table 4-1.

Table 4-1. Comparison of the 50-year organ dose associated with the various approaches for 1-year chronic intake of ^{232}Th.

Organ	NUREG-1400	Air monitoring	50% coworker dose	Units
Lung	0.021	0.228	1.583	rem
Bone Surface	0.038	0.415	2.879	rem
Colon	<0.001	0.001	0.009	rem
Prostate	<0.001	0.001	0.008	rem

The NUREG-1400 approach likely gives the most realistic exposure estimate for thorium from 1981 to 1989. However, given the limitations of the air data, since it results in an estimated air concentration below the reporting level, it is difficult to draw any conclusions on how bounding of an estimate it would be. The coworker intakes presented in ORAUT (2016) are considered bounding but result in estimated exposures that are not supported by the air data during the same time period. If routine air

concentrations were at the levels associated with the coworker intake rates, there should have been a systemic air concentration 6 to 7 times the reporting level. There is no indication of a systemic air concentration above the reporting level; therefore, after 1980, the intake rate based on the reporting level of the air data is considered the best estimate of routine thorium exposure and represents a sufficiently accurate bounding scenario.

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ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS

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ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

(1)

AIR SAMPLE LOCATIONS - LAB SECTION
773-A, 735-A, 774-A, 776-A, 779-A

NO.	LOCATION 773-A	NO.	LOCATION 773-A
1	B-149	27	B-131
2	B-145	28	B-134
3	B-133	29	B-138
4	B-102	30	B-135
5	B-102	31	B-139
6	B-103	32	B-196
7	B-106	33	B-142
8	B-107	34	B-146
9	B-110	35	B-146
10	B-197	36	B-143
11	B-111	37	B-147
12	B-114	38	B-150
13	B-115	39	B-151
14	B-118	40	
15	B-118	41	B-154
16	B-119	42	B-155
17	B-119	43	B-196
18	B-122	44	B-158
19	B-123	45	B-159
20		46	B-163
21	B-197	47	B-162
22	B-126	48	B-162
23	B-126	49	C-102
24	B-127	50	C-101*
25	B-130	51	C-103
26	B-130	52	C-107

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* Not in service

Figure A-1. Air sample locations for 773-A, 735-A, 774-A, 776-A, 779-A (DuPont 1981e).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

(2)

NO.	LOCATION 773-A	NO.	LOCATION 773-A
53	C-111	81	C-158
54	C-114	82	C-162
55	C-118	83	C-162
56	C-119	84	C-163
57	C-119	85	C-159
58	C-123	86	C-159
59	C-130	87	B-005 NE
60		88	B-005 NW
61	C-131	89	B-005 SW
62	C-131	90	B-005 SE
63	C-131	91	B-065
64	C-134	92	B-067
65	C-135	93	B-069
66	C-135	94	B-070
67		95	B-070
68	C-197 N	96	B-002
69	C-139	97	B-003
70		98	B-001
71	C-147	99	
72	C-146	100	
73	C-150	101	C-075
74	C-151	102	C-077
75	C-155	103	C-079
76	C-197 S	104	C-005 SE
77	C-154	105	C-005 SW
78	C-154	106	C-005 M
79	C-158	107	C-003 N
80		108	C-003 M

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Figure A-2. Air sample locations for 773-A, 735-A, 774-A, 776-A, 779-A (continued) (DuPont 1981e).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

(3)

NO.	LOCATION	NO.	LOCATION
	773-A		
109	C-003 S	130	
110	C-005 NW	131	D-152
111	C-001	132	D-153
112	C-051	133	D-154
113	C-002	134	D-155
114	C-050	135	D-156
115	C-007	136	D-160
	735-A	137	D-160
116		138	D-160
117		139	D-165
118	A-146	140	
119	A-147	141	D-059
120		142	D-063
121	A-148	143	D-063
122	A-149	144	D-055
123	A-150	145	D-073
124	A-151	146	D-074
	774-A	151	A-1100
125	Water Pit	152	A-1122
126		153	A-022
	776-A	154	A-015
127	Control Rm.		
128	Truck Dock		
	779-A		
129			

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Figure A-3. Air sample locations for 773-A, 735-A, 774-A, 776-A, 779-A (continued) (DuPont 1981e).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

"E" SECTION ROOM AIR SAMPLES

* Constant Air Monitors

Sample #	Location	Sample #	Location
*1	E-065 M.S.M. Repair	*28	High Bay South
2	E-067	29	High Bay West
3	Blank	30	Blank
*4	East Side of Cell 16 Front	*31	Blister Area West Rear Cell 10
5	Between Cells 12 & 13 Front	32	Blister Area Center Rear Cell 1
*6	Front Cell 8	*33	Blister Area East Rear Cell 15
7	Blank	*34	E-075
*8	Front Cell 2	*35	E-074 South
9	Blank	36	Blank
*10	Men's Locker Room	*37	E-073 North
*11	Monitoring Room	38	E-074 North
12	E-071	*39	E-072
13	Blank	40	Blank
14	E-041	*41	Old Cell Block Mezzanine East
15	E-043	42	Old Cell Roof East
16	E-051 West	43	Old Cell Block Mezzanine West
17	E-045	44	Blank
*18	E-047	45	Blank
19	E-049	46	Blank
20	E-051 East	47	Old Fan Room West Center
21	E-076 West	*48	Old Fan Room East Center
*22	E-076 East	49	Blank
23	Truck Dock West	50	New Fan Room West
*24	Truck Dock East	*51	New Fan Room Center
25	M.S.M. Decon Room Ent. Corridor	52	New Fan Room East
*26	E-063	53	New Cell Roof Center
27	High Bay North	*54	New Cell Block Mezzanine Center
		55	New Cell Roof West

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Figure A-4. Air sample locations for E Section (DuPont 1981e).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

F SECTION ROOM AIR SAMPLES

*Constant Air Monitors

Sample #	Location	Sample #	Location
1	Blank	29	CPF Cell I Roof Are
*2	CPF Lab North West	30	Blank
3	CPF Lab North Center	31	CPF Rear of Cell 1
4	Blank	32	Blank
5	CPF Front of Cell 1	33	Blank
*6	CPF 15' Front of Cell 1	34	Blank
*7	CPF 15' Front of R&S Cell	35	Blank
8	CPF Front of R&S Cell	36	Blank
*9	CPF 15' North of R&S Cell	37	Blank
10	Blank	38	Blank
11	SED-I South East	39	Blank
12	SED-I North East	40	Blank
13	SED-I South West	*41	TFF Filter Area
14	SED-I North West	*42	TFF "E" Box
*15	SED-II Lower Level	43	TFF "D" Box
16**	Blank Sed I - South Hood	*44	TFF 10' North "F" Bo
17**	Blank Sed I	45	~~Blank~~ TFF Cell Roof
18	Blank	46	Blank
19	Blank	47	Blank
20	Blank	*48	TFF Front of Cell "A
21	Blank	49	Blank
*22	CPF North East R&S Filter Bank	50	Blank
23	CPF North West R&S Filter Bank	51	Front of ^{60}Co Cell
*24	CPF Rear of R&S Cell	52	Blank
25	CPF Rear of R&S Cell	53	Blank
26	CPF R&S Roof	54	Blank
27	CPF Rear of Cells 2 & 3	55	Blank
*28	CPF Rear of Cells 1 & 2	56	Blank

** New location 12-6-72

Rev. 6/14/72

Figure A-5. Air sample locations for F Section (DuPont 1981e).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

"F" SECTION ROOM AIR SAMPLES (Cont'd)

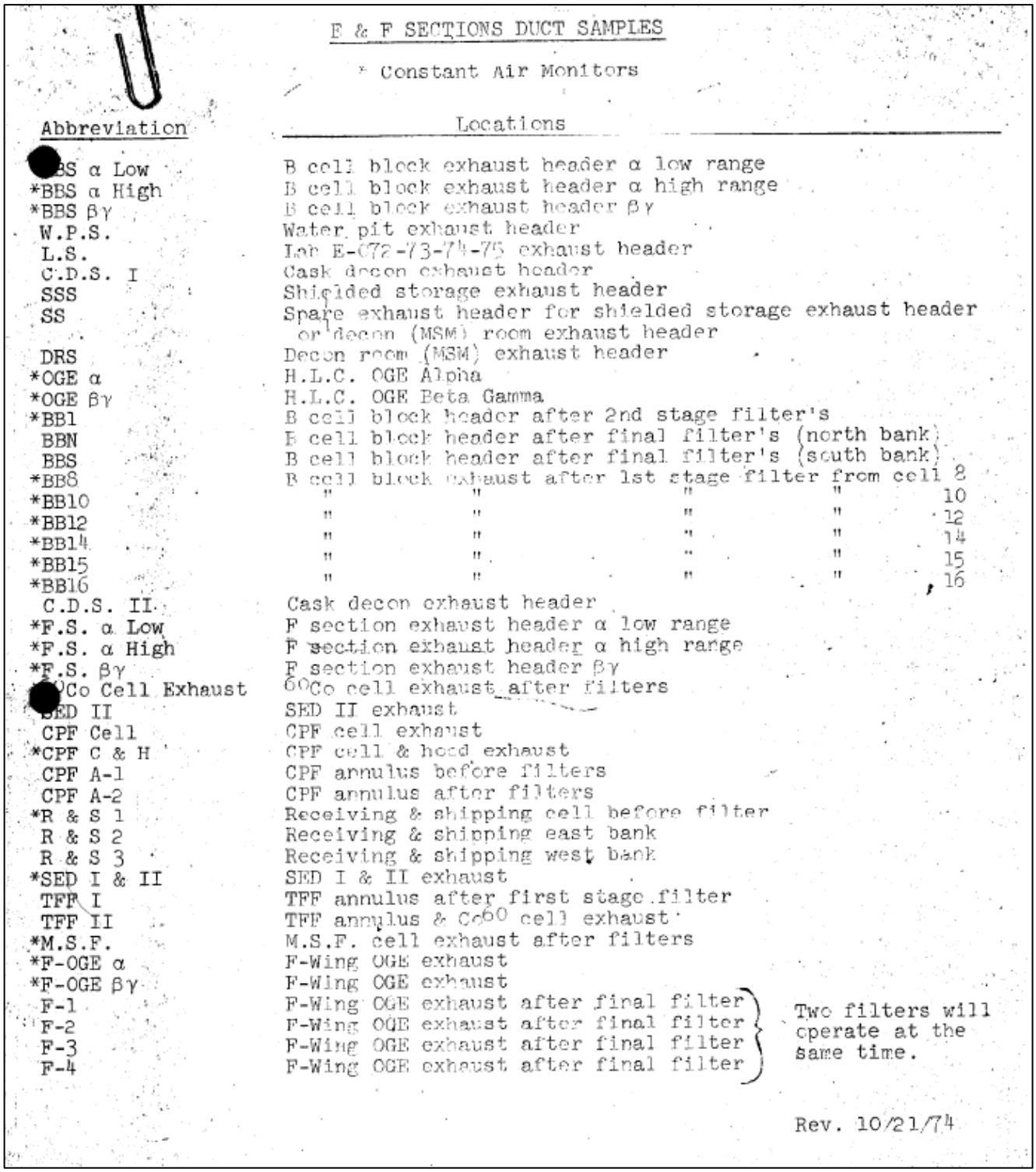
*Constant Air Monitor

Sample #	Location
*57	CPF Filter Room West
58	CPF Filter Room East
59	F-102 Service Cooridor over South Solution Addition Pots
60	Blank
61	F-102 Service Cooridor over North Solution Addition Pots
*62	SED-II Upper Level East
63	SED-II Upper Level West
64	F 080.2
*65	F 080.3
66	F 080.3 Valve Bag Room
67	SED II Lower P.T. Area
68	SED I South By Visa Con.

Rev. 7-80

Figure A-6. Air sample locations for F Section (continued) (DuPont 1981e).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)



E & F SECTIONS DUCT SAMPLES

* Constant Air Monitors

Abbreviation	Locations
*BBS α Low	B cell block exhaust header α low range
*BBS α High	B cell block exhaust header α high range
*BBS βγ	B cell block exhaust header βγ
W.P.S.	Water pit exhaust header
L.S.	Lab E-072-73-74-75 exhaust header
C.D.S. I	Cask decon exhaust header
SSS	Shielded storage exhaust header
SS	Spare exhaust header for shielded storage exhaust header or decon (MSM) room exhaust header
DRS	Decon room (MSM) exhaust header
*OGE α	H.L.C. OGE Alpha
*OGE βγ	H.L.C. OGE Beta Gamma
*BB1	B cell block header after 2nd stage filter's
BBN	B cell block header after final filter's (north bank)
BBS	B cell block header after final filter's (south bank)
*BB8	B cell block exhaust after 1st stage filter from cell 8
*BB10	" " " " 10
*BB12	" " " " 12
*BB14	" " " " 14
*BB15	" " " " 15
*BB16	" " " " 16
C.D.S. II	Cask decon exhaust header
*F.S. α Low	F section exhaust header α low range
*F.S. α High	F section exhaust header α high range
*F.S. βγ	F section exhaust header βγ
[illegible]Co Cell Exhaust	^{60}Co cell exhaust after filters
[illegible]ED II	SED II exhaust
CPF Cell	CPF cell exhaust
*CPF C & H	CPF cell & hood exhaust
CPF A-1	CPF annulus before filters
CPF A-2	CPF annulus after filters
*R & S 1	Receiving & shipping cell before filter
R & S 2	Receiving & shipping east bank
R & S 3	Receiving & shipping west bank
*SED I & II	SED I & II exhaust
TFF I	TFF annulus after first stage filter
TFF II	TFF annulus & ^{60}Co cell exhaust
*M.S.F.	M.S.F. cell exhaust after filters
*F-OGE α	F-Wing OGE exhaust
*F-OGE βγ	F-Wing OGE exhaust
F-1	F-Wing OGE exhaust after final filter } Two filters will operate at the same time.
F-2	F-Wing OGE exhaust after final filter }
F-3	F-Wing OGE exhaust after final filter }
F-4	F-Wing OGE exhaust after final filter }

Rev. 10/21/74

Figure A-7. Air sample locations for E and F Section duct samples (DuPont 1975d).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

773-A STACKS

*Constant Air Monitors

Abbreviation	Locations
W.P.S.	Water Pit Stack
L.S.	Lab E-072-73-74-75 Exhaust Stack
C.D.S.	Cask Decon Stack
SSS	Shielded Storage Stack
SS	Spare Stack for Sheilded Storage Stack or Decon (MSM) Room Stack
DRS	Decon Room (MSM) Stack
*A.B.S. α Low	A cell block stack α low range
*A.B.S. α High	A cell block stack α high range
*A.B.S. βγ	A cell block stack βγ
*BBS α Low	"B" cell block stack α low range
*BBS α High	"B" cell block stack α high range
*BBS βγ	"B" cell block stack βγ
*F.S. α Low	"F" stack α low range
*F.S. α High	"F" stack α high range
*F.S. βγ	"F" stack βγ
*B.S. α Low	B stack α low range
*B.S. α High	B stack α high range
*B.S. βγ	B stack βγ
*C.S. α Low	"C" stack α low range
*C.S. α High	"C" stack α high range
*C.S. βγ	"C" stack βγ

Rev. 6/30/72

Figure A-8. Air sample locations for 773-A stacks (DuPont 1975d).

ATTACHMENT A
EXAMPLE AIR SAMPLE REPORTS (continued)

Radiation Control
Air Sample Form 1

ROUTINE AIR SAMPLE RESULTS - TECHNICAL AREA

All routine room air samples removed after normal time intervals and above 4.5 x 10^{-12} µCi/cc Cm α, 1 x 10^{-12} µCi/cc Cf α, Pu α or unidentified α or 1 x 10^{-10} µCi/cc βγ are recorded below. All other routine room air samples were less than these values or were removed before completion of the normal sampling period and are recorded on Air Sample Form 2. See attached sheet for sample locations. Inoperative samples are noted under remarks.

Sample No.	Date Time ON	Date Time OFF	Date Time Counted	µCi/ccx10^{-12} α	µCi/ccx10^{-10} βγ	Recount Date Time Counted	µCi/ccx10^{-12} α	µCi/ccx10^{-10} βγ
ALL Ø	6-29 3 08	6-30	7-1 4 °°	Ø	Ø			

Remarks Ø ALL SAMPLES < 1X10-12 uc/cc & OR < 1X10-10 uc/cc BY

Figure A-9. Example of routine air sample results log sheet (DuPont 1981a).