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Analysis of Savannah River Site Thoria and Thoron Air Sampling Data as a Method of Intake Bounding between 1965 and 1971	Revision: 00 Effective Date: 05/18/2010 Type of Document: Report Supersedes: None

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1.0 EXECUTIVE SUMMARY

This report describes the facilities, processes and equipment used to prepare and encapsulate thorium at Savannah River Site (SRS) 300-M area in the 1960s. Although whole body counting equipment was used to quantify thorium exposure at SRS (DuPont 1965a) in this time frame, the site *in vivo* records are located within the personal radiological records. In order to locate these records, a complete review of all personnel files would be necessary to develop a co-worker model. Since such a review is considered infeasible, an alternative method was developed to bound intake rates of thorium for unmonitored workers during the 1965 to 1971 time period. This report analyzes air sample data as a method to bound thorium intakes. Exposures to thorium are feasible even after the thorium production period ended. Bounding intake rates during this period are based on routine contamination survey measurements in the area.

2.0 INTRODUCTION AND FACILITY DESCRIPTION

Whole body counting equipment was used to quantify thorium exposure at the Savannah River Site (SRS) (DuPont 1965a), however, due to difficulties in recovery of these records as noted above, an alternative method was developed to bound intake rates of thorium during that period when thoria (thorium oxide) fuel components were assembled in the 300-M area. This report analyzes air sample data as a method to bound thorium intakes.

The 300-M area facilities, equipment and processes are described in Reed and Swanson (2006). Figures 1 through 14 illustrate Building 313-M and the thorium processing facilities and equipment. The major thoria processing campaigns which occurred in the 300-M area for the period of interest (1964 through 1971) are shown in Table 1 (Morris 2008). With minor exceptions, for example helium leak testing on encapsulated slugs in Building 320-M, this work occurred in Building 313-M in a room specially built for the purpose. The Building 313-M thorium processing room was nominally 20 feet by 30 feet. A single glovebox cabinet was centered in the room (Chew 2009).

Air samples were collected and analyzed to determine the internal exposure potential to SRS workers assigned to this area. Data from 1964 were included in the analysis because it was reasonable to assume that there would have been a delay between chronic thorium exposure and routine *in vivo* counting. Routine contamination surveys of the area after processing were completed and evaluated to assess the exposure potential after the operational periods.

3.0 THORIUM AIR SAMPLE DATA AND ANALYSIS

3.1 AIR SAMPLE DATA

Two hundred seventy (270) individual air sample results were used in this analysis. The air sample data sheets used in this analysis are in the Site Research Database (DuPont 1964, 1965b, 1965c, and 1967a). Two hundred sixty two (262) of the samples were identified as "routine" and were collected using portable air pumps operating nominally at an airflow rate of 3.5 cubic feet per minute. The remaining eleven samples were special impactor samples discussed below. The routine samplers were placed to represent the location of the operator and the sampling head was extended up to face-level. The intent was that the routine sample would represent a breathing zone sample. This was confirmed in an interview with a former health physics technician who collected the majority of the samples (Chew 2009). Routine samples may have been counted several times. Initial counts may have been made to estimate the order of magnitude of the air concentration. Inevitably, the short-lived radon progeny decay and the counts made 24 or 72 hours after sampling provide a better estimate of the long-lived radioactive material concentration, which is the quantity of interest. For this analysis the data representing the longest counting delay were used.

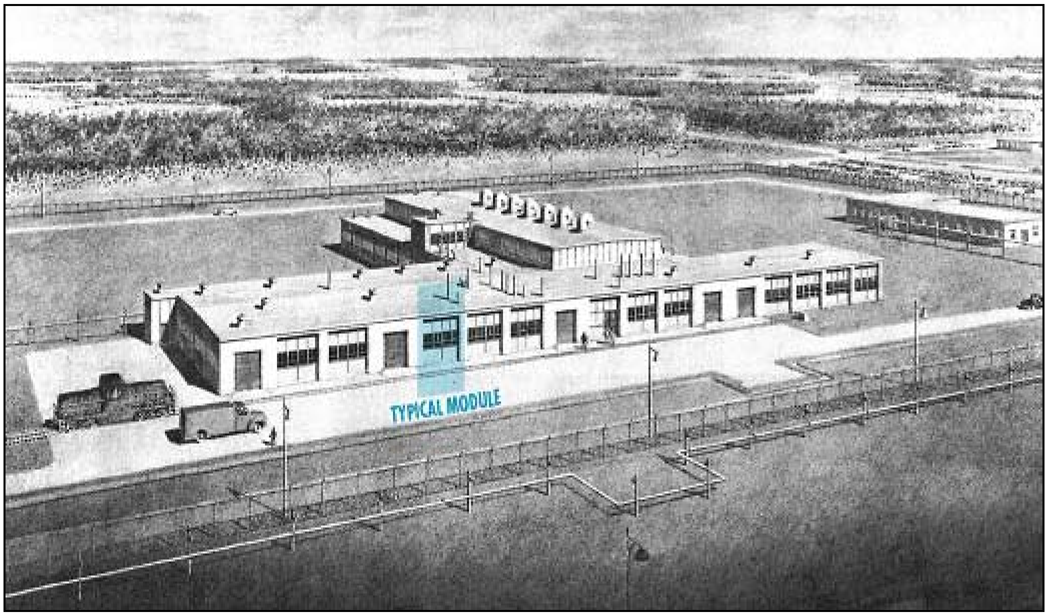

Figure 1. Architectural sketch of Building 313-M emphasizing the modular design of the facility. The east side of the building is facing the viewer.

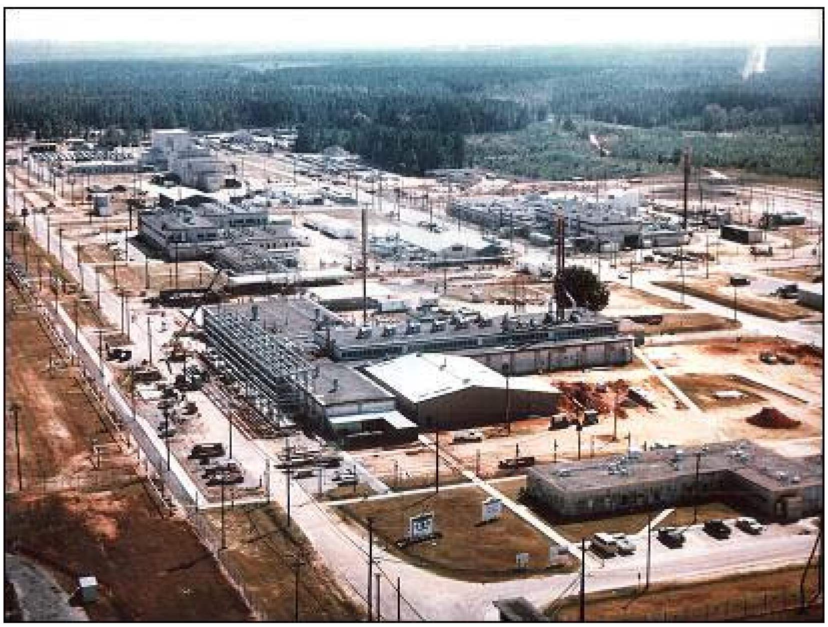

Figure 2. 1980s aerial view of the 300-M area, looking southeast. Building 313-M is the large building at the center.

Eight (8) samples were collected with special "impactor" sampling equipment. Impactor samples were high volume [1] samples taken for a short duration, typically 10 minutes, to characterize short-term operations with elevated exposure potential. Notes associated with the sampling show that respiratory protection was worn when the sampled operations were occurring. The former health physics technician who conducted the sampling confirmed that these operations were rare (Chew 2009). The impactor was designed to eliminate most the sub-micrometer-sized radon progeny. These small particles would follow the air stream and exit the back of the impactor while larger particles associated with mechanical processes would be collected on a greased planchette. The impactor air sample counts were promptly counted.

Figure 3. View of Building 313-M looking to the northeast.

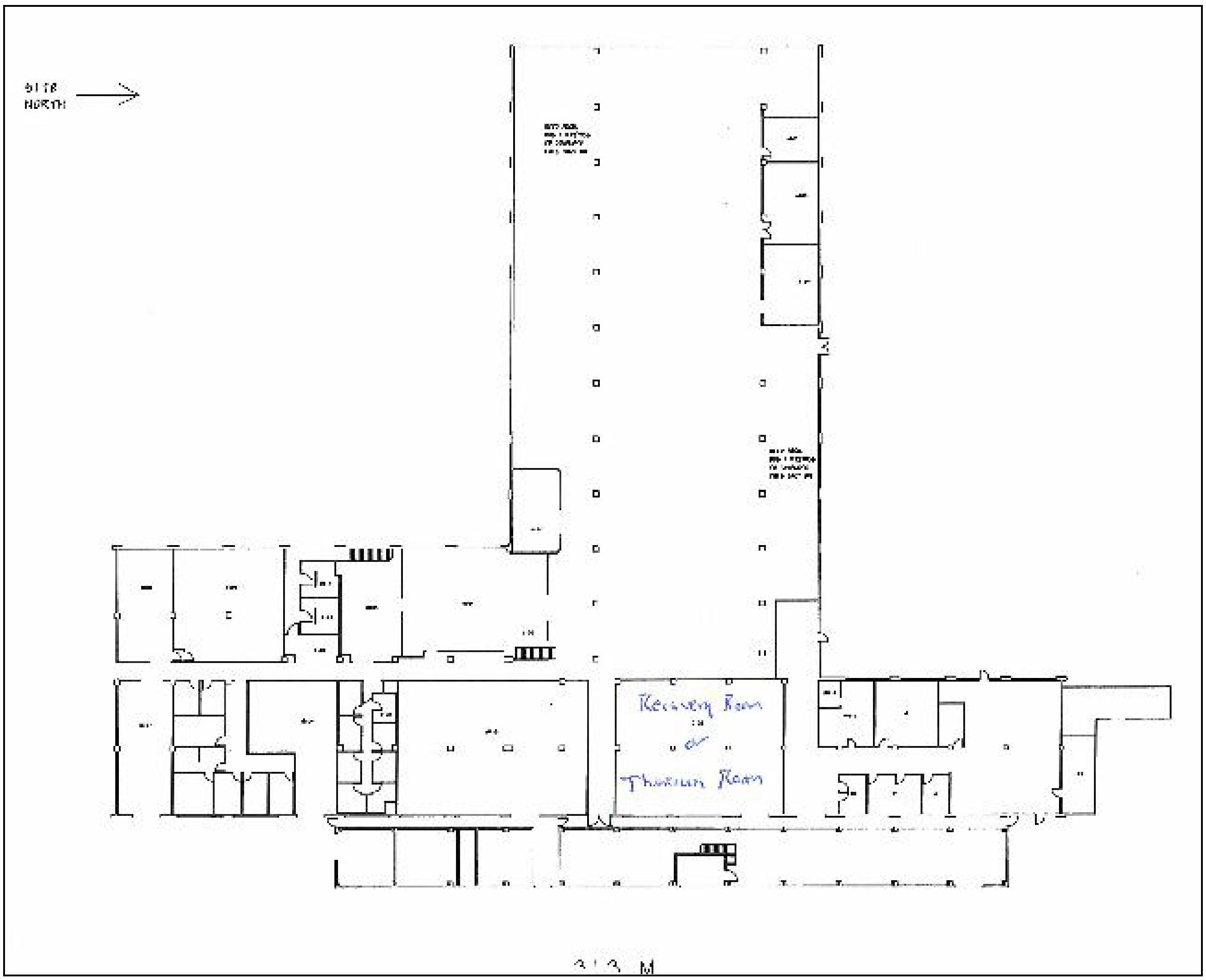

Figure 4. Building 313-M layout showing where thorium operations were performed. Location labeling provided by SRS classification analyst T. Coughenour.

Figure 5. Thorium glovebox during construction. Note the highbay setting and partial height walls. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

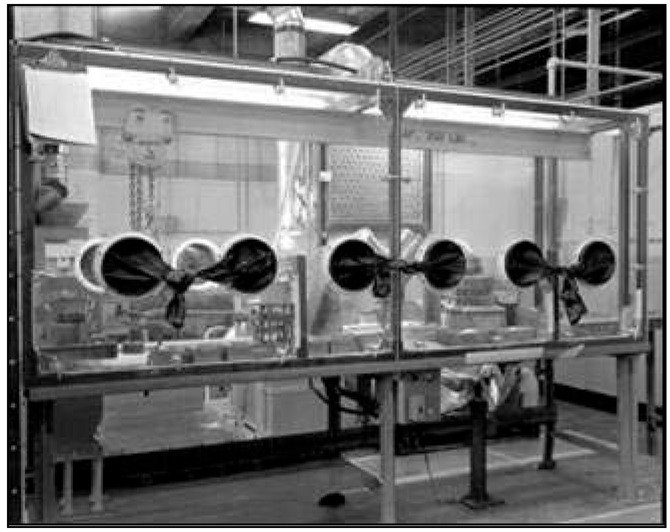

Figure 6. Thorium glovebox during operations. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

Figure 7. Thorium glovebox during operations. Note the thorium slugs lying horizontal in the far right of the glovebox. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

Figure 8. Containment ventilation equipment with HEPA filtration. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

Figure 9. HEPA filter and ventilation blower for the enclosure. Also note the bagged cans of material in foreground behind the radiological chain. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

Figure 10. Worker at thorium glovebox containment. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

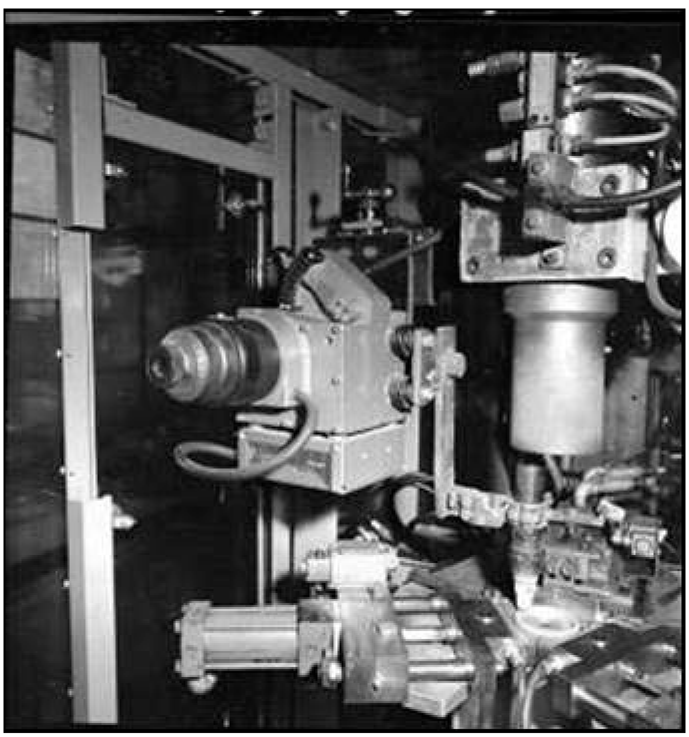

Figure 11. Welding equipment. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

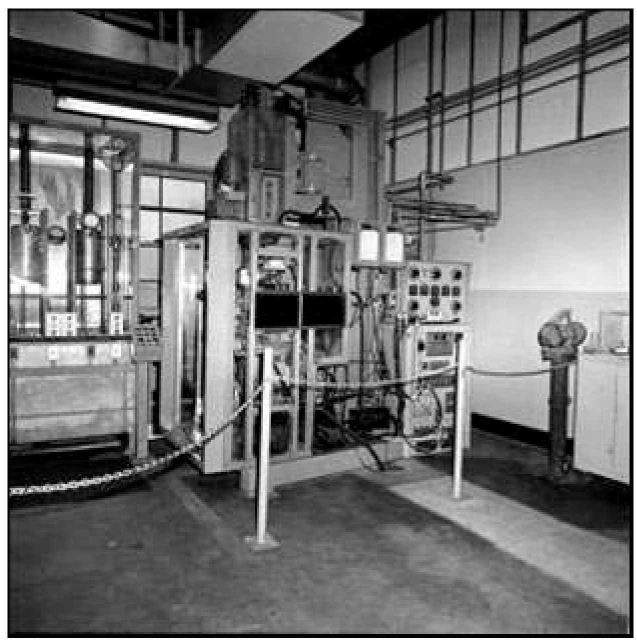

Figure 12. Welding enclosure with radiation chain in the foreground. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

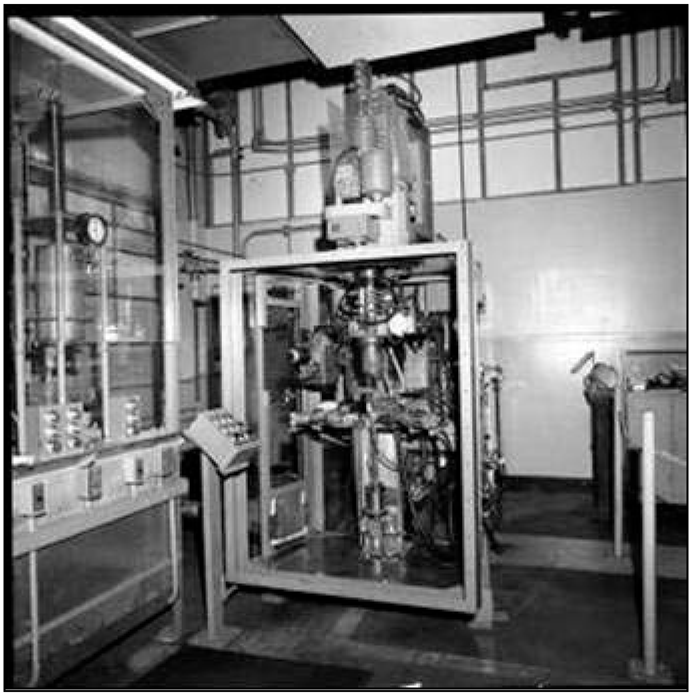

Figure 13. Welding enclosure – side view. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

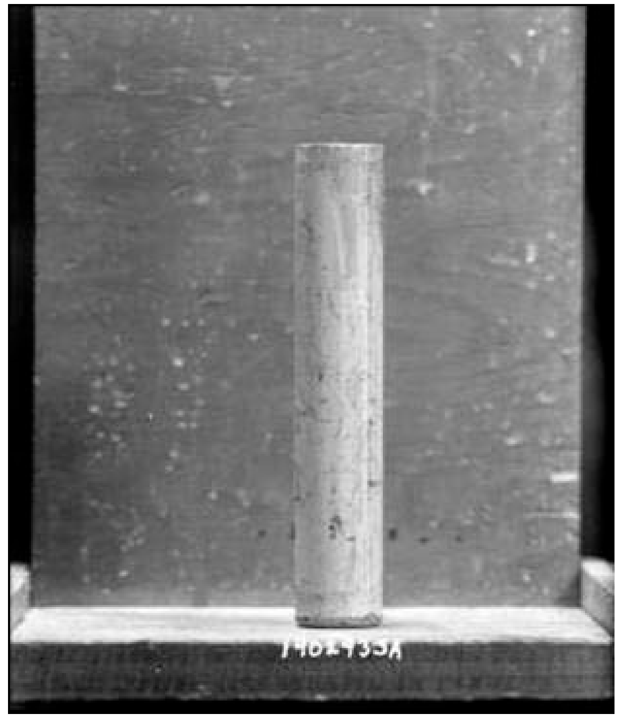

Figure 14. Thorium slug. Source: Coughenour (2009). The photograph is unclassified and does not contain UCNI.

Table 1. Beginning and ending dates (to the nearest month) of thoria production campaigns in the SRS 300 area based on monthly reports.

Beginning	Ending	Amount of thoria processed, kg	Average thoria production rate, kg/day
8/1964	12/1964	49,000	322
1/1965	8/1965	101,400	419
4/1967	8/1967	114,156	751
11/1967	12/1967	3,570	60
1/1968	2/1968	6239	108

One impactor sample yielded results that were 680% of the Maximum Permissible Concentration (MPC) [2]. The other 7 impactor samples were below the MPC value and near zero concentration.

3.2 AIR SAMPLE DATA ANALYSIS

To provide convenient reporting context, the air samples results are converted to units of MPC. The MPC value for thorium is 2×10^{-12} μCi/cm^3. This is the same value that was used to control airborne plutonium and was the thorium MPC value in use at SRS during the period in question (Stoddard 1964). A convention of assigning the value 0.01 when a measured value is reported as zero has been applied to prevent illogical data from interfering with lognormal statistical analysis which demands that all values exceed zero.

The air concentrations were calculated using the raw data available in the data sheets and assumptions regarding alpha counting efficiency (30% under 2 π geometry for a calibration source [3]), particle collection efficiency of the sampling media (95% for both routine [3] and impactor [4]), and sample self-absorption (50% for routine [3] and 55% for impactor [4]). This has the advantage of separately accounting for the important variable factors. The overall counting efficiency for routine samples (29%) and impactor samples (25%) is similar to the reciprocal of the "counter factor" value shown on some of the contemporary air sample counting sheets.

The routine and impactor air sample data are combined for analysis. The data appear to be lognormally distributed; the hypothesis that the data are lognormally distributed cannot be rejected at the 95% confidence level. Figure 15 is a probability plot of the sample data. It is compared on the same graph to the cumulative probability function of the fitted lognormal distribution.

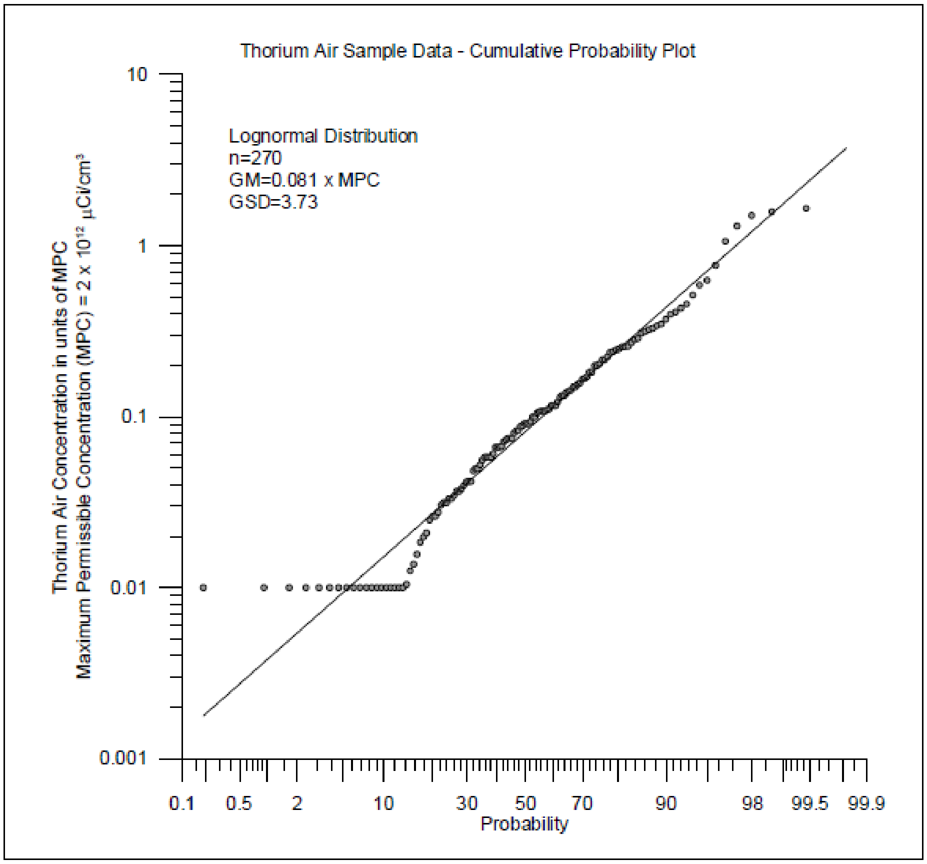

Figure 15. Probability plot for thorium air samples results.

When the routine thorium air sample data are fitted to a lognormal distribution the resulting geometric mean (GM) is 8.1% of the MPC with a geometric standard deviation (GSD) of 3.73. (The median and GM are numerically identical in a lognormal distribution.) The arithmetic mean is 20% and the 95th percentile of this distribution is 71% of the MPC. Ninety-six percent of the routine samples were below 100% of MPC value. The maximum observed sample was 678% of the MPC. This sample was taken using the impactor during “chopper operations.” It represented a 10 minute period when respiratory protection was in use.

Figure 16 illustrates the impactor and routine air sample data referenced to the semi-log scale on the left side of the graph. Superimposed on the same graph is an illustration of the daily average thoria production rate (Morris 2008). To enable semi-log graphing and lognormal distribution fitting, samples with air concentration values of zero are set equal to 0.01. In some cases multiple impactor samples were taken on the same day with identical results. In these cases the zero data are shown as 0.011 and 0.012 to separately represent the samples on the graph. The figure demonstrates that routine thorium air sampling results were consistently below half of the MPC and that the sampling was done during the thoria production campaigns.

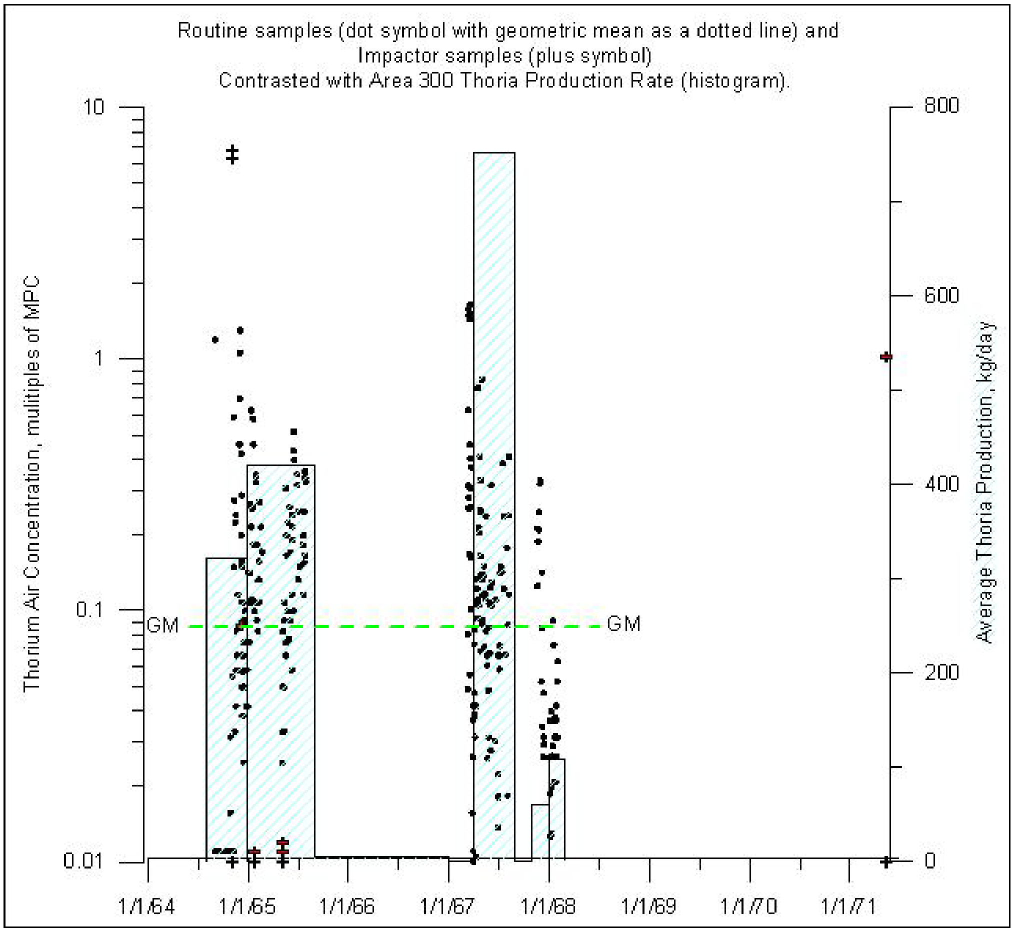

Figure 16. Airborne thorium concentration and thorium production rate.

4.0 CONTAMINATION SURVEY DATA AND ANALYSIS

4.1 CONTAMINATION SURVEY DATA

Available Radiation Survey Log Sheets (Form OSR 4-17) include transferable alpha contamination sample results and were reviewed for the 300-M area for the period of 1965 through 1972. “Disc smear” (swipe) samples to evaluate transferable alpha contamination were collected and analyzed following standard procedures. Routine room survey (e.g., floor and work surface) results were included in this review; contamination survey results for production equipment, product, waste drums, etc., were not evaluated. A total of 449 routine room survey results were complied for the 300-M area, 130 of which were specifically identified with thorium-related operations in 313-M during the period 1966 through 1972. The survey logs for the sample results used in this analysis are in the Site Research Database (DuPont 1966a-e, 1967b-c, 1968a-b, 1969b-f, 1970c-d, and 1972).

4.2 CONTAMINATION SURVEY DATA ANALYSIS

Alpha contamination survey results for routine room surveys in the thorium area of 313-M are depicted in Table 2 and Figure 17. In general, the highest contamination results are observed during the 1967-1968 production campaigns. Elevated results in the post-production period are generally due to decontamination and decommissioning operations when previously inaccessible contamination was exposed. Data are provided as background information to assist in better characterizing the thorium operations.

Table 2. Transferable alpha contamination survey results by year for 313-M thorium area.

Year	Location	Transferable contamination (alpha) in dpm			
		<100	100–1000	>1000	Total
1966	313-M Thorium Room	3	2	1	6
1967	313-M Slugs Final Inspection		3	1	4
	313-M Thorium Room	13	11	2	26
1968	313-M Thorium Room	1	2	4	7
1969	313-M Autoclave	14			14
	313-M Coke & Smoking	10			10
	313-M Plating Line	6	8		14
	313-M Recovery	4	9		13
	313-M Regulated Areas	2			2
	313-M Slugs Final Inspection	14			14
1970	313-M Autoclave	2		1	3
	313-M Coke & Smoking	2			2
	313-M Plating Line		2		2
	313-M Recovery		2		2
	313-M Slugs Final Inspection	2	1		3
1972	313-M Thorium Room	5	3		8
Total		78	43	9	130

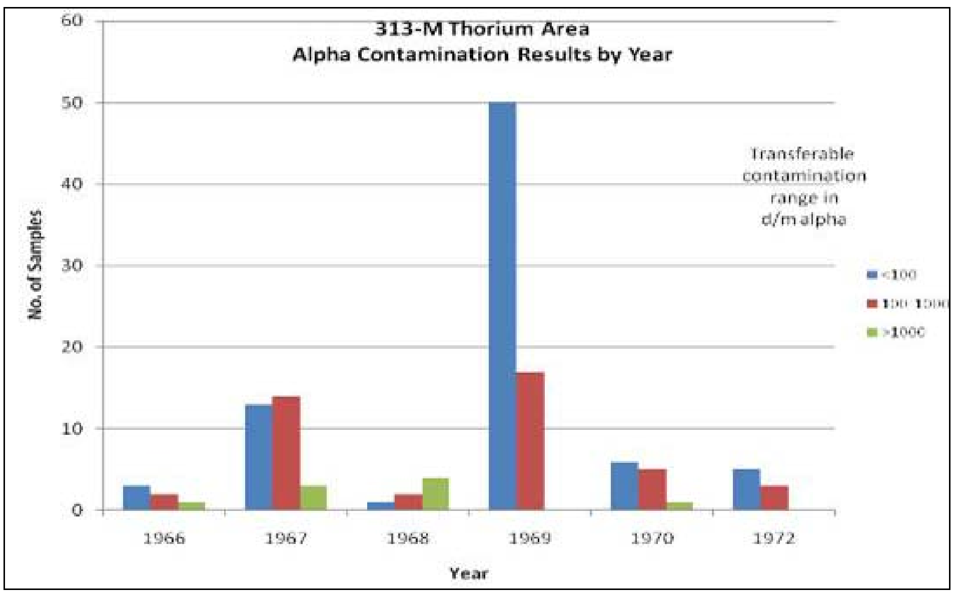

Figure 17. Transferable alpha contamination survey results by year for 313-M thorium area.

5.0 THORON AIR CONCENTRATIONS

Various radiological air concentrations were measured at SRS during the thorium operations period. Although air samples were collected and measured for thorium during these operations, there is no evidence that thoron and its daughters were measured.

SRS measured thorium air samples by performing several alpha counts (an initial count shortly after the completion of sampling and time decayed counts, usually at 24 hours and 72 hours). The results of these measurements are documented on three different formats of data sheets, i.e., single Air Sample Log Sheets or Thoria Compaction Facility data sheets attached to the Air Sample Log Sheets or Weekly Routine Air Sample Results data sheets (see Attachment A-1 for examples of the data sheets).

Air Sample Log Sheets documented single and multiple sample collections with the types of instrument used to collect the sample, the location of the sample, the work processes underway, in some cases (single samples) the date and time of the beginning of the initial count, the flow rate, volume sampled, and initial alpha count (usually between one minute and a few hours) after sample collection and a second alpha count about 24 hours after the initial count. Data sheets attached to the Log Sheets take two formats; the first is the Thoria Compaction Facility data sheet which contains sampling date, start and stop date and time, the date of the initial count, the initial count without a time, 24-hour count and a 72-hour count. The second format is the Weekly Routine Air Sample Result sheet which contains building number, sampling location, sampling date, sampler type, flow rate, net alpha count rate, and a time basis for the calculations (usually 16 hours). From these data, air concentrations could be calculated for thorium.

The analysis of SRS air samples for thorium was performed by collecting a known volume of sample and performing multiple alpha counts (initial-a short time after sampling, 24 hours and 72 hours). These delayed counts were made in order to allow the relatively short-lived daughters of radon and thoron to decay, thereby leaving the long-lived alpha activities for the evaluation of airborne thorium concentrations.

5.1 DATA SOURCES

The air sample data sheets used for the thoron analysis are in the same collection of documents used for the thorium analysis in Section 3.0 of this report (Site Research Database (DuPont 1964, 1965b, 1967). Eighty-seven (87) air sample results from the original 270 thorium air sample results were used for this thoron analysis. The samples in the thorium operations study that represented background or samples collected with impactor sampler were not used in this thoron analysis since they were not used to evaluate the general work environment nor were the air sample results from data sheets other than the Thoria Compaction Facility data (see attached examples of various data sheets). This data were chosen as a result of the multiple counts available on these data sheets and was conducive to the model described below to determine thoron concentrations.

5.2 METHODOLOGY

This section presents a methodology for estimating the bounding thoron activities which could have been present in the workplace from airborne thoron and its daughters. Thoron air concentrations were determined using the previously described air sample counting data results as follows:

Thoron Air Samples
Normally when an air sample is collected for the analysis of a long lived isotope, the activity on the filter increases linearly during the sample time and does not decay after. The activity on the filter can then be measured at any time after the sample ended and it is a direct measurement of the filter activity when the sample collection period ended. That activity on the filter is divided by the volume of air sampled to get the air concentration. Inherent with this is the assumption that the isotope does not decay appreciably during the sampling or analysis.

When the isotope being sampled has a half-life along the magnitude as the sample collection period and delay times, the above assumption is not valid. Figure 18 illustrates both situations.

To complicate the issue further, one must assume there is both long-lived activity and short-lived activity on the filter paper when it is being counted. The short lived activity can be determined with two counts but it is not the same as a typical long-lived calculation.

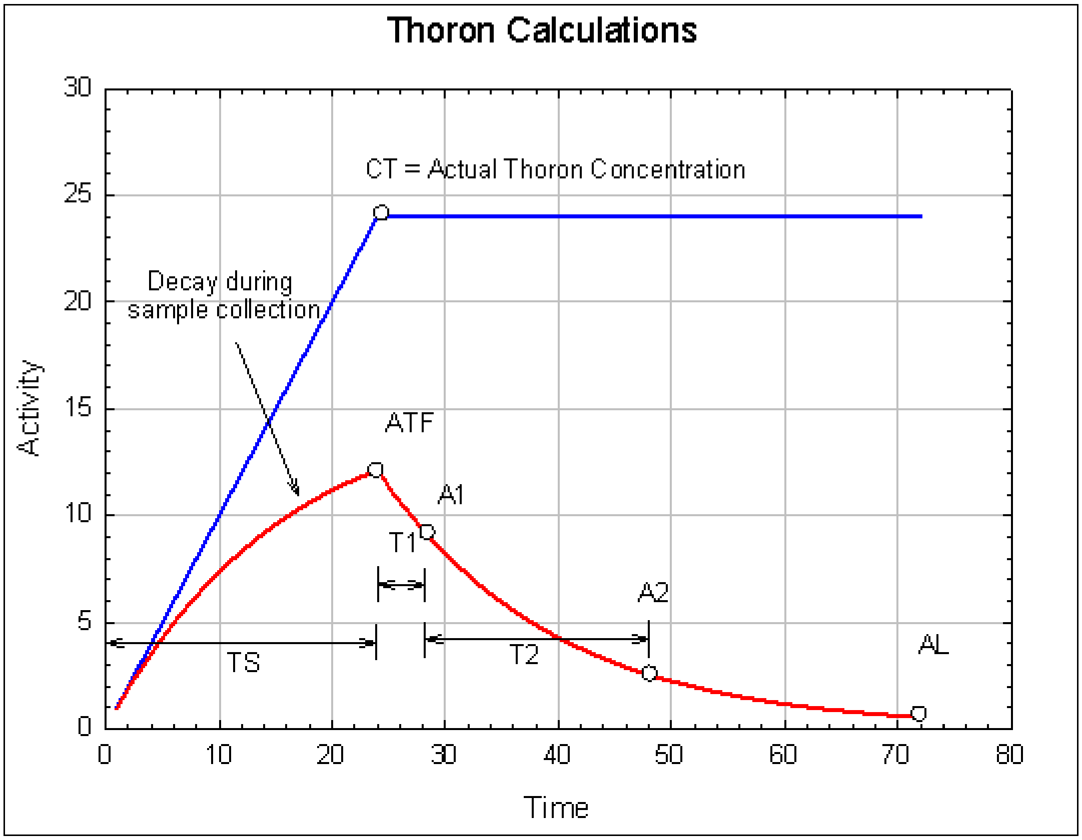

Figure 18. Kinetics of thoron decay illustrating time intervals used in Equations 1 through 8.

To determine the thoron concentration from air sample data from SRS the following model is presented.

Let A_1 and A_2 be the filter activity during the first and second count.
Let A_L be the long-lived activity on the filter paper
Let AT_1 and AT_2 be the thoron activity on the filter during the first and second count
Let *ATF* be the thoron activity on the filter paper at the end of the sampling
Let *TS* be the sample time (time the sample ran)
Let T_1 be the time between the end of sampling and the first count
Let T_2 be the time between the first and second counts.
λ is the Pd-212 decay constant (ln(2)/10.64 hours)

$$A_1 = A_L + AT_1 \qquad \text{Eq. 1}$$

$$A_2 = A_L + AT_2 \qquad \text{Eq. 2}$$

$$AT_2 = AT_1 \times (e^{-\lambda T_2}) \qquad \text{Eq. 3}$$

Solve the three equations for AT_1

$$AT_1 = \frac{A_1 - A_2}{1 - e^{-\lambda T_2}} \qquad \text{Eq. 4}$$

Correct for decay between the end of the sampling and the first count.

$$ATF = AT_1 \times (e^{\lambda T_1}) \qquad \text{Eq. 5}$$

Correct for the buildup of thoron on the filter during the sampling interval.

$$ATF = CT \times \left(R/_{\lambda}\right) \times (1 - e^{-\lambda T_S}) \quad \text{Eq. 6}$$

Where:

CT = the thoron concentration in the air
R = the sampling rate (volume per time)

Equation 6 can be rearranged to

$$CT = ATF \times \left(\lambda/_{R}\right) \times \frac{1}{(1-e^{-\lambda T_S})} \quad \text{Eq. 7}$$

Combine Equation 7 with the identities developed in previous equations.

$$CT = \frac{(A_1 - A_2)}{1-e^{\lambda T_2}} \times e^{\lambda T_1} \left(\lambda/_{R}\right) \times \frac{1}{(1-e^{-\lambda T_S})} \quad \text{Eq. 8}$$

The concentration calculated using equation 8 is in units of counts/minute/volume (cpm/cm^3). Parameters specific to the sampling and counting system may be used to convert the count rate concentration to activity/volume (µCi/cm^3).

- After the activities are determined for all of the terms in the above equations they are used in the spreadsheet to convert these “thoron” CPM values, using the air sample parameters in the original thorium analysis spreadsheet to activity concentrations (µCi/cc) and thoron intake rates in pCi/day.

- The intake rates in pCi/d were calculated initially based on a worker breathing rate of 1.2 m^3/hr (ICRP 1994) for 8 hours. Since the breathing intake rate is based on an 8-hour period and the samples were collected over a 24-hour period, the 8-hour concentration is increased by a factor of 3 to assume that this increased activity concentration was inhaled over the 8-hour work shift.

5.3 RESULTS AND CONCLUSIONS

Figure 19 shows a probability plot of the estimated thoron concentration in units of uCi/cc. A lognormal distribution representing the fitted data is shown on the same plot. The geometric mean of the fitted lognormal distribution is 4.34E-12 uC/cc with a GSD of 5.27. The observed 95th percentile of this distribution is approximately 6.67E-11 uCi/cc. The maximum observed concentration from this distribution is 1.51E-10 uCi/cc. Calculations of thoron inhalation rate at the 95th percentile is 1,900 pCi/day or 0.11 WLM per year. The result of this analysis suggests that the thoron air concentrations are small and may be negligible.

6.0 <u>INTERVIEW HIGHLIGHTS</u>

An interview with the former health physics technician (Chew 2009) provided insight into the thoria operations. The interviewee was asked to provide specific process, air sampling, and respiratory protection details. The following bullets include excerpts of this interview*:*

- *The routine samples were taken using this [Bell and Gossett] machine. [Routine samples] were representative of the breathing zone of the worker. They were located where the operators were standing and were not mounted on a wall.*

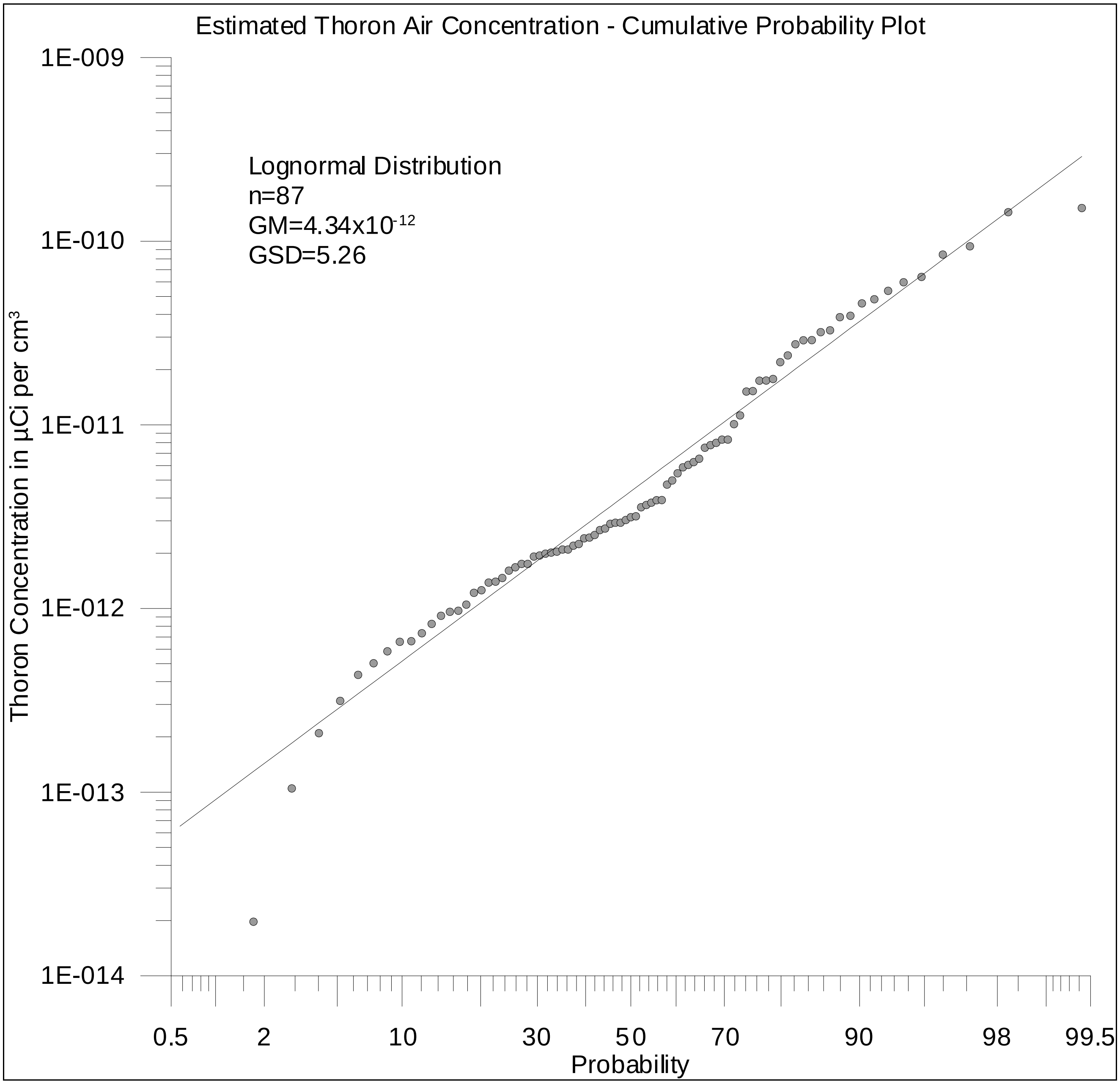

Figure 19. Probability plot for thoron air samples results.

- *There were no opportunities for workers to be highly exposed without monitoring.*
- *The impactor was used when sampling near the chopper. The chopper was rarely used and when it was assault masks were worn.*
- *Respiratory protection was used prior to establishing the contamination level of a slug as it left the airlock, and during chopper operations.*
- *Respiratory protection was used during recovery from an incident in when a slug melted in a furnace in Building 320.*
- *Contamination was well controlled.*

- *The processing line was a closed system and it was effective as designed.*

- *Thoria operations never involved more than ten people at a time. There was one area supervisor, four or five foremen, and five or six operators assigned to thoria operations.*

The relatively low number of operators is somewhat confirmed through the monthly technical reports for the 300-M area. Table 3 presents the number of workers monitored for thorium in the whole body counter in 1965 (DuPont 1965d-h).

Table 3. Number of thorium chest and whole body counts reported in 1965.

Month in 1965	No. thorium chest counts reported	Total no. of WBCs reported (including Th chest counts)	Summary of results
Jan	10	32	The monthly reports state there were no positive results for gamma emitting radionuclides other than normal amounts of Cs-137 and K-40. The one exception is a positive WBC result (10.3 nCi of Zn-65) for a new employee counted in Mar 1965 due to assimilation at another site.
Feb	11	39	
Mar	6	29	
Apr	2	28	
Totals	29	128	The Aug 1965 progress report, 3/700 M area section states chests counts using the whole body counting equipment showed no significant assimilation of thoria (DuPont 1965h).

7.0 DAILY THORIUM INTAKE RATE

Dose reconstruction requires that air concentration be converted to daily intake rate in units of activity or mass for each thorium isotope. Assuming a breathing rate of 1.2 m^3 per hour (ICRP 1994) and an 8-hour work day, the intake rate can be calculated. A multiplicative correction factor of 3 is applied to the air sample concentration parameters to account for the likelihood that essentially all of the exposure potential represented by 24-hour routine air samples was generated during the 8-hour shift when workers were present. To ensure an assumption that is favorable to the claimant, the measured airborne thorium activity is assumed to be fully equilibrated between thorium-232 and thorium-228. This maximizes the activity per unit mass and as a consequence the isotopes exist in a 1-to-1 ratio. Due to the extremely long half life (and therefore low specific activity) of thorium-232, the mass is essentially all associated with thorium-232. Conversely the mass of thorium-228 is immeasurably small and is set to zero.

The chronic annual thorium intake rates are of interest for simplified dose calculations and for comparison to *in vivo* counting data. The only additional assumption needed to convert daily intake rate to annual intake rate is the exposure duration, which is set at 260 thorium work days per year. Table 4 presents daily and annual intake rates for thorium isotopes based on an 8-hour daily exposure at the 50th and 95th percentile concentrations modified to include the factor of 3 account for the likelihood that the airborne activity may have been generated during one 8-hour work shift per day instead of the 24-hour shift represented by the routine air samples.

Table 4. Intake rates of Th-232 and Th-228 expressed in units of activity for two different levels of chronic airborne activity.

Intake rates	50th percentile	95th percentile
Daily intake rate Th-232, Bq/d	0.087	0.76
Daily intake rate Th-228, Bq/d	0.087	0.64
Annual intake rate Th-232, Bq/y	23	200
Annual intake rate Th-228, Bq/y	23	200

The theoretical Minimum Detectable Activity (MDA) for thorium was calculated from whole body count data collected in the years just before 1965. This calculation assumed the highest observed background rate in the region of interest where photons from Pb-212, a thorium progeny, would be found. The counting efficiency in this region was extrapolated from calibration data. Other assumptions included a 20-minute counting time and a 42% equilibrium between thorium-228 and thorium-232. The resulting upper-bound MDA for thorium-232 is approximately 1700 Bq (45 nCi). This is almost a factor of 9 greater than the annualized intake rate shown in Table 4 and shows that the bounding intake rate would not be detectable using whole body counting equipment in use at that time.

8.0 SUMMARY

The air samples taken during thoria production operations in the period when *in vivo* counting records have not been located and an interview with the former health physics technician who monitored the operations indicate that the thoria production operations were well controlled and the intake potential was low. The data and interviews show that during the periods when thoria processing campaigns were being conducted, a bounding thorium intake rate can be established based on the log-normally fitted air sample data and assumptions regarding breathing rate. The interview with the former health physics technician suggested that exposure potential was equally low during periods of maintenance and decommissioning. This was confirmed by review of routine contamination survey data for that period. No data specific to the radon-220 (thoron plus progeny) exposure potential was located, but a conservative interpretation of air sample data allowed a bounding assessment to be conducted. The potential exposure from radon-220 and progeny is bounded at 6.3E-4 WLM per day.

9.0 ATTRIBUTIONS AND ANNOTATIONS

[1] Billy Smith. A technical error during the interview with the former health physics technician is noted. He stated that the impactor ran at 10 cfm. Based on the sample times and total volume sampled the actual flow rate had to be approximately 35 cfm. This error is judged to be of no consequence.

[2] Robert Morris. Two impactor samples were taken on the same day, at the same location, sampling the same volume of air and reporting the same count rate data. They were reported on two different data sheets. We assume this is one sample reported twice.

[3] Robert Morris. These assumptions are based on extensive experience with alpha counter and air sampling equipment. Several of them can be substantiated in a memo prepared by the Air Force Institute for Operational Health Physics (Nichelson 2005)

[4] Billy Smith. Page 46 in DuPont (1965b) shows that the impactor used was a Staplex brand. From professional experience we know that the Staplex Annual Kinetic Impactor (AKI) has been in use for decades without significant modification. Performance data on the AKI is available on line (Staplex 2009).

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ATTACHMENT A
EXAMPLES OF VARIOUS AIR SAMPLE DATA SHEETS

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OSR 4-15 (Rev. 9-58)

Air Sample Log Sheet

LOG SHEET NO. A, M 06142

REF. SURVEY NO.

TYPE INSTRUMENT USED: ☐ STAPLEX ☐ IMPACTOR ☐ DUCT ☒ MOTO AIR PUMP ☐

INSTRUMENT NO.

LOCATION OF SAMPLE: Thoria Canning Room

PROCESS CONDITIONS AND PERTINENT DATA: Routine

BUILDING NUMBER: 313 - M

TAKEN BY: CJJ.

AIR FLOW (CU. FT./MIN.): 2.7

TOTAL VOLUME AIR SAMPLED

SAMPLE	TIME	DATE
ON	2⁰⁵pm	3/21
OFF	8³⁰/a	3/22

	DATE	TIME	LENGTH COUNT	TOTAL COUNT	CON. FAC. C_1	C/M MV	BKGD C/M, MV	CORR. C/M, ΔMV	COUNTED BY
INITIAL BETA-GAMMA COUNT									
INITIAL ALPHA COUNT	3-22	8⁵⁵/a	1 m		4.5			202	CJJ
24 hr dy	3 23	2³⁰/p	1 m					0	RDM
4 HOUR C_2 ALPHA COUNT									
24 HOUR C_2 ALPHA COUNT	3-23	9³⁰/a	1 m		1.5			15	RDM
TRITIUM			WET BULB	DRY BULB					

FISSION PRODUCT CALCULATION

A. FILTER PAPER, TYPE ______

C/M ( ) | COUNTER FACTOR ( ) |

4.29 × 10⁸ | VOL. IN CU. FT. ( ) | COLL. EFF. ( )

= 2.3 × 10⁻¹⁰ µc F.P./CC AIR

B. IMPACTOR

C/M ( ) = no Th Bkg | COUNTER FACTOR ( )

4.17 × 10⁸ | VOL. CU. FT. ( )

= µc F.P./CC AIR

PLUTONIUM AND URANIUM CALCULATION

A. FILTER PAPER, TYPE ______

C_0 = C_1 ( ) − C_2 ( ) $e^{-\lambda}$ (ΔT) / 1 − $e^{-\lambda}$ (ΔT)

C_0 ( ) | COUNTER FACTOR ( ) |

4.29 × 10¹⁰ | VOL. IN CU. FT. ( ) | COLL. EFF. ( )

= µc U OR PU/CC AIR

B. IMPACTOR

C/M ( ) − no Th Bkg | COUNTER FACTOR ( )

2.50 × 10¹⁰ | VOL. CU. FT. ( )

= 2.2 × 10 µc U OR PU/CC AIR

TRITIUM CALCULATION

DIRECT AIR

C_1 ( ) (4.8 × 10⁻⁵) (ΔMV) ( )

= µc/cc T AIR

SILICA GEL

C_1 ( ) (10⁻⁴) ΔMV ( ) ABS. HUM. ( )

= µc/cc T AIR

HOLD FOR DECAY	DAILY
WEEKLY	MONTHLY

DISCARDED BY:

REMARKS

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EXAMPLES OF VARIOUS AIR SAMPLE DATA SHEETS
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4.Y.

THORIA COMPACTION FACILITY

C.7. 4.8

C.F.M. 3.7

DATE ON	TIME ON	DATE OFF	TIME OFF	DATE OF INITIAL COUNT	INITIAL COUNT	24 HR. COUNT	72 HR. COUNT	CALCULATION & REMARKS
11-20	8 00 am	11-21	8 00 am	11-21-67	598	46	24	JHS
11-21	8 00 am	11-22	11 00 am	11-22-67	777	90	49	JHS
11-22	11 00 am	11-23	11 00 am	11-24-67	379	59	36	JHS
11-23	11 00 am	11-24	11 00 am	11-24-67	606	71	40	JHS
11-27	8 00 am	11-28	8 00 am	11-29-67	–	93	47	JHS
11-28	8 00	11-29	8 00 am	11-29-67	733	115	61	JHS
11-29	8 00 am	11-30	8 00 am	11-30-67	[illegible]79	108	63	JHS
12-4	8 00 am	12-5	11 00 am	12-5-67	600	43	10	JHS
12-[illegible]	11 00	12-6	10 00 am	12-6-67	980	66	26	JHS
12-6	10 00 am	12-7	11 00 am	12-[illegible]-67	394	60	17	JHS
12-7	11 00 am	12-8	11 00 am	12-8-67	178	–	8	JHS
12-11	8 00 am	12-12	8 00 am	12-12-67	332	–	5	JHS
12-12	9 00 am	12-13	9 00 am	12-13-67	441	48	9	JHS
12-13	10 00 am	12-14	10 00 am	12-14-67	420	18	6	JHS
12-14	10 00 am	12-15	11 00 am	12-15-67	340	17	7	JHS

ATTACHMENT A
EXAMPLES OF VARIOUS AIR SAMPLE DATA SHEETS
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300-M HEALTH PHYSICS

WEEKLY ROUTINE AIR SAMPLE RESULTS

SAMPLES ALLOWED TO DECAY 24 HRS. PRIOR TO INITIAL COUNT   Hm 06180

Week ending: 12-15-67

AIR SAMPLES LOCATION: 1. Balance
2.
3.
4.
5.

Time On	Date On	Time Off	Date Off	Loc. No.	α-Net c/m	Check If <1/10 MPC	β-γ-Net c/m	Check If <1/10 MPC	Calculated On-Hr. Basis	Calculation and Remarks
8 Am	11-29	8 Am	11-30	1	58	✓			24h	OK
8 Am	11-30	8 Am	12-1	1	27	✓			24h	OK
8 Am	12-1	8 Am	12-4	1	89	✓			72h	OK
8 Am	12-4	8 Am	12-5	1	48	✓			24h	OK
8 Am	12-5	8 Am	12-6	1	142	✓			24h	OK
8 Am	12-6	8 Am	12-7	1	68	✓			24h	OK
8 Am	12-7	8 Am	12-8	1	47	✓			24h	OK
8 Am	12-8	8 Am	12-11	1	61	✓			72h	OK
8 Am	12-11	8 Am	12-12	1	46	✓			24h	OK
8 Am	12-12	8 Am	12-13	1	39	✓			24h	OK
8 Am	12-13	8 Am	12-14	1	36	✓			24h	OK