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Potential Neptunium Exposure to Plutonium Fuel Facility Construction Workers in Building 235-F at the Savannah River Site	ORAUT-RPRT-0080	Rev. 00
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02/07/2017	00	New report about neptunium exposure to the plutonium fuel facility construction workers in Building 235-F at the Savannah River Site. Incorporates formal internal and NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by James M. Mahathy.

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ACRONYMS AND ABBREVIATIONS

cm	centimeter
cpm	counts per minute
DOE	U.S. Department of Energy
dpm	disintegrations per minute
ft	foot
GM	geometric mean
GSD	geometric standard deviation
HEPA	high-efficiency particulate air
HP	health physics
hr	hour
H&V	heating and ventilation
in.	inch
kg	kilogram
mrad	millirad
mrem	millirem
NBL	Neptunium Billet Line
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
PuFF	$^{238}PuO_2$ Plutonium Fuel Form Facility
qtr	quarter
R	roentgen
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
TLD	thermoluminescent dosimeter
yr	year
μCi	microcurie

1.0 INTRODUCTION

Operations at the neptunium billet line in Building 235-F at the Savannah River Site (SRS) continued during the construction of the Plutonium Fuel Form Facility (PuFF) in the same building. Construction started in 1973 and was complete in January 1977. However, equipment acceptance tests and procedures preparation began earlier, and test runs were conducted through June 1977, with cold runs completed in July 1977.

The purpose of this discussion is to determine if workers constructing the PuFF facility received significant exposure from the work in the neptunium billet line. To this end, it is first necessary to review operations during the construction period and to determine the radiological conditions that existed at the time. The source of potential neptunium and plutonium exposure to construction workers would be expected to result from the operations in the neptunium billet line facility.

2.0 NEPTUNIUM BILLET WORK

Building 235-F was part of original construction at SRS in the early 1950s. It hosted various production missions through its operational life. Three of the facilities in Building 235-F are the Actinide Billet Line (which in this paper is called the Neptunium Billet Line or NBL), the Alloy Line, and the PuFF.

The Alloy line was constructed in the 1960s to cast and machine uranium alloyed metal cores. It operated until the early 1970s and was decontaminated and decommissioned in 1984 and 1985 (DOE 1996, p. 236).

Figure 2-1 presents the layout of the first floor of Building 235-F. Note that “A/L” indicates the locations of air locks between rooms. Rooms 107A, 107D, and 107B contained the NBL, designated as “AB Line” in this floor plan. The Operations side was in Room 107A and the Maintenance side of the line was in Room 107D. The end of the line, where the billets were removed, was in Room 107B (DuPont 1974l, 1980). The Alloy Line can be seen in Figure 4-1, below, in the area that later became Rooms 160 and 162 in Figure 2-1. It divided this area vertically with the operations side on the left and the maintenance side on the right as viewed in this figure (DuPont 1975c, p. 135; DuPont 1969, p. 12).

Rooms 1002, 1003, and 1004 in Figure 2-1 comprised the PuFF. Room 1005 between the neptunium facility and the PuFF was a regulated storage room for PuFF. It should be noted that Room 123 designates the men’s change room, and Room 136 designates the women’s change room.

Figure 2-2 shows the neptunium glovebox line. This is in a fairly small room with several gloveboxes. This photo shows the front side of the gloveboxes with several technicians and supervisors observing the work. The technicians are dressed in protective clothing and appear to be wearing pocket dosimeters on the upper left part of their clothing. On their waists, they are wearing bellybutton dosimeters because there was a significant gamma and neutron dose rate emanating from the neptunium inside the gloveboxes.

Figure 2-3 provides two photos of the maintenance side of the neptunium glovebox line. Billets were taken out of the line at the end, smeared for contamination, and packaged for transfer to storage or to building 321M for further operations. The wrapped billets are shown on the floor in the left photo.

Tables 2-1 and 2-2 list examples of the neutron and gamma dose rates on several neptunium and plutonium billets before transfer to another facility for storage or further processing. Although the neptunium billets were processed in August 1980, and the plutonium billets in April 1980, the radiation levels should be representative of those during the PuFF construction period. Note that the gamma

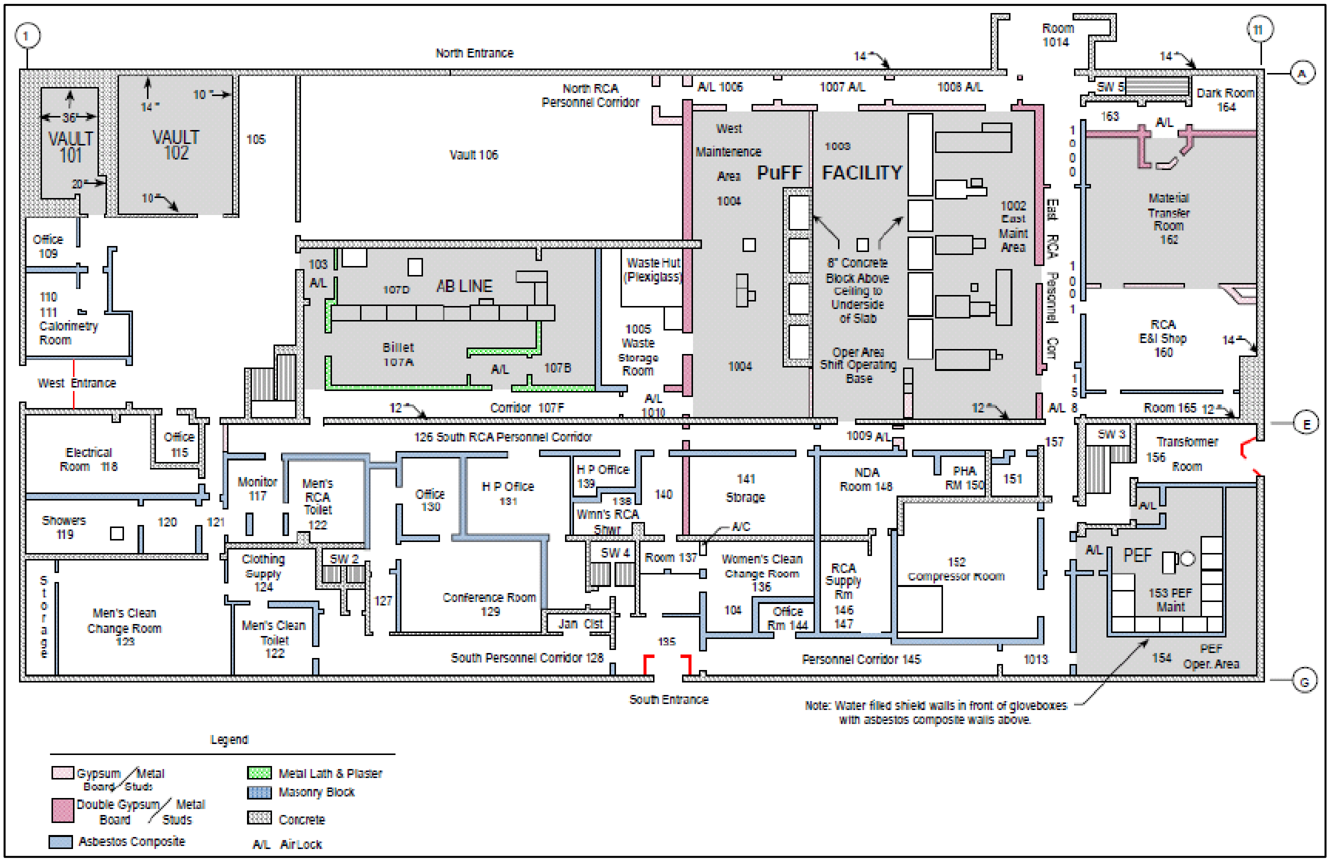

Figure 2-1. Building 235-F First Floor Plan (Taylor and Phifer 2012, p. 55).

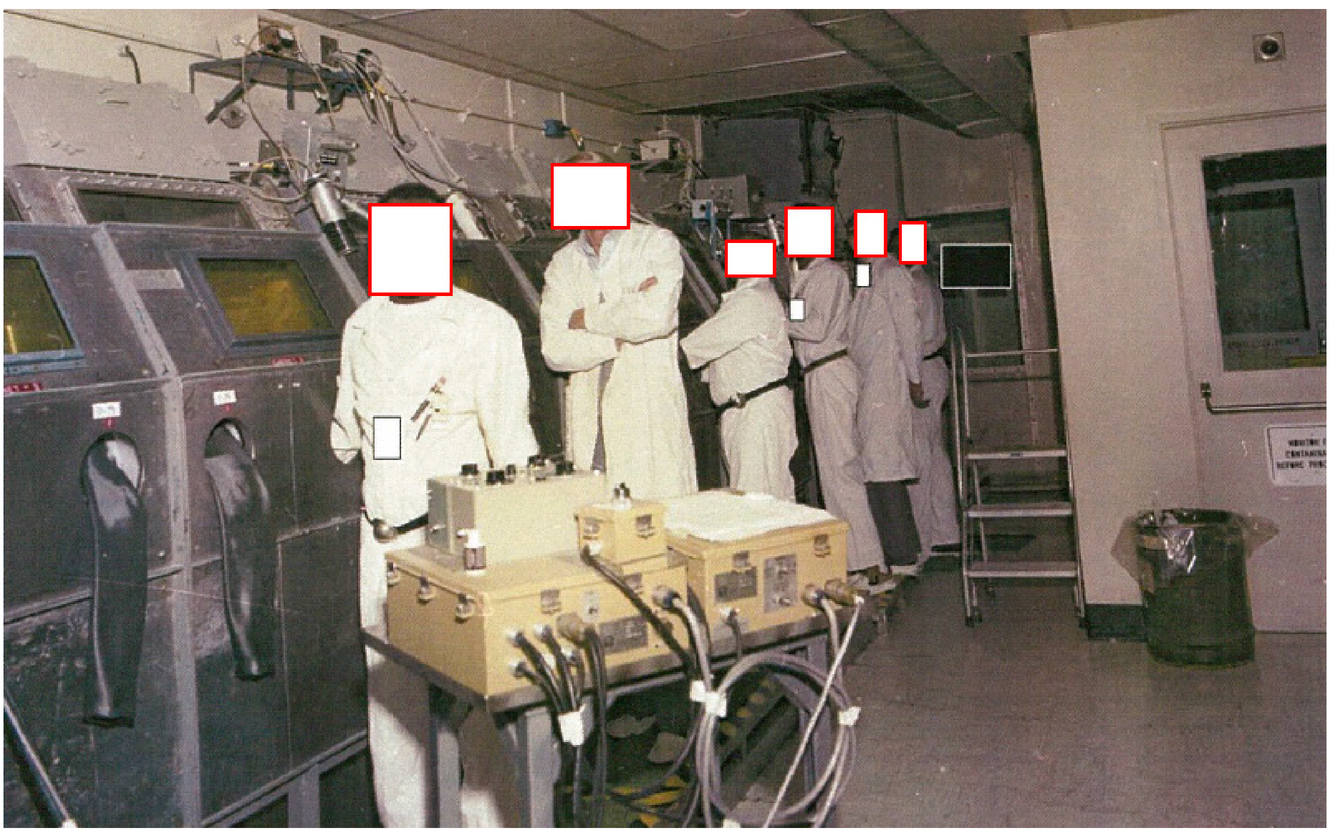

Figure 2-2. Neptunium glovebox line (DuPont ca. 1975) (DPSPF 30200-6).

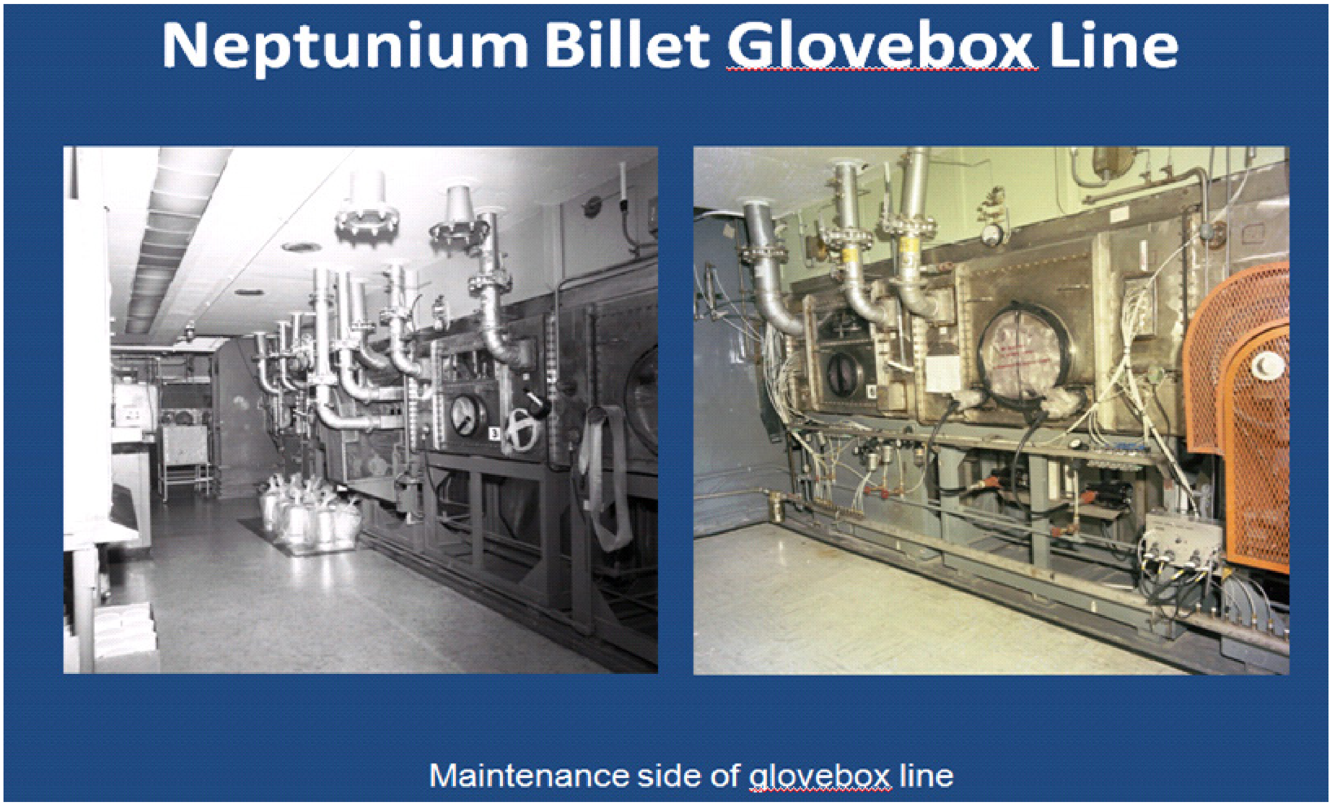

Figure 2-3. Neptunium billet glovebox line (NIOSH 2014).

Table 2-1. Radiation levels from selected Mark 53A neptunium billets.[a]

Billet #	**$\gamma + n^f$ at 8 cm (mrem/hr)**	**n^f at 8 cm**	**Fixed alpha contamination, top <3,000 dpm**	**Fixed alpha contamination, bottom/sides <3,000 dpm**	**Fixed alpha contamination, bottom/sides <1,000 dpm**
NJ 393	710	10	<3,000	<500	<1,000
NJ 394	702	2	<3,000	<500	<1,000
NJ 395	1,010	10	<3,000	<500	<1,000
NJ 396	900	5	<3,000	<500	<1,000
NJ 397	1,050	5	<4,000	<1,000	<1,000
NJ 398	1,005	5	<5,000	<1,000	<1,000
NJ 399	900	3	<3,000	<500	<1,000
NJ 400	800	5	<3,000	<500	<1,000

a. Source: NIOSH (2014).

Table 2-2. Radiation levels from selected Mark 42 plutonium billets.[a]

Billet #	**$\gamma + n^f$ at 8 cm (mrem/hr)**	**n^f at 8 cm**	**Fixed alpha contamination, top and sides, <1,000 dpm**	**Fixed alpha contamination, bottom, <3,000 dpm**
6063	120	20	Yes	Yes
3060	140	20	Yes	Yes
3063	160	30	Yes	Yes
3064	180	50	Yes	Yes
3065	165	15	Yes	Yes
2064	120	20	Yes	Yes
6075	115	15	Yes	Yes
3066	140	40	Yes	Yes

a. Source: NIOSH (2014).

dose rates for the neptunium billets are higher than for the plutonium billets, whereas the neutron dose rates are higher for the plutonium billets (NIOSH 2014). Fixed alpha contamination levels for the sides, top, and bottom of each billet were measured for compliance with the existing criteria. For the alpha levels in these examples, either a checkmark was used or a dpm value with a less than sign.

Over 1,500 air sample report forms with over 18,600 individual air sample results for Building 235-F that were collected between 1973 and 1977 were obtained from site records. Although these forms may not include all air sampling that was done in 235-F, they are taken to be representative of the air concentration levels.

Table 2-3 summarizes air concentrations from routine air samples in Building 235-F between 1973 and January 1977 for eight locations in the building. These locations are the production and maintenance sides of both the NBL and the Alloy Line, the expected sources of airborne contamination, corridors adjacent to the construction area, and the construction area.

Table 2-3. Air concentrations from routine air samples in Building 235-F, 1973 to January 1977.[a]

Location	Number of samples	Maximum (μCi/cm^3 × 1.0E-12)	50th percentile (μCi/cm^3 × 1.0E-12)	95th percentile (μCi/cm^3 × 1.0E-12)	GM (μCi/cm^3 × 1.0E-12)	GSD
Construction Area	101	0.22	-0.045	0.169	0.0322	2.22
Clean Corridor East	729	1.20	-0.054	0.190	0.0384	5.15
107F - Regulated Corridor	1507	1.71	-0.045	0.230	0.0234	5.18
107A - NBL Operations	1004	11.5	-0.029	0.185	0.0422	9.98
107D - NBL Maintenance	953	1.83	-0.021	0.200	0.0381	5.49
107B - NBL End	697	1.10	-0.043	0.200	0.0253	5.65
160 - Alloy Line Operations	1624	10.7	-0.044	0.266	0.0366	4.66
162 - Alloy Line Maintenance	1623	174	-0.039	0.300	0.0928	10.8

a. Sources: Brown (2012, 2016a, 2016b, 2016c, 2016d), DuPont (1973–1974).

Routine air samples were typically collected over 24 hours and in most cases were collected end to end; when one stopped the next began. The results on the air sample report forms had units of μCi/cm^3 × 10^{-12}. The air filters were counted for alpha activity and were reported as plutonium. SRS used Radioactivity Concentration Guides in the 1970s to determine when workers were required to use respirators. The guide for neptunium was 4 × 10^{-12} μCi/cm^3 and for plutonium was 2 × 10^{-12} μCi/cm^3 (DuPont 1974a). Results were reported as plutonium because both might have been present and the plutonium guide was more restrictive.

Routine air samples were taken daily at many locations in the building during the construction of the PuFF. Air samples were collected on the production side of the NBL and were indicated as 107A, and on the maintenance side of the NBL as 107D. Samples from the area at the end of the NBL line were marked as 107B. Samples were also collected from the area of the Alloy Line and indicated as Room 160 and Room 162.

Samples collected in the construction area on the first floor, Rooms 1002, 1003, and 1004 in Figure 2-1, and a few on the second floor for work in rooms containing air moving equipment, were marked as First Level Construction Area and Second Level Construction Area. These are combined in Table 2-3 as Construction Area. The Clean Corridor East was between the PuFF Facility and Rooms 160 and 162. The Regulated Corridor, designated 107F in Figure 2-1, was along the side of Rooms 107A and 107B, connecting the NBL to the PuFF Facility (DuPont 1986a).

Results less than one-tenth of the plutonium concentration guide, or 0.2 × 10^{-12} μCi/cm^3 , were not calculated further and were listed on the forms as "<0.2". More than 95% of the results reviewed were below this concentration. The air sample forms in most cases contained the original counts per minute (cpm) results where the air filters were counted for alpha activity at 6 hours and 24 hours after collection. For results that exceeded the "<0.2" threshold, recounts were generally performed days later. This was to distinguish any short-lived alpha activity on the filters resulting from radon progeny from long-lived alpha activity resulting from plutonium or neptunium. The air concentrations determined by these recounts were noted on the forms and, in some cases, the recount results and time of the analyses were also included. For those cases where the recount exceeded one tenth of the plutonium concentration guide, the forms usually had an additional notation describing the activity that created the airborne contamination, such as a broken glove.

Using these count data along with the sample volumes and a conversion factor to translate the measured counts per minute into disintegrations per minute, the site's equations were used to calculate air concentrations in $\mu Ci/cm^3$ for those samples where the site personnel had not; those cases where the forms listed the air concentration only as "<0.2". These equations used to calculate air concentrations from the count data were found in site documents from the time (DuPont 1986b, pp. 106–107) and included on the air sample forms. For those samples where the results were reported on the forms and were over 0.2×10^{-12} $\mu Ci/cm^3$, the calculated results matched well with the results reported by the site. For those cases where the air filter had no long-lived alpha activity, the calculation would provide results close to zero and in many cases, due to the random nature of the counting statistics, negative results.

Attachment A provides graphs of these calculated and reported concentrations plotted by date. These graphs are lognormal plots of air concentrations against the date of sample collection. Only the positive values from the site-provided results or the calculated results are plotted in these graphs.

Results from site air sample collection forms from 1973 through 1977 for Building 235-F were entered into datasets that were used for the calculations. A quality assurance review was performed on these data to determine that the data agreed with the original forms with an acceptably low error rate. Errors identified in the review and during the subsequent statistical analysis were corrected in the data sets against the original forms. Attachment B contains the quality assurance report for this review.

In Table 2-3, the Number of samples column lists the number of routine air sample results with a plutonium concentration either provided on the air sample forms or calculated by the analysis. The Maximum column indicates the highest value for that area. The 50th percentile and 95th percentile for each location were calculated from these data.

A statistical model was developed for each location that included a linear, normal component to include the negative values and the smaller positive values combined with a lognormal component to include the higher air concentrations. The geometric mean (GM) and geometric standard deviation (GSD) for each location were calculated from only the lognormal portion of each model. Probability plots showing the data and the fitted models for each location are presented in Attachment C and include other statistical parameters resulting from these models.

For all areas, the GMs and the 95th percentiles for the routine air sample results were far less than the radioactivity concentration guides for plutonium or neptunium of 2×10^{-12} $\mu Ci/cm^3$ and 4×10^{-12} $\mu Ci/cm^3$, respectively. The 50th percentiles for all locations were very close to zero. This would be the result if the greatest majority of the samples did not contain long-lived alpha activity.

Samples collected for specific activities and for short periods, typically 10 or 15 minutes, were labeled as Special. One special sample result labeled East Maintenance Room and collected on December 4, 1975, and had the job description "removing concrete from hole." The East Maintenance Room was Room 1002 in Figure 2-1, inside the PuFF. Two special air samples were found from the construction period and identified as 1st Level Construction. Both were on December 3, 1974. The job descriptions on those forms were "Cut Drain Line" and "Weld Drain Line." These and the East Maintenance Room results were less than 0.2 × 10^{-12} µCi/cm^3. No special air samples were identified as for the 2nd Level Construction Area.

An additional 69 routine samples for the 1st Level Construction Area were collected between February and July of 1977, after construction was completed and during startup activities for the PuFF. Those were also all less than 0.2 × 10^{-12} µCi/cm^3 and are included in the air sample data plotted in Figure 3-1 below.

3.0 CONSTRUCTION OF THE FACILITY

The following is a brief description of the construction progress described in more detail in Attachment D. The PuFF construction work was apparently started very soon after the initial mention of the design work in the November 1973 Works Technical Report, DPSP-73-1-11 (DuPont 1973a). The first report of construction progress was 12% complete as of April 1974.

As seen in Figure 3-1, construction in 1974 proceeded at a steady but slower pace than in 1975. During 1974, the effort consisted of preparatory work including removing existing structures, pouring foundations for columns and walls (Figure E-1), embedding conduit, stripping floor coverings, installing the concrete air-duct housing on the top of Building 235 (Figures E-2 and E-3), installing high-efficiency particulate air (HEPA) filter housings, pouring the concrete base under the cells and the walls of the trench under the cells, pouring concrete for the building-supply fans and air conditioning equipment, installing the electrical conduit from the substation, installing base plates for the front-shield walls and framing for the back-shield walls, and refinishing the stainless-steel cell

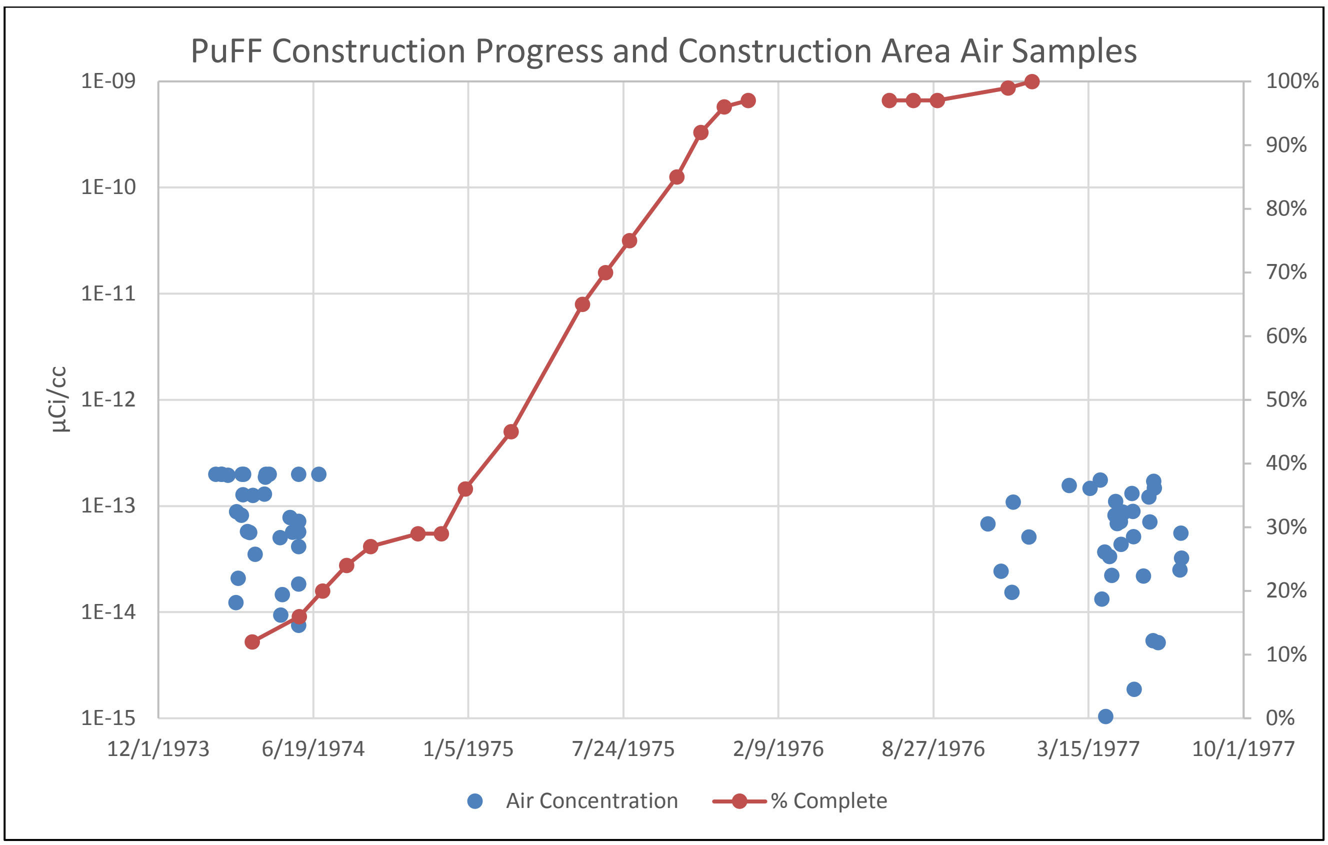

Figure 3-1. PuFF construction progress and air sample results in the construction area (based on Table D-1).

liners. This work accomplished during 1974 made up approximately 29% of the overall construction effort.

During 1975, the pace picked up considerably. The following systems were installed: air-supply ducts for the process areas, hot-press and vacuum pumps, main-line glove cabinets, radiation shield walls in front of the east and west cell lines, manipulators through tubes for all cells (aligned and tack-welded), inlet ventilation ducts containing reheat coils and connections to the primary heat exchanger outside Building 235-F, radiation shields, service panels, hydraulics, three process furnaces, HP monitoring system blowers, Metallography Laboratory cabinets, instrumentation cells, wiring for cell consoles, and the halon fire protection system. Figure E-6 shows a completed hot cell structure that reflects the final stages of construction. These systems and the testing of other systems resulted in 92% construction completion by the end of October 1975. During the next 2 months, dye checks and rework of welds on fittings in the copper lines in the argon, helium, and air-monitoring systems continued.

Beginning in January 1976, PuFF construction was 97% complete. However, the construction and turnover completion slipped by several months because of the design and installation of cell pressure-relief devices. Because of these problems, construction was suspended on March 12, 1976, and resumed on July 12, 1976. Construction was completed during January 1977. From January through July 1977, various test runs and cold runs with ThO_2 were conducted. Processing of $^{238}PuO_2$ began on July 23, 1977.

As indicated above, there were times when there were no billets being fabricated and transferred, and when construction of PuFF was suspended. Either of these circumstances would imply minimal potential for construction worker exposure.

Attachment E shows a series of photographs taken at various stages of PuFF development and construction. Although the dates on these photographs allow them to be related to the construction progress described in Attachment D, the subject matter visible in them provides little information. Nevertheless, the areas shown are all very clean with little to no debris. There are also no radiation barriers or signs indicating a radiation or contamination area. The workers in Figures E-1 and E-4 appear to be in regular clothing rather than protective clothing, implying the construction work area was considered a radiologically clean area. It cannot be determined from the photograph if the workers were wearing film badges.

4.0 RADIOLOGICAL CONTROLS

The purpose of this section is to discuss the controls for construction workers during the construction of the PUFF Facility. The SRS radiological controls were specified in various documents and procedures, such as DPSOP 40, Special Hazards Bulletins, standards, Special Work Permits, and Control Guides. These documents specified the basic requirements for the type and use of protective clothing, radiation and contamination control levels in specific areas, external dosimetry, bioassay, air sampling, posting of radiation and contamination areas, use of stepoff pads, limits of exposure, and anything else that could affect worker health and safety.

Daily, weekly, and monthly control surveys were performed at specified locations in Building 235-F. These were performed to monitor ambient exposure rates and to ensure contamination levels were within either regulated zone guides that required the survey to include a “P.T. smear survey” or clean zone guides that required the survey to include a “Disc smear survey.” The term “paper towel” smear survey is used in other documents and is a large area smear sample (Brown 2012).

The stepoff pads between the regulated areas and the clean areas were surveyed daily and compared to the Clean Zone Guides. The process room stepoff pads were also surveyed daily and compared to the Regulated Zone Guides. The Regulated Corridor and the decontamination room were surveyed weekly and compared to the Regulated Zone Guides. The second-level shops, offices, corridors, and storage areas were surveyed quarterly and compared to the Clean Zone Guides (Brown 2012).

A set of 16 weekly forms including the daily surveys for that week and 2 quarterly forms that included the monthly surveys for those quarters have been acquired for Building 235-F for the period between December 1973 and December 1974. The surveyors' initials were entered on the forms when the areas were within the guidelines. No survey data were included on these forms; exceeding the guidelines for any area would have required that the data be recorded in the Radiation Survey Log. For all of these forms, the surveyors' initials were entered and there was no indication of any area exceeding the appropriate guideline (Brown 2012).

One set of floor smear results for the 2nd Level Regulated Area taken on July 12, 1974, was within the set of forms from SRS. The form showed 18 locations with results between less than 3 dpm to 17 dpm (Brown 2012, p. 32).

Five Radiation Survey Logsheets for Building 235-F were reviewed that showed radiation surveys during the construction period. None of these was in the PuFF work area (Brown 2012, pp. 24–29).

- A survey in the Heating and Ventilation (H&V) Room on the second level dated June 10, 1974, was for the removal of "North bank of compact line room air exhaust filters and duct work." It stated that the air sample collected during the job calculated to <0.2 × 10^{-12} μCi Pu/cm^3 and that a paper towel survey of the floor area revealed <500 dpm alpha transferable contamination. A paper towel smear survey of the exterior of the ductwork showed removable contamination was also below this level.

- A Radiation Survey Logsheet dated June 11, 1974, for the H&V Room had smear and air sample results for construction work that involved the removal of Room 6 air exhaust duct. The air sample during this job was <0.2 × 10^{-12} μCi Pu/cm^3 and smears in the general area and outside of the ductwork were <500 dpm alpha. The form also showed surveys for a job in the Material Transfer Room, Room 162 in Figure 2-1, that was completed without the spread of contamination and with an air sample result of <0.2 × 10^{-12} μCi Pu/cm^3.

- Surveys in the Material Transfer Room and the H&V Room including smears and air samples taken on June 12, 1974, during the dismantling of ductwork and the placement of the materials into an airlock. The form indicates the job was completed without the spread of contamination and an air sample was <0.2 × 10^{-12} μCi Pu/cm^3. Smears taken read <1,000 cpm beta-gamma and <500 dpm alpha. That form also noted that the workers were in "fresh air supplied plastic suits."

- On June 17, 1974, during the removal of a hood exhaust and room exhaust duct in the H&V Room, all air samples were <0.2 × 10^{-12} μCi Pu/cm^3. At the completion of the job smears were taken and measured to be <1,000 cpm beta-gamma and <500 dpm alpha. This form also said workers were in "fresh air hoods" during the removal of the exhaust duct.

- On June 20, 1974, during installation of ductwork in the H&V Room, one worker tore a glove and his hand was contaminated to 3000 dpm alpha. The worker, named on the form, was successfully decontaminated and nasal smears were negative. Fresh air hoods were worn on the job. The air sample during the work was <0.2 × 10^{-12} μCi Pu/cm^3. A smear on a flange to the hood exhaust showed 8,000 dpm alpha. Smears of the floor showed <1,000 cpm beta-gamma and <500 dpm alpha.

- Tools were surveyed on June 28, 1974, in the Health Physics (HP) Office, Room 131 in Figure 2-1, for Construction Division workers to be able to move them from the area. No fixed or smearable contamination was detected on the tools. Materials in the Material Transfer Room that were ready to put in an airlock were surveyed. The job was completed without the spread of contamination. However, an air sample showed 1×10^{-12} µCi Pu/cm^3. The workers were already on mask requirements due to contamination in the North Airlock.

The primary procedure specifying the various criteria for SRS worker protection was DPSOP-40, *Radiation and Contamination Control*. The particular procedure either stated the necessary requirements or directed the workers to other documents such as Special Hazards Bulletins for specific instructions. The personnel monitoring requirements given in DPSTS-RH-0.07 were as follows (DuPont 1966):

> *For all personnel who enter areas in which they will receive a sustained radiation dose at a rate greater than 1 mrem/hr, or intermittent exposure which accumulate to greater than 25 mrem in a week, shall be required to wear film badges somewhere between the waist and neckline. The film shall be processed, read, and the data permanently recorded at least once a month.*

The external radiation exposure guidelines were provided in the Special Hazards Bulletin # 7, *Radiation Exposure Control* (DuPont 1975a). The guidelines for external whole-body exposure limit dose were 3 rem/qtr and 3 rem/yr.

Bioassay control guidelines for construction workers were provided in Revision 5 of DPSOL 193-302 (DuPont 1971, p. 4). This procedure provided the frequency of routine urine samples based on the radionuclides that construction workers could have encountered during their work. Workers who could have been exposed to plutonium provided one sample every 3 years and at employment termination. Neptunium is not specified, but there is a category for “other radionuclides,” the sampling frequency for which would be specified in the project plans by area HP.

Provision was also made for whole-body or chest counting for new employees who worked in radiation zones at another installation where radioactive materials were handled. They were required to have a whole-body and chest count, preferably at the same time as their entry physical. A whole-body or chest count was required whenever an employee’s bioassay sample indicated a confirmed intake or had been involved in a contamination incident and the count was considered necessary by HP. In addition, a whole-body or chest count was required at employment termination if the employee previously had a whole-body or chest count.

In the design of all facilities used for working with high levels of radiation, there were engineered controls in place to minimize worker exposure. In the case of the NBL, the gloveboxes served that purpose. The NBL gloveboxes are assumed to have contained shielding to reduce the radiation levels to which the workers fabricating the billets could be exposed. Buildings were designed to have air flowing from areas of lower contamination potential into areas with higher potential. This airflow was routinely verified. Figure 4-1 shows a form used to document airflow directions in key locations in Building 235-F. It shows that the air was flowing from clean areas and corridors into the NBL and Alloy Line areas.

Along with the engineered controls, the workers wore protective clothing for contamination control and badges for monitoring their exposures. They were also required to have whole-body counts and provide urine samples if conditions warranted. HP personnel also performed routine radiation and smear surveys, took air samples, or operated continuous air monitors in the area.

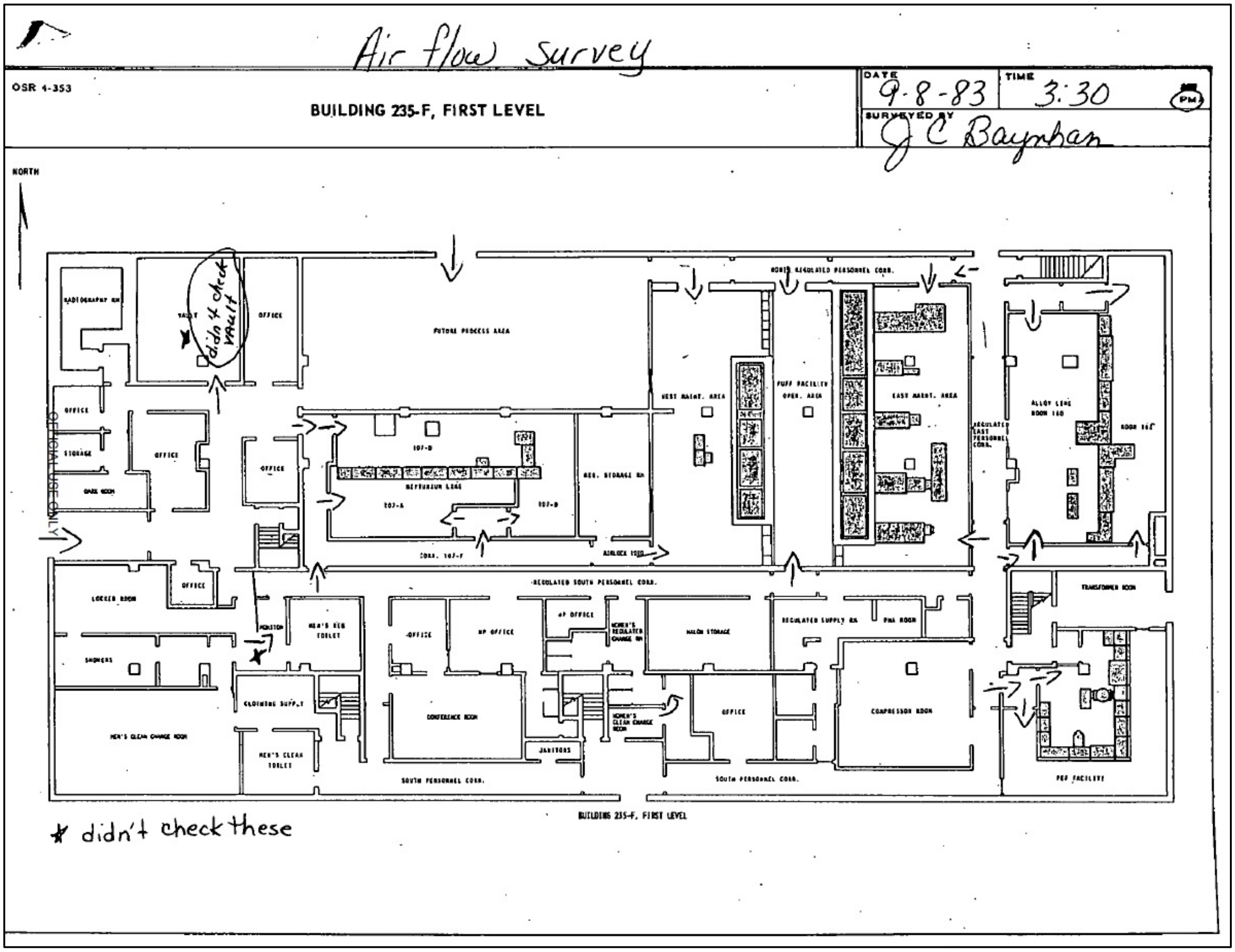

Figure 4-1. Typical airflow survey for Building 235-F (DuPont 1983).

The work in the NBL facility was designated as a Regulated Zone (radiation levels <300 mrad or 50 mrem/hr). At times, when billets were wrapped and placed in the work area waiting to be transferred (see Figure 2-3), the NBL was designated (at least temporarily) as a Radiation Danger Zone. However, the radiation levels outside the NBL would have been considerably lower. For workers at the PuFF construction site to be exposed to radiation from the NBL, they would have to have passed in close proximity to the facility. As noted above, the NBL is a small, self-contained unit, which (according to Figure 2-3) has several access portals.

Areas within the corridors were monitored routinely for ambient exposure rates. It is not certain they entered the PuFF construction area via the corridor outside of the NBL facility to report for work.

Attachment D lists the months during the construction period that Mark 53A compact billets were being fabricated as well as the quantity of neptunium used for the billet fabrication. The data show that billets were not fabricated every month. Note that there were no billets fabricated in May and August 1974 and November 1975 due to the unavailability of NpO_2. It is unclear from the available reference (ORAUT 2014) whether billets were fabricated during the months of January, February, March, May, June, and September 1975. In addition, billet fabrication is not indicated for February, April, May, October, November, and December 1976, and January, February, and March 1977.

Also listed in Attachment D is the percentage of progress in the design of the PuFF facility, along with the percentage of construction progress. Many of the jobs that were completed or in progress are also listed for each month. Note that the design of the facility was completed in February 1975 and construction was completed in January 1977. Beyond that, additional work that was in progress included acceptance testing, procedures development, and preparation for startup, which continued into 1977.

5.0 CONCLUSION

The Savannah River Site had an extensive radiation protection program from the initial operation of the first facility, and expanded as new facilities were placed into operation. The radiation protection program included but was not limited to:

- Engineered controls in the design of the facilities (e.g., gloveboxes, shielding, hot cells, and remote-handling tools),
- Defined areas that were access controlled (i.e., Regulated Areas and Radiation Danger Areas),
- Use of protective clothing,
- Film badges and/or thermoluminescent dosimeters (TLDs) for determining exposure to penetrating radiation,
- Routine urine bioassay samples and whole-body and chest counting for measuring internal exposure,
- Radiation safety training,
- Procedures and special work permits for conducting work, and
- Radiation surveys, smear surveys for detecting contamination, and air sampling.

The primary source of any external exposure to PuFF construction workers would have been due to close proximity to the NBL. As indicated, the NBL is a relatively small facility that was self-contained in one room. Although the NBL was classified as a high hazard facility (WSRC 1990), there is no indication it significantly affected the surrounding areas. PuFF construction workers would not have had access inside the NBL due to work controls in place, and they had very little access to the area immediately surrounding the facility except during the early stages of construction when they could have passed through the corridor next to the NBL to access the worker change rooms. Ambient radiation levels in the corridors, in the production areas, and in the clean areas were routinely monitored.

A close examination of the photographs shows that the PuFF work area was treated as radiologically clean. There are no radiation or contamination signs or barriers in the photos, and there is evidence of safety precautions being considered.

Because of the radiological controls in place at the NBL and around the construction of the PuFF and the procedures requiring film or TLD badges in areas where potential worker exposures could occur, it is reasonable to assume that construction workers would have been monitored for external radiation exposure either directly if warranted or indirectly through the area monitoring dosimeters. Therefore, the potential for undocumented external radiation exposures to the PuFF construction workers is very unlikely.

Internal exposure to PuFF construction workers from airborne contamination from the NBL line and the Alloy Line was unlikely due to routine, consistent air sampling and contamination monitoring.

- Airflow between regulated and clean areas was routinely checked and documented to show the air was moving from clean into regulated areas.

- Daily, weekly, and quarterly contamination monitoring was performed and documented. Levels were appropriately compared to clean zone and regulated zone guides. Stepoff pads between clean and regulated areas were monitored daily and compared to clean zone guides.

- Routine air sampling was performed at many locations within the building and counted for alpha activity. Samples were collected generally daily with continuous sampling; the next sample beginning immediately after the previous one.

- In the Radiation Survey Logsheets used to document health physics coverage for special, short-term activities, the ongoing activity was documented along with the air concentration and the level of protective clothing being worn by the workers.

- For air filter samples results that have been located, analyses of the routine air concentrations for locations in the PuFF construction area, the adjacent corridors, and within the rooms that contained the NBL line and the Alloy Line all showed air concentrations at the 95th percentile to be below both the plutonium concentration guide, 2×10^{-12} μCi/cm^3, and the neptunium concentration guide, 4×10^{-12} μCi/cm^3.

- For all locations, the 50th percentiles were close to zero, which would be expected if the greatest majority of air samples contained no long-lived alpha activity.

- The highest air concentration of any sample in the PuFF construction area or adjacent corridors was below the plutonium and neptunium concentration guides with the greatest majority of results well below these limits.

From the air sample data and site documents obtained and reviewed, there appears very little likelihood that the construction workers building the PuFF facility in Building 235-F between 1973 and 1977 would have received inadvertent, unmonitored internal or external exposures.

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ATTACHMENT A
SELECTED BUILDING 235-F AIR CONCENTRATIONS

LIST OF FIGURES

ATTACHMENT A
SELECTED BUILDING 235-F AIR CONCENTRATIONS (continued)

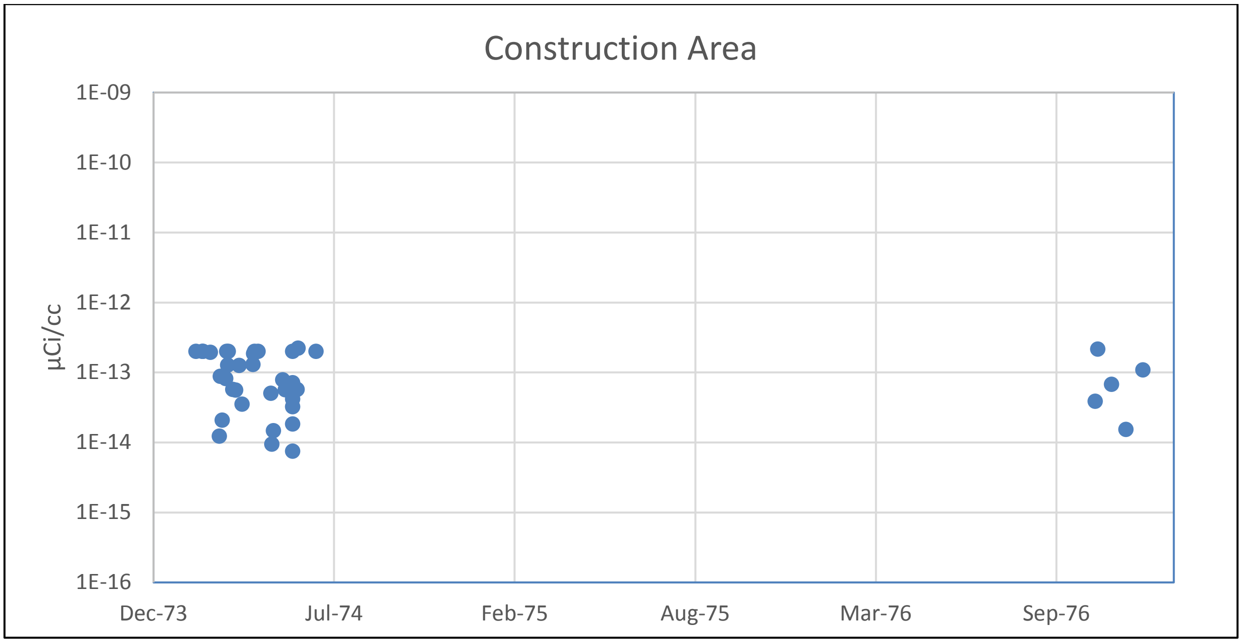

Figure A-1. Construction area air concentrations, February 12, 1974, to December 28, 1976. No results exceeded the administrative limit of 2 × 10^{-12} µCi/cm^3.

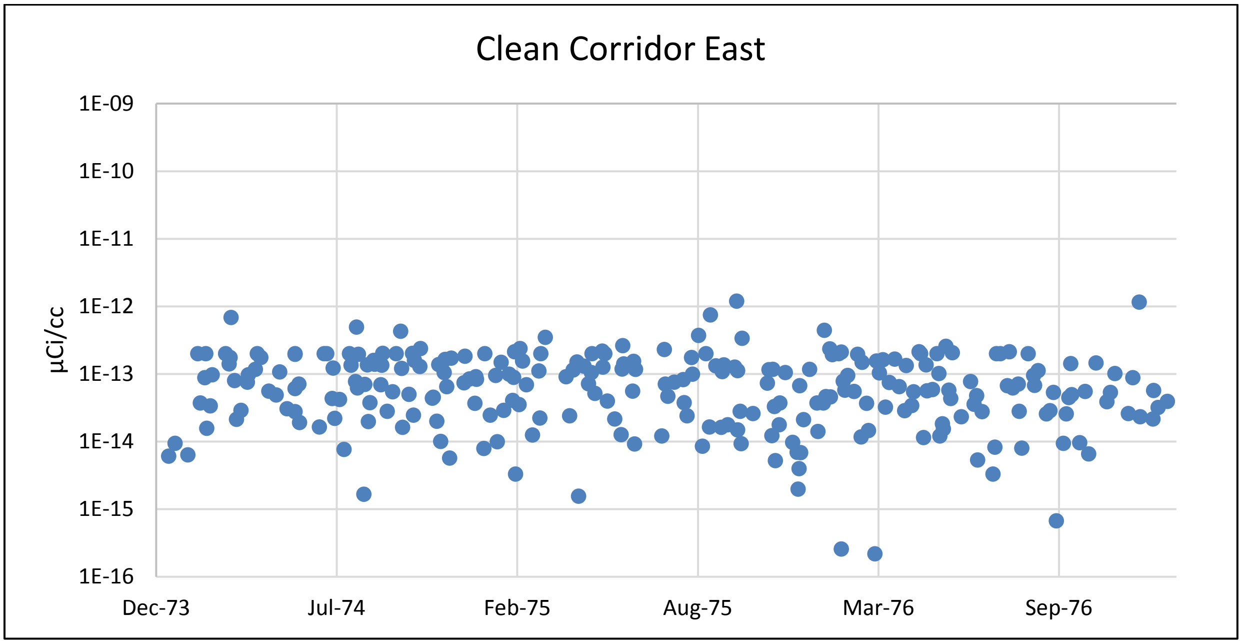

Figure A-2. Clean Corridor East air concentrations, January 4, 1974, to January 31, 1977. No results exceeded the administrative limit of 2 × 10^{-12} µCi/cm^3.

ATTACHMENT A
SELECTED BUILDING 235-F AIR CONCENTRATIONS (continued)

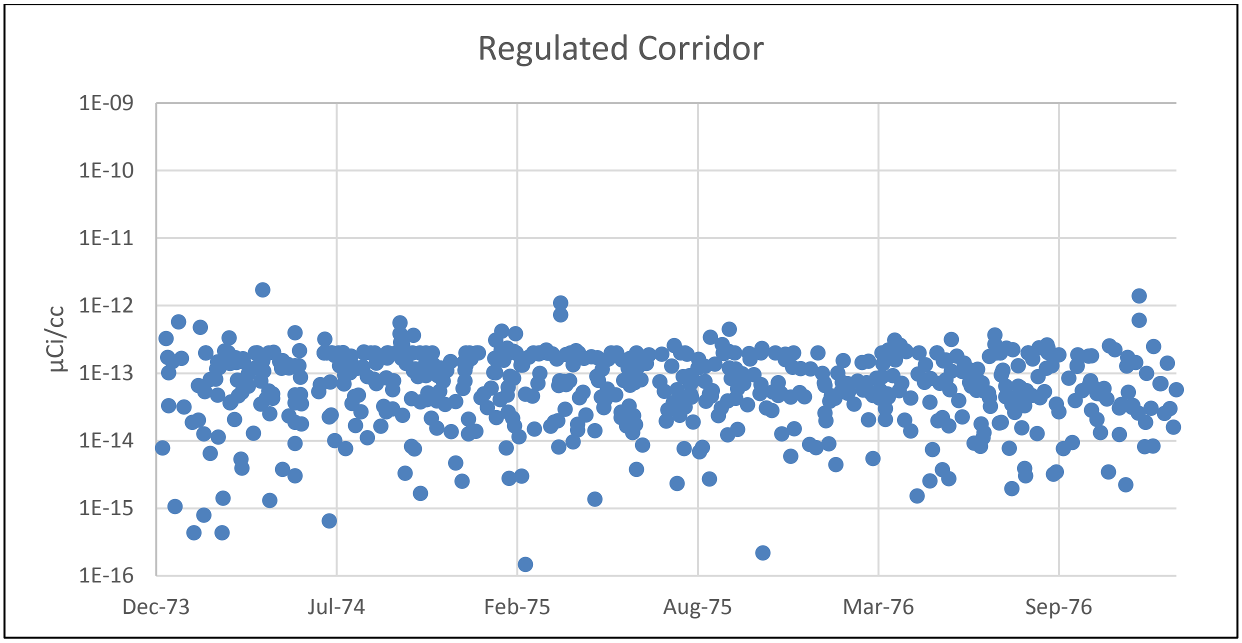

Figure A-3. Regulated Corridor (107F) air concentrations, January 4, 1974, to January 31, 1977. No results exceeded the administrative limit of 2 × 10^{-12} µCi/cm^3.

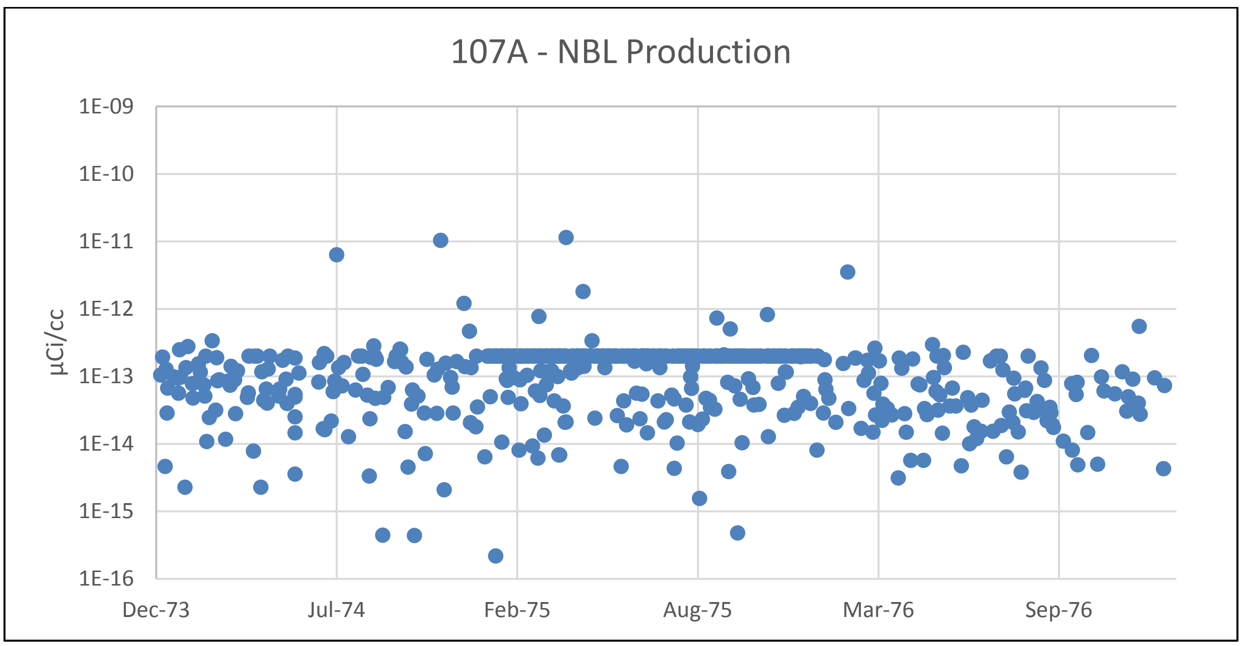

Figure A-4. Room 107A air concentrations, December 28, 1973, to January 28, 1977.

Four results exceeded the administrative limit of 2 × 10^{-12} µCi/cm^3. These had the following notations on the air sample forms:

- On 07/16/1974, 6.38E-12: "Air activity to 400 x 10^{-12} acpm/cc air during glove change."
- On 11/08/1974, 1.04E-11: "Glove Ruptured. Floor cont. to 1 x 10^5 trans."
- On 03/27/1975, 1.15E-11: "Glove rupture on 4-12 shift."
- On 02/02/1976, 3.55E-12: "High air activity during glove change. 165 x 10^{-12} uCi/ml."

ATTACHMENT A
SELECTED BUILDING 235-F AIR CONCENTRATIONS (continued)

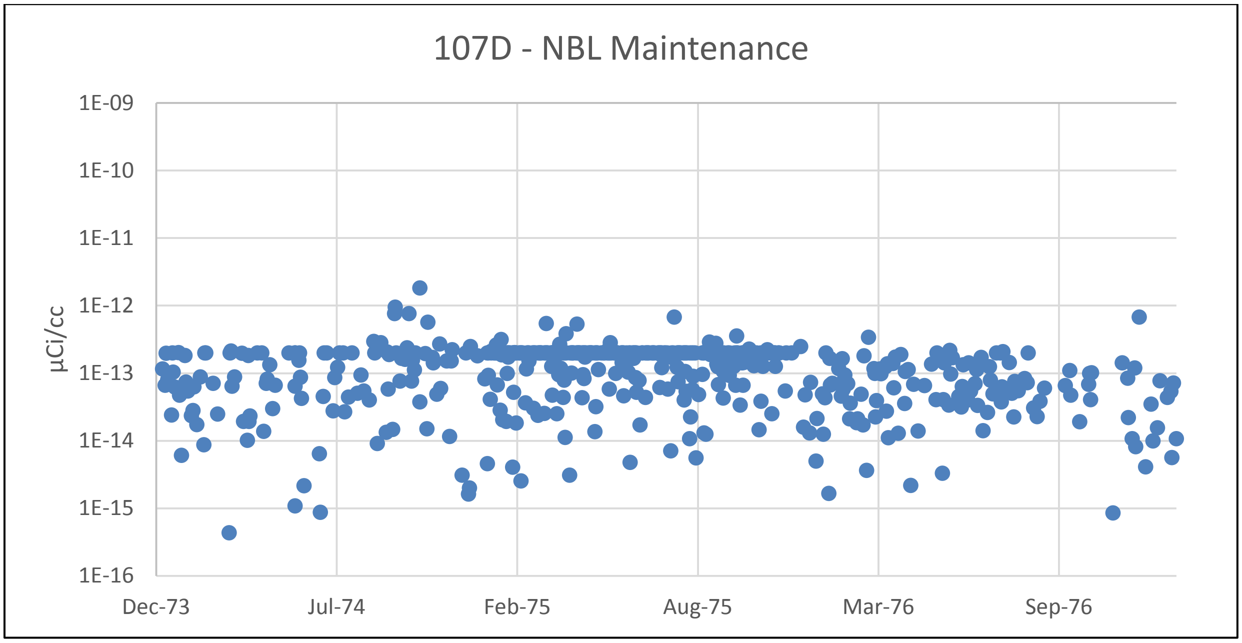

Figure A-5. Room 107D air concentrations, December 31, 1973, to January 31, 1977. No results exceeded the administrative limit of 2×10^{-12} µCi/cm^3.

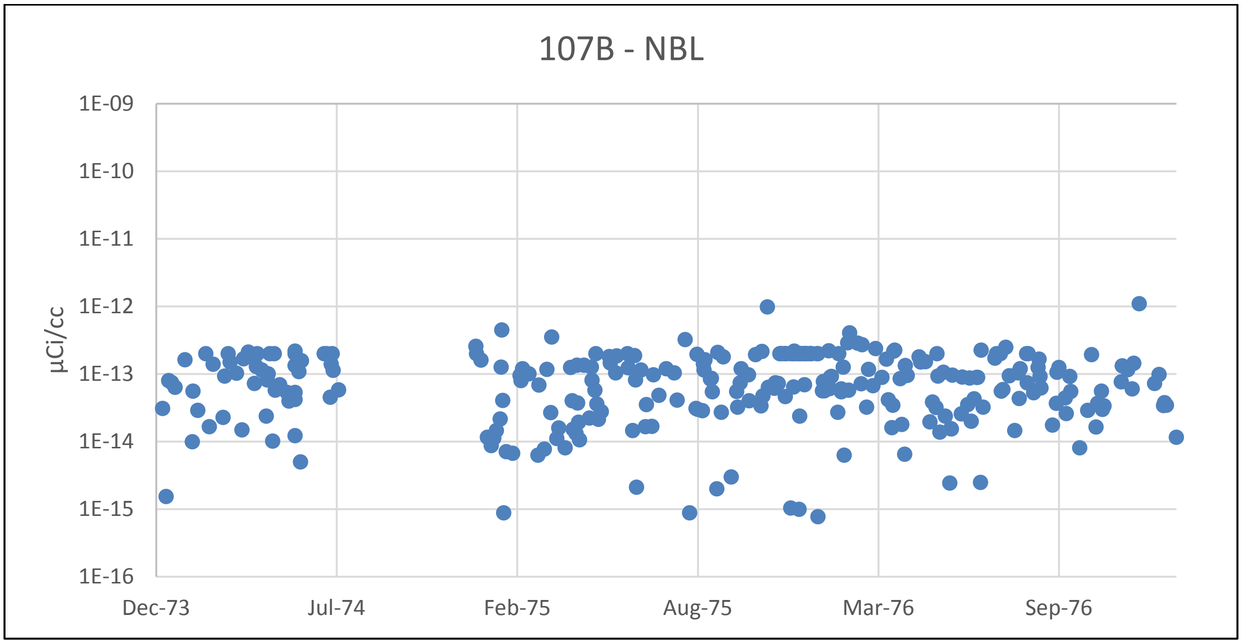

Figure A-6. Room 107B air concentrations, December 31, 1973, to January 31, 1977. No results exceeded the administrative limit of 2×10^{-12} µCi/cm^3.

ATTACHMENT A
SELECTED BUILDING 235-F AIR CONCENTRATIONS (continued)

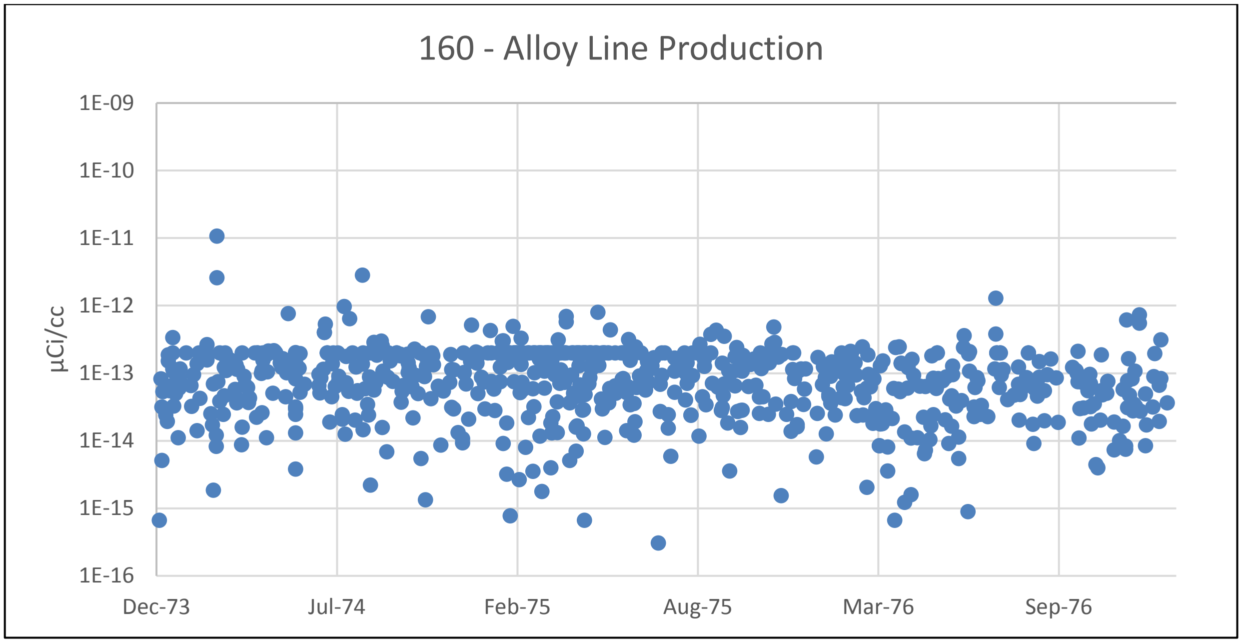

Figure A-7. Room 160 air concentrations, December 31, 1973, to January 31, 1977.

Three results exceeded the administrative limit of 2 x 10-12 µCi/cc. These had the following notations on the air sample forms:

- On 03/05/1974: 1.07E-11 and 2.59E-12, “Hut work. Change panel in CAB #2, Rm 162.”
- On 08/13/1974: 2.82E-12, there was no note.

ATTACHMENT A
SELECTED BUILDING 235-F AIR CONCENTRATIONS (continued)

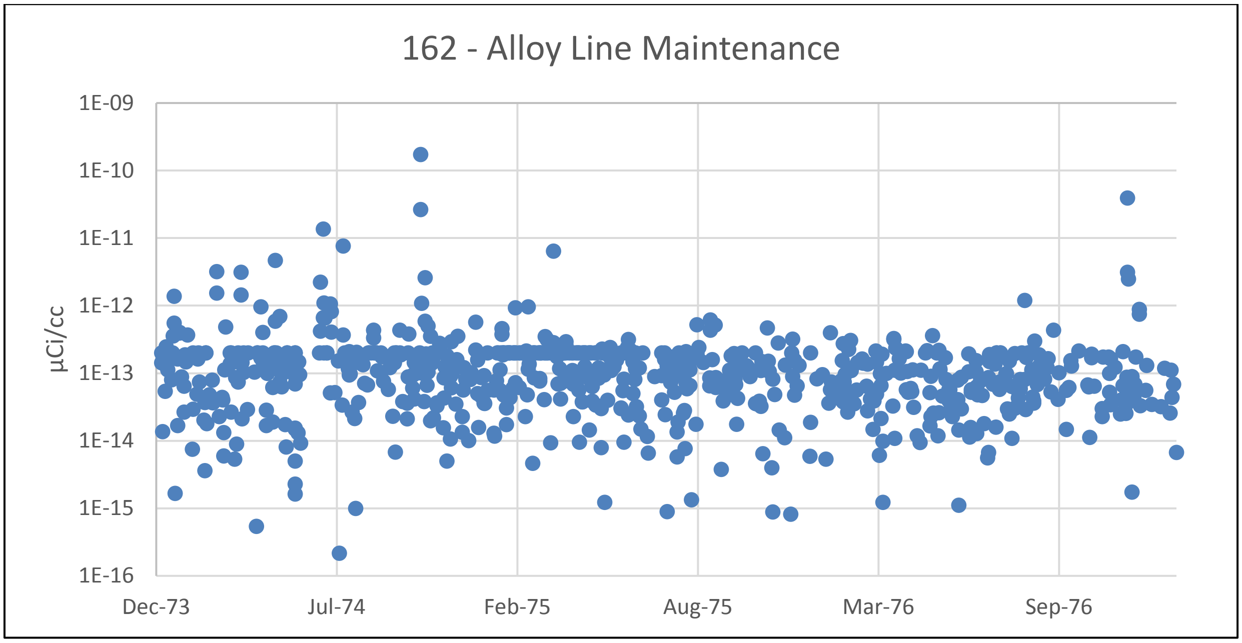

Figure A-8. Room 162 air concentrations, December 31, 1973, to January 31, 1977.

Thirteen results exceeded the administrative limit of 2 x 10-12 µCi/cc. These had the following notations on the air sample forms:

- On 03/05/1974, 3.19E-12, “Hut work. Change panel in CAB #2, Rm 162.”
- On 04/01/1974, 3.11E-12, “Survey of room & impactor air samples revealed no reason for activity.”
- On 05/09/1974, 4.70E-12, “No decay on 72 hour count.”
- On 06/28/1974, 2.23E-12, “Const. remove alloy line exhaust.”
- On 07/01/1974, 1.36E-11, “Fr. Cont. remove exhaust duct.”
- On 07/23/1974, 7.66E-12, “Bagging out equipment ingots & waste.”
- On 10/17/1974, 1.74E-10 and 2.66E-11, “Room contaminated during glove change.”
- On 10/22/1974, 2.61E-12, “Decon work being done.”
- On 03/13/1975, 6.39E-12, there was no note.
- On 12/08/1976, 3.91E-11 and 3.11E-12, “Rm on mask during 24 hour sampling period (glove changes and decon).”
- On 12/9/1976, 2.50E-12, “Waste removal & decon work.”

ATTACHMENT B
AIR MONITORING QUALITY ASSURANCE REPORT

August 26, 2016

Sampling Plan 1: Air Sample Master 235-F 1973-1975 SRDB 114648.xlsx

All Fields Plan

Fields

Page #	Time On	Pu 6-hour count
Start Date	Time Off	Pu 24-hour count
Stop Date	Volume	Corr.
Location	Conv Factor	LT
Sample Type	Background	Pu E-12
Job Description	Pu Initial Count	

Sampling Plan

N = 100,623
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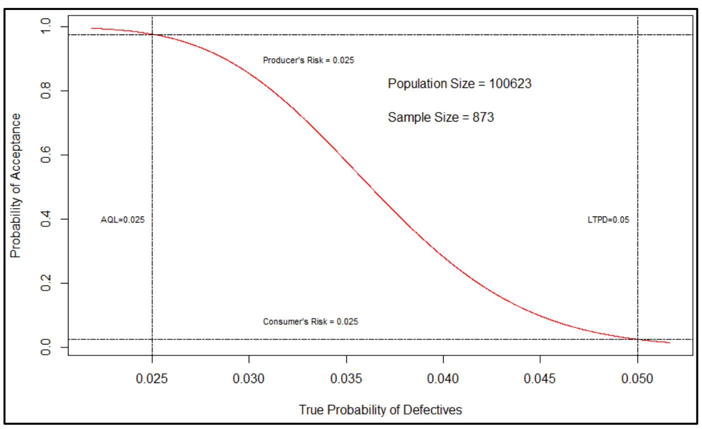
LTPD = 5%
α = 0.025 (producer's risk or ORAUT risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 873



Results

6 errors / 873 checked = 0.69%

We are at least 95% confident that the transcription error rate for the SRS air monitoring dataset in SRDB 114648 is between 0.25% and 1.49%.

Evaluation

The transcription error rate interval for this SRS air monitoring dataset is entirely below 5%. There is no issue with the transcription error rate.

ATTACHMENT B
AIR MONITORING QUALITY ASSURANCE REPORT (continued)

Sampling Plan 2: Air Sampling Results 235-F 041816_rev1 1974-1975 SRDB 153801.xlsx

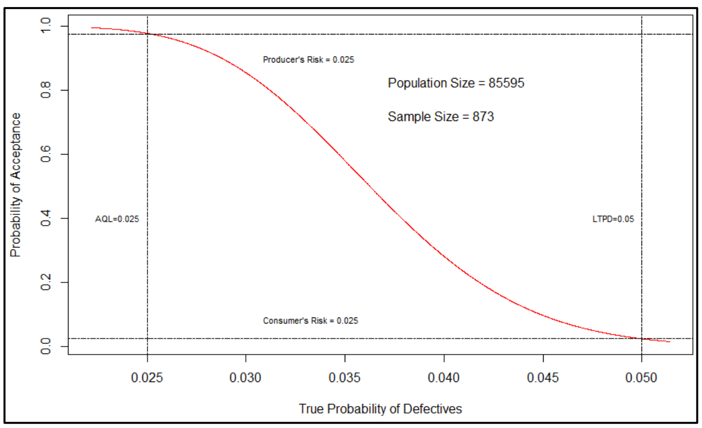
All Fields Plan

Fields

Page #
Start Date
Stop Date
Location
Sample Type
Job Description
Time On
Time Off
Volume
Conv Factor
Background
Pu Initial Count
Pu 6-hour count
Pu 24-hour count
Corr.
LT
Pu E-12

Sampling Plan

N = 85,595
AQL = 2.5%
LTPD = 5%
α = 0.025 (producer's risk or ORAUT risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 873



Results

2 errors / 985 checked = 0.20%

We are at least 95% confident that the transcription error rate for the SRS air monitoring dataset in SRDB 153801 is between 0.03% and 0.73%.

Evaluation

The transcription error rate interval for this SRS air monitoring dataset is entirely below 5%. There is no issue with the transcription error rate.

Note: The number of cells checked exceeds the number required by the sampling plan. When the original Excel spreadsheet was converted to a CSV file, the converted file contained several hundred completely blank rows of data. The sampling plan chose 114 of these blank rows, which needed to be replaced by rows with actual data in them. When the new cells were randomly selected, more than 114 were drawn and checked. The only consequence of this is that the interval with 985 checked is slightly narrower than an interval with 873 checked.

ATTACHMENT B
AIR MONITORING QUALITY ASSURANCE REPORT (continued)

Sampling Plan 3: Air Sampling Results 235-F 1974 Rev1 SRDB 114643.xlsx

All Fields Plan

Fields

Date On	Volume of Air	24-hour count
Time On	Conv. Factor	CP
Date Off	Initial Count	Daily Release
Time Off	6-hour count	Page #

Sampling Plan

N = 636
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LTPD = 5%
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β = 0.025 (consumer's risk or DCAS risk)
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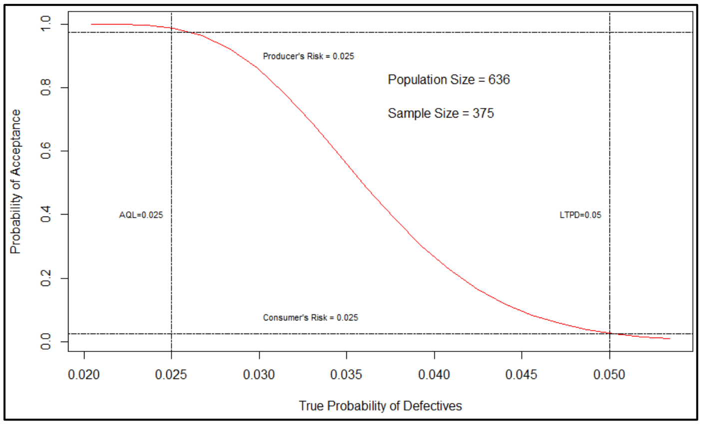

Results

2 errors / 375 checked = 0.53%

We are at least 95% confident that the transcription error rate for the SRS air monitoring dataset in SRDB 114643 is between 0.31% and 1.42%.

Evaluation

The transcription error rate interval for this SRS air monitoring dataset is entirely below 5%. There is no issue with the transcription error rate.

ATTACHMENT B
AIR MONITORING QUALITY ASSURANCE REPORT (continued)

Sampling Plan 4: M270-11451-HP5F-1-P007 Air Monitoring Data 235-F 1974-1976 SRDB 154342.xlsx

All Fields Plan

Fields

Date On	Cfm (sampling)	6-hour count
Time On	CF	24-hour count
Date Off	C.P.	Cp
Time Off	Initial Count	Ident
Cfm (exhaust)		

Sampling Plan

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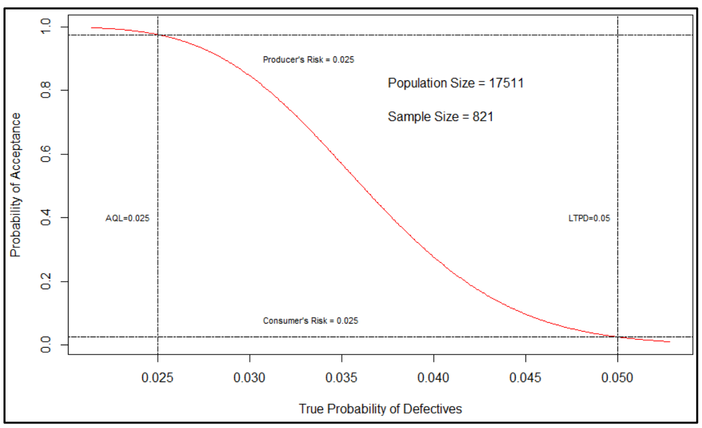
LTPD = 5%
α = 0.025 (producer's risk or ORAUT risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 821



Results

15 errors / 821 checked = 1.83%

We are at least 95% confident that the transcription error rate for the SRS air monitoring dataset in SRDB 154342 is between 1.05% and 2.96%.

Evaluation

The transcription error rate interval for this SRS air monitoring dataset is entirely below 5%. There is no issue with the transcription error rate.

ATTACHMENT B
AIR MONITORING QUALITY ASSURANCE REPORT (continued)

Sampling Plan 5: Air Sample Data 235-F 1975-1976 SRDB 153800.xlsx

All Fields Plan

Fields

Page #	Time Off	Background
Start Date	Volume	Pu Initial Count
Stop Date	Corr.	Pu 6-hour count
Location	Plutonium Impactor RaTn	Pu 24-hour count
Sample Type	Conv Factor	LT
Job Description	Plutonium Impactor CORR	PuE-12
Time On		

Sampling Plan

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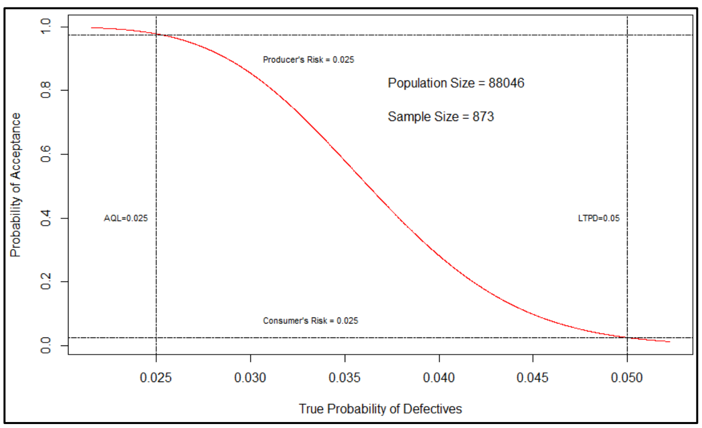
β = 0.025 (consumer's risk or DCAS risk)
n = 873



Results

4 errors / 873 checked = 0.46%

We are at least 95% confident that the transcription error rate for the SRS air monitoring dataset in SRDB 153800 is between 0.13% and 1.17%.

Evaluation

The transcription error rate interval for this SRS air monitoring dataset is entirely below 5%. There is no issue with the transcription error rate.

ATTACHMENT B
AIR MONITORING QUALITY ASSURANCE REPORT (continued)

Sampling Plan 6: Air Sampling Results 235-F final 1976-1977 SRDB 153806.xlsx

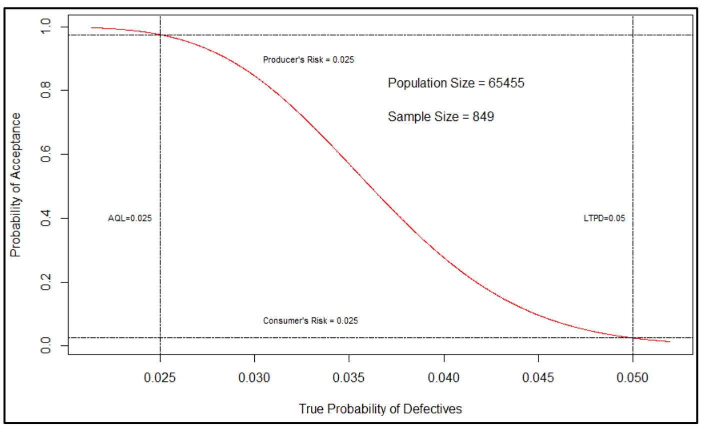
All Fields Plan

Fields

Loc Code	Sample Type	Pu 6-hour count
Page #	Job Description	Pu 24-hour count
Start Date	Volume	LT
Stop Date	Pu Scaler Con. Factor	Pu E-12
Time On	Background	Plutonium Impactor RaTn
Time Off	Pu Initial Count	Plutonium Impactor CORR
Location		

Sampling Plan

N = 65,455
AQL = 2.5%
LTPD = 5%
α = 0.025 (producer's risk or ORAUT risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 849



Results

1 error / 849 checked = 0.12%

We are at least 95% confident that the transcription error rate for the SRS air monitoring dataset in SRDB 153806 is between 0.0031% and 0.65%.

Evaluation

The transcription error rate interval for this SRS air monitoring dataset is entirely below 5%. There is no issue with the transcription error rate.

ATTACHMENT C
PROBABILITY PLOTS OF AIR CONCENTRATIONS

LIST OF FIGURES

ATTACHMENT C
PROBABILITY PLOTS OF AIR CONCENTRATIONS (continued)

In these graphs, calculated air concentrations are plotted against standard normal quantiles. These were calculated using models with a normal section that covers negative values and small positive values and a lognormal section that covers higher values. Red dots are air concentrations; the black line is the fit to the data. The straight part of the black line is the normal section of the model and the curved part is the lognormal section.

Provided on the graphs are statistical values resulting from the models:

- f is the fraction of the model that is fit with the normal distribution.
- mu is the mean of the normal distribution.
- sd is the standard deviation of the normal distribution.
- GM is the geometric mean of the lognormal distribution.
- GSD is the geometric standard deviation of the lognormal distribution.
- N is the number of results for that location; the number of red dots in the plot.

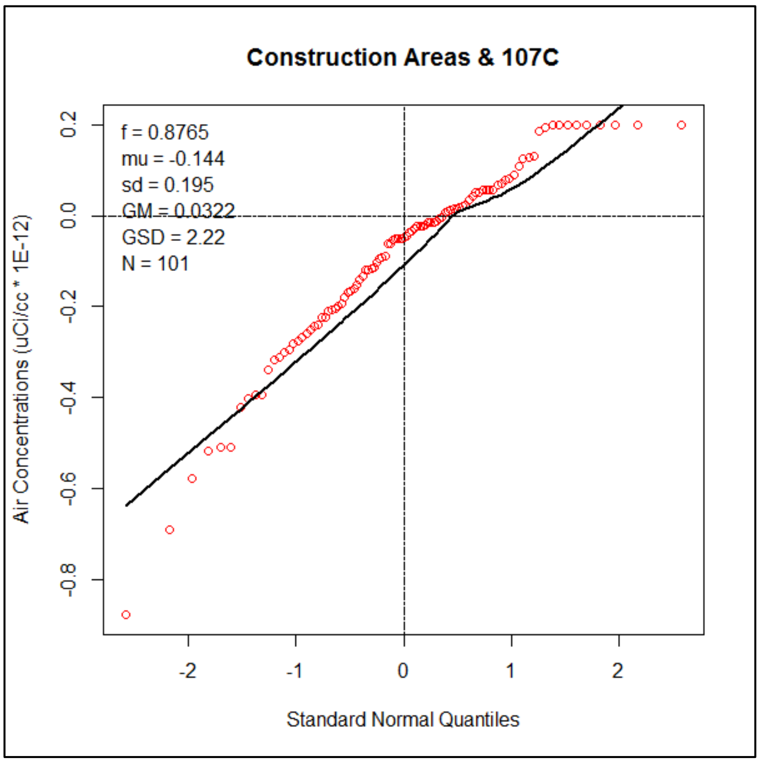


Figure C-1. Air concentrations against standard normal quantiles, construction areas and Room 107C.

ATTACHMENT C
PROBABILITY PLOTS OF AIR CONCENTRATIONS (continued)

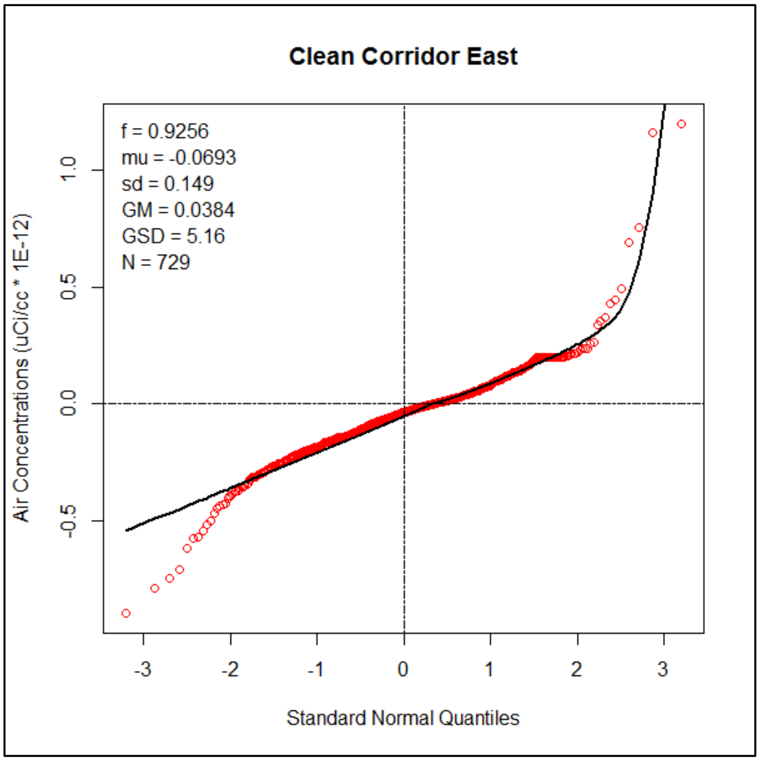


Figure C-2. Air concentrations against standard normal quantiles, Clean Corridor East.

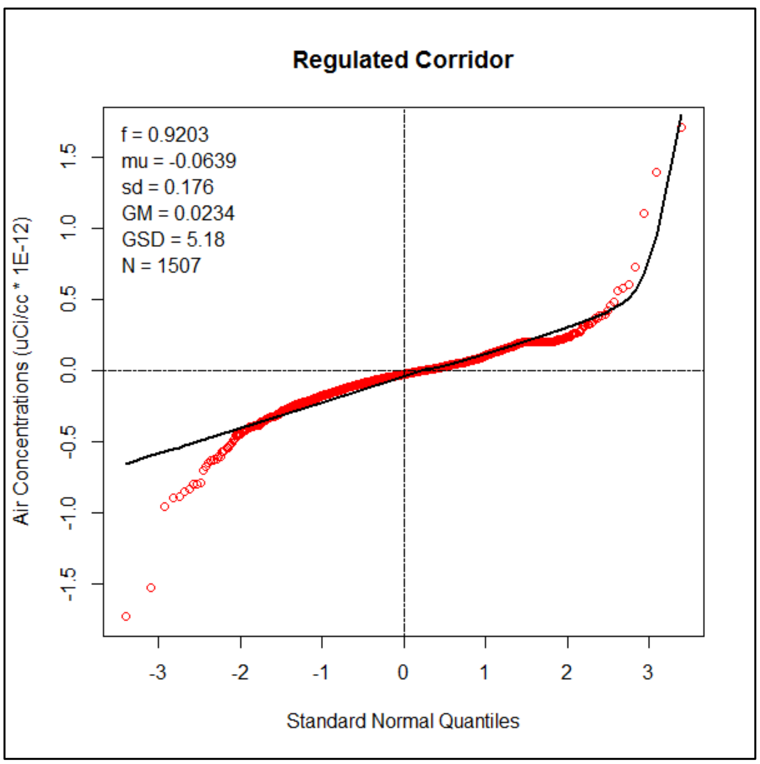


Figure C-3. Air concentrations against standard normal quantiles, Regulated Corridor.

ATTACHMENT C
PROBABILITY PLOTS OF AIR CONCENTRATIONS (continued)

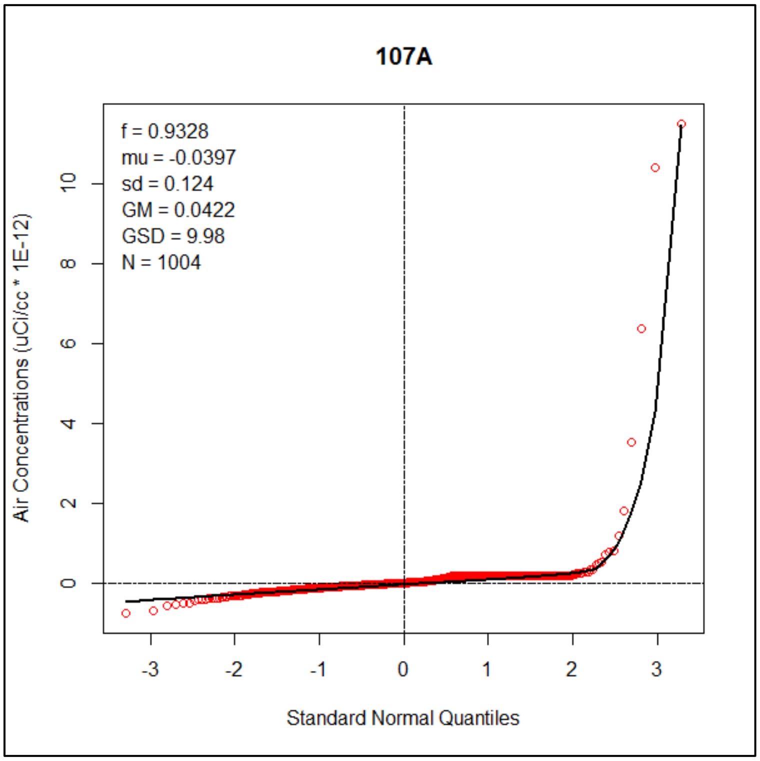


Figure C-4. Air concentrations against standard normal quantiles, Room 107A.

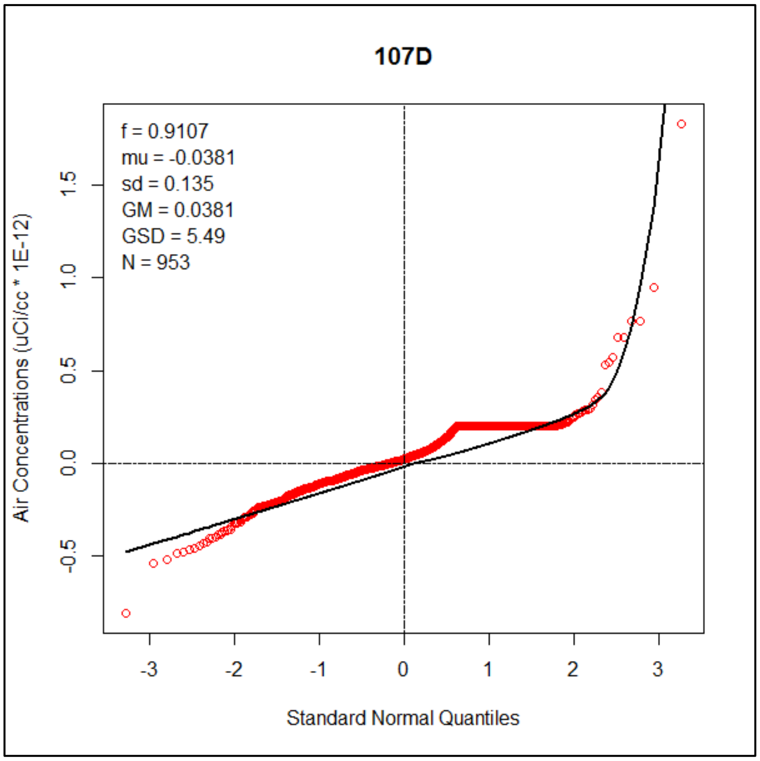


Figure C-5. Air concentrations against standard normal quantiles, Room 107D.

ATTACHMENT C
PROBABILITY PLOTS OF AIR CONCENTRATIONS (continued)

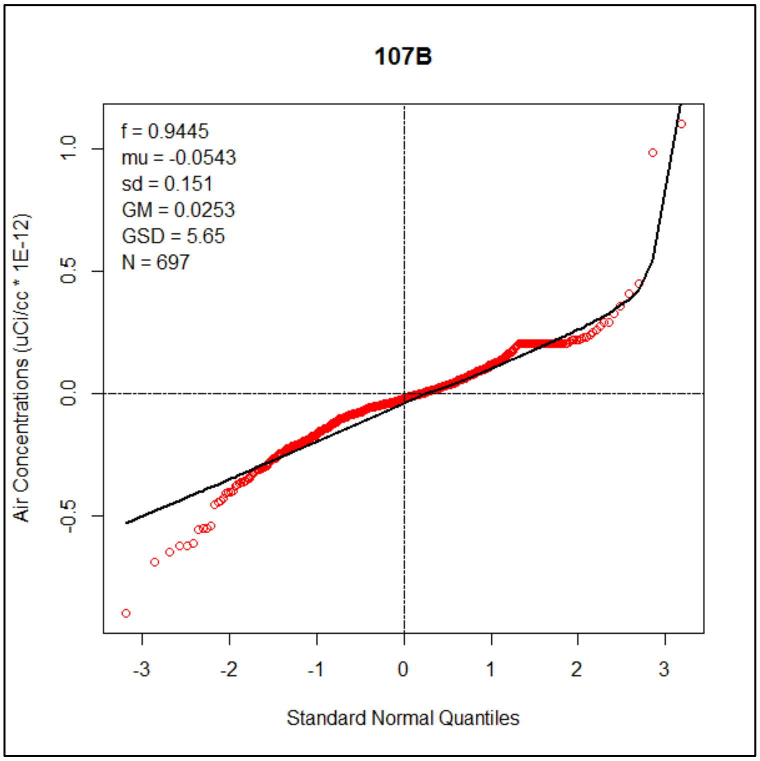


Figure C-6. Air concentrations against standard normal quantiles, Room 107B.

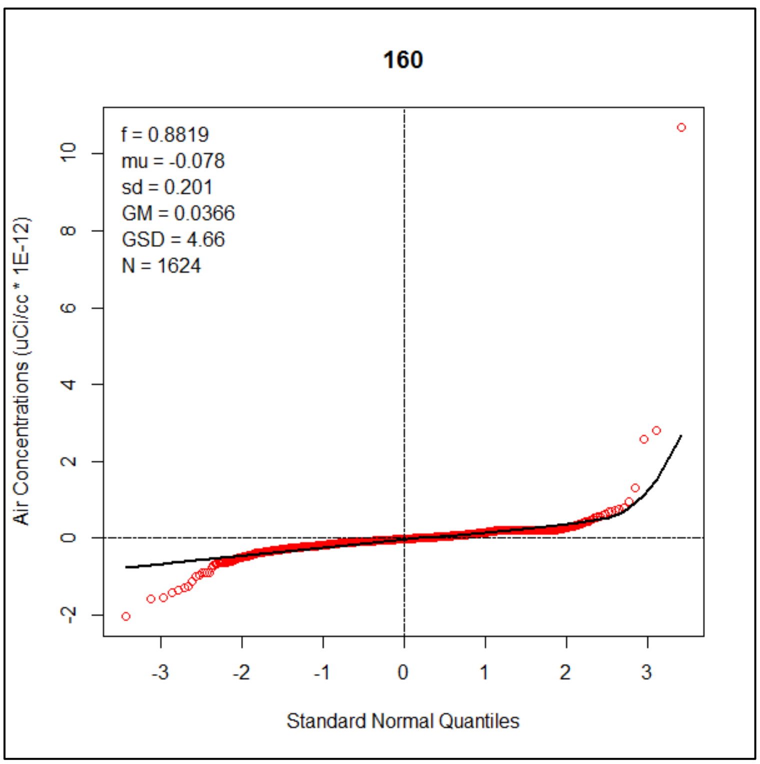


Figure C-7. Air concentrations against standard normal quantiles, Room 160.

ATTACHMENT C
PROBABILITY PLOTS OF AIR CONCENTRATIONS (continued)

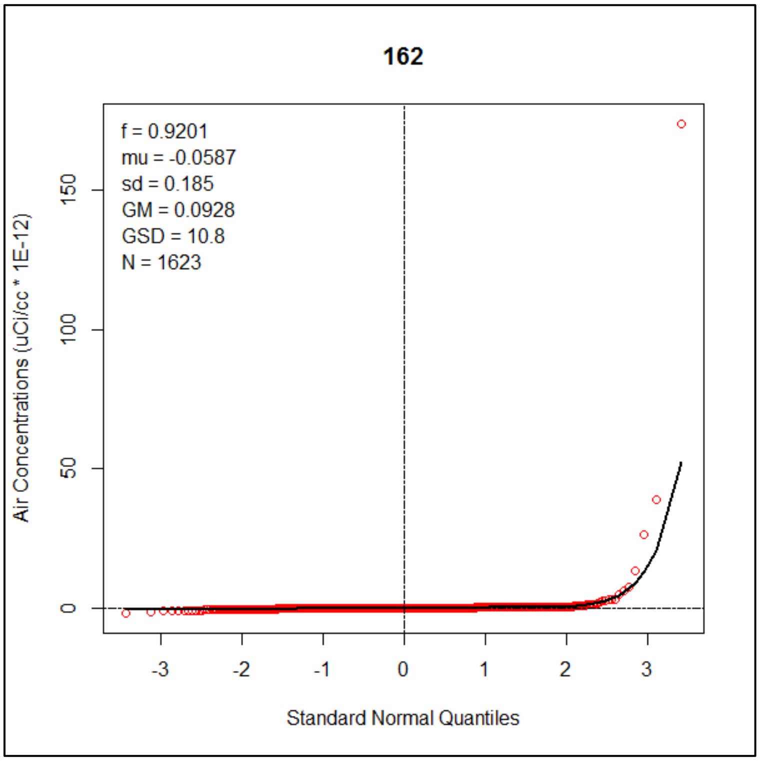


Figure C-8. Air concentrations against standard normal quantiles, Room 162.

ATTACHMENT D
NEPTUNIUM BILLETS FABRICATED DURING THE DESIGN AND CONSTRUCTION OF THE PuFF

Table D-1 chronicles the fabrication of 283 neptunium billets and documents concurrent design and construction progress for the PuFF from November 1973 to July 1977.

Table D-1. Neptunium billet fabrication during design and construction, 1973 to 1977.

Date	Reference	Production activity	Percentage of design and construction progress
Nov-73	ORAUT 2014	7 Mark 53A compact billets from 15.6 kg Np.	First mention in Works Technical Reports DPSP-73-1-11 (DuPont 1973a). Design work in progress to provide for production of disks and spheres, and for iridium encapsulation of spheres (also for dismantling spheres). Date to open given as January 1976. Designed to have nine shielded cells, six using cabinets, on first floor. Auxiliary equipment on second floor. Design limit: 0.5 mrem/hr for continuous exposure, 5 mrem/hr for intermittent.
Dec-73	ORAUT 2014	13 Mark 53A compact billets from 8.4 kg Np.	Design about 50% complete. Foundation for two of the columns in east-west wall prepared. Support for two process rooms was strengthened, portions removed. Shielding by 21 in. of limonite concrete in front and 12 in. on sides. Utility cabinets shielded by 4 in. H_2O. Processing to be done with manipulators.
Jan-74	DuPont 1974b	5 Mark 53A compact billets from 6.0 kg Np.	Design about 54% complete. Embedded conduit installed. Framing and other preparatory work for pouring the cell foundation continuing. Stripping of roof covering in progress in preparation for installing the concrete exhaust-air duct on top of Building 235-F. New HEPA filter housings and plenums are being assembled on second floor; these will service the Np and billet lines in addition to the PuFF facility. Np billet line cleansed for production of Mark 22A (Pu-242) billets.
Feb-74	DuPont 1974c	7 Mark 53A compact billets from 8.4 kg Np; no reject compacts.	Design about 60% complete. Installation of embedded conduit and pouring of the concrete base pad under the cells completed. Concrete walls of trench under Cells 1 through 5 poured, and framing for the remainder of the trench walls essentially complete. Pouring of the concrete base for the exhaust-air duct on top of 235-F begins, and excavation for the air duct to the new F-Area sand filter in progress.
Mar-74	DuPont 1974d	5 Mark 53A compact billets from 6.0 kg Np; no reject compacts.	Design 65% complete. Foundation for the cells completed, and repouring of the first-level floor is imminent. Concrete exhaust-air duct atop Building 235-F about 60% complete. Pouring of pad for building- supply fans and air-conditioning equipment complete (outside world), and underground electrical conduit from the new substation installed.
Apr-74	DuPont 1974e	4 Mark 53A compact billets from 4.8 kg Np; no reject compacts.	Design 65% complete; construction about 12% complete. Pouring of first floor completed, and steel base plate for the front-shield wall installed. Front shield wall (21-in.-thick limonite concrete) will be poured in Central Shops and installed in sections after cells installed. Framing in progress for the back shield wall (14.5-in.-thick limonite concrete), which will be poured in place. Concrete exhaust duct atop 235-F about 80% complete, and transition duct (from rectangular duct to circular underground pipe) poured.
May-74	DuPont 1974f	No NpO_2 was available for fabrication of compact billets.	Design 67% complete; construction about 15% complete. Framing for rear shield walls, including installation of doors and window frames, continues. Removal of high hats on second floor in progress; this area will be used for auxiliary equipment. Concrete exhaust duct atop Building 235-F 90% complete.

ATTACHMENT D
NEPTUNIUM BILLETS FABRICATED DURING THE DESIGN AND CONSTRUCTION OF THE PuFF (continued)

Date	Reference	Production activity	Percentage of design and construction progress
Jun-74	ORAUT 2014	14 Mark 53A compact billets from 16.8 kg Np; no reject compacts.	Design 73% complete. Forms for limonite concrete shield constructed. Rear wall for Cell 9 poured. Upgrading of vent ducts for Cell 9 poured. Upgrading of vent ducts on second floor 70% complete. Removal of first bay underway.
Jul-74	DuPont 1974g	11 Mark 53A compact billets from 13.2 kg Np; no reject compacts. Special samples taken from Al-NpO_2 blend to determine if the NpO_2 and Al powders were blended adequately in the Z-type blender. Samples of powder from the dies were taken to see if the blend was segregating during subsequent handling.	Design 77% complete; construction 20% complete. Pouring of limonite concrete for all cell rear walls completed, and upgrading of the ventilation ducts on second level of 235-F complete. Final concrete pour for the exhaust duct on the roof made.
Aug-74	DuPont 1974h	No NpO_2 was available for fabrication of compact billets.	Design 83% complete; construction 24% complete. Liners for six rune cells received, but the interior finish did not meet plant requirements. New building supply fan and air-conditioning equipment installed. Both high hats in the second level floor removed, and structural steel supports for the new floor in this area installed.
Sep-74	DuPont 1974i	8 Mark 53A billets from 9.6 kg Np; 1 reject compact.	Design 87% complete; construction 25% complete.
Oct-74	ORAUT 2014	19 Mark 53A compact billets from 22.8 kg Np.	Design 87% complete; construction 27% complete. 7-ft-diameter underground duct to connect to 235-F exhaust to 294-F filter installed. Earth backfill completed. Six stainless-steel cell liners refinished.
Nov-74	ORAUT 2014	15 Mark 53A billets from 18 kg Np.	Design 90% complete; construction 27%. Remaining three cell lines completed.
Dec-74	DuPont 1974j	15 Mark 53A billets from 18 kg Np; 1 reject compact.	At year end, design 98% complete; construction 29% complete. Design and construction completion schedules remain the same as forecast in November (July 1975 for design and February 1976 for construction).
Jan-75	ORAUT 2014; Author unknown 1982	None indicated	Design 99% complete; construction 36% complete. Two 2- by 7-ft walls cut through east wall of 235-F for air-supply ducts to process area.

ATTACHMENT D
NEPTUNIUM BILLETS FABRICATED DURING THE DESIGN AND CONSTRUCTION OF THE PuFF (continued)

Date	Reference	Production activity	Percentage of design and construction progress
Feb-75	ORAUT 2014	None indicated	Design complete; construction 45% complete. Hot-press and vacuum pumps installed behind Cell 4. Main line glove cabinet installations finished. Concrete poured to complete second floor.
Apr-75	DuPont 1975b	8 Mark 53A compact billets from 9.6 kg Np; no reject compacts. Five billets in Building 235-F of 20% Pu-240 for the Mark 41 development run. The tubes have been cut and packaged in Building 235-F and sent to JB-Line for plutonium recovery.	Construction 55% complete. Installation of all sections of radiation shield wall in front of east and west cell lines completed. Manipulator through-tubes for all cells installed, aligned, and tack-welded. Inlet-ventilation ducts containing reheat steam coils installed on the second floor and connected to the primary heat exchanger outside Building 235-F. Rear shielding windows installed in all cells.
May-75	ORAUT 2014	None indicated	Construction 60% complete. Top sections of radiation shields poured, completing east and west cell lines. Service panels and hydraulics installed.
Jun-75	ORAUT 2014	None indicated	Construction 65% complete. Three process furnaces installed. HP monitoring system blowers installed. Metallography Laboratory cabinets installed. Instrumentation cells installed.
Jul-75	DuPont 1975c	12 Mark 53A compact billets from 14.4 kg Np; no reject compacts.	Construction 70% complete.
Aug-75	DuPont 1975d	8 Mark 53A compact billets with 9.6 kg Np.	Construction 75% complete. Centorr representatives operating the hot press to demonstrate it meets specifications. During pressure tests, graphite ram extensions and a graphite lower ram clamp fractured. Installation of manipulator through-tubes begun in Cells 1 through 5. Wiring for cell consoles and for the halon fire protection system completed. Equipment transfer lock into Cell 6 and the liquid waste glovebox installed.
Oct-75	DuPont 1975e	11 Mark 53A compact billets from 13.2 kg Np as oxide; no reject compacts.	Construction is 85% complete. Helium purifier installed, but an improper welding procedure was used and it would be necessary to cut and reweld 10 welds. Satisfactory leak tests made on all cells. Testing of the attached gloveboxes underway.
Nov-75	DuPont 1975f	NpO_2 powder was not available for processing.	Construction 92% complete. Construction schedule for facility completion and turnover changed from February to April 1976.
Dec-75	DuPont 1975g	7 Mark 53A compact billets from 8.4 kg Np as oxide; no reject compacts.	Construction 96% complete. Repair of substandard welds at fittings in copper lines in the argon, helium, and air-monitoring systems about 75% complete. Dye checks indicate excessive porosity in some new welds. These areas ground out and rewelded as discovered.

ATTACHMENT D
NEPTUNIUM BILLETS FABRICATED DURING THE DESIGN AND CONSTRUCTION OF THE PuFF (continued)

Date	Reference	Production activity	Percentage of design and construction progress
Jan-76	DuPont 1976a	9 Mark 53A compact billets from 10.8 kg Np; no reject compacts; 3 batches of NpO_2 returned to HB-Line for recalcination because of high weight loss (more than 0.5%).	Construction 97% complete. Construction schedule for facility completion and turnover changed from May to July because of the design and installation of the cell pressure relief devices. All cell bulk shielding windows installed.
Mar-76	DuPont 1976b	15 Mark 53A compact billets from 18.0 kg Np; no reject compacts.	Construction remains 97% complete. On March 12, construction work suspended until design of the cell pressure relief devices is complete. Beneficial occupancy of cells and first-floor equipment assumed by Operations on March 12.
Jun-76	DuPont 1976c	7 Mark 53A compact billets from 8.4 kg Np; no reject compacts.	No work during this month.
Jul-76	DuPont 1976d	13 Mark 53A compact billets from 15.6 kg Np; no reject compacts.	Construction remains 97% complete. On July 12, construction resumed in the PuFF Facility. The following work necessary to complete the facility (completion forecast for November 1) includes installation of pressure vacuum relief devices for inert gas cells.
Aug-76	DuPont 1976e	10 Mark 53A compact billets from 12.0 kg Np; no reject compacts.	Construction work, installation of pressure vacuum relief devices for inert gas cells continues.
Sep-76	DuPont 1976f	8 Mark S3A compact billets from 9.6 kg Np; no reject compacts.	Construction remains 97% complete. Remaining work scheduled for completion by November. Exhaust ventilation from process cabinets and rooms changed to discharge into new roof tunnel leading to the F-Area sand filter.
Dec-76	ORAUT 2014	None indicated	Construction 99% complete. Ventilation system being tested. Some modifications being made.
Jan-77	ORAUT 2014	None indicated	Construction completed.
Feb-77	ORAUT 2014	None indicated	Acceptance test set for March 8, 1977. Ventilation system accepted in February. In-line alpha monitor being tested.
Mar-77	ORAUT 2014	None indicated	Separations took occupancy on March 8, 1977. A few welds "still to be made." Procedures being prepared.
Apr-77	DuPont 1977a	16 Mark 53A billets from 19.2 kg Np; 1 reject compact.	Preparations for startup continued. Equipment run-in and continuity checks started.

ATTACHMENT D
NEPTUNIUM BILLETS FABRICATED DURING THE DESIGN AND CONSTRUCTION OF THE PuFF (continued)

Date	Reference	Production activity	Percentage of design and construction progress
May-77	DuPont 1977b	15 Mark 53 A billets from 180 kg Np; 1 reject compact.	Test runs for PuO_2 started in Cell 1. Test welding on iridium in helium atmosphere started in Cell 6.
Jun-77	DuPont 1977c	16 Mark 53A billets from 19.2 kg Np; no reject compacts; 20.148 kg NpO_2 sent to Building 235-F in 21 batches.	Cold runs with ThO_2 as stand-in for PuO_2 continued. Nine ball-mill runs made and six pellets cold-pressed and sized into shards. Three $Th0_2$ spheres successfully hot-pressed.
Jul-77	DuPont 1977d	5 Mark 53 A billets from 6.0 kg Np; 1 reject compact.	Cold runs with ThO_2 as a stand-in for PuO_2 completed. Processing of $^{238}PuO_2$ began on July 23. All major equipment and the argon supply for operation of the vacuum-pressure mounting system have been installed in Building 235-F PuFF Metallography Facility.

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS

LIST OF FIGURES

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

The following photographs show the PuFF facility in various stages of development. As shown, the construction areas were clean with little to no debris. There are no radiation barriers or signs in the photographs, which indicates they were not radiation or contamination areas. The workers in Figures E-1 and E-4 appear to be in regular rather than protective clothing.

Figure E-1. Worker readying to pour concrete, April 4, 1973 (DuPont 1973b). Note that the worker does not appear to be wearing protective clothing for the prevention of radioactive contamination (DPSPF 17880-4).

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

Figure E-2. Roof above the PuFF Facility in Building 235-F, April 4, 1973 (DuPont 1973c). Maintenance access and exhaust piping were installed later (DPSPF 17880-11).

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

Figure E-3. Additional work on the roof of Building 235-F, April 4, 1973 (DuPont 1973d) (DPSPF 17880-12).

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

Figure E-4. Glovebox housing area during construction, December 11, 1973 (DuPont 1973e). Note that the worker does not appear to be wearing protective clothing for the prevention of radioactive contamination (DPSPF 17564-8).

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

Figure E-5. Concrete removal in glovebox housing area, April 4, 1974 (DuPont 1974k) (DPSPF 17508-7).

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

Figure E-6. Completed hot cell structure, February 26, 1975 (Du Pont ca. 1975h) (DPSPF 18813-23).

Figure E-7. Construction of a support room, February 26, 1975 (DuPont 1975i) (DPSPF 18813-28).

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

Figure E-8. Duct work in construction area, November 20, 1976 (DuPont 1976g). Note the duct to other parts of the building is closed off (DPSPF 18678-4).

ATTACHMENT E
CONSTRUCTION AREA PHOTOGRAPHS (continued)

Figure E-9. Room construction, November 20, 1976 (DuPont 1976h). It is not clear what this particular room was used for. Note the clean conditions in the work area (DPSPF 18678-11).

Figure E-10. Room construction demonstrating safety awareness and hazard markings, November 20, 1976 (DuPont 1976i) (DPSPF 18678-24).