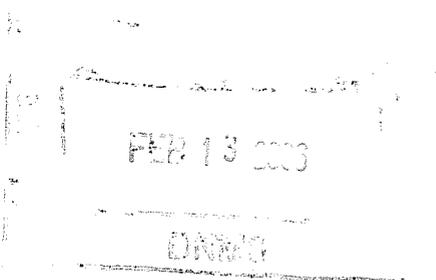


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February 10, 2006

United States Nuclear Regulatory Commission  
Region IV  
ATTN: Mr. Robert Evans  
611 Ryan Plaza Drive, Suite 400  
Arlington, TX 76011

Re: Termination NRC Radioactive Materials License Number SUB-1382, NRC Docket Number 040-08769

Dear Mr. Evans:

Please accept this letter as the ExxonMobil Billings refinery's official request for you to review and approve the revised version of the report entitled Radiological Survey and Dose Modeling for Termination of License SUB-1382 that has been submitted to you via PDF file by Mr. Mark Garcia of Weston Solutions, Incorporated of Albuquerque, New Mexico.

This report contains the additional information requested by your office's resources. It is our hope that with these additions, you will approve the report and allow us to further our efforts in the termination of NRC Radioactive Materials License SUB-1382. Should you have any questions or require any additional information, please contact me at (406) 657-5218 or Mr. Garcia at (505) 837-6586.

Thank you for your time and consideration in this matter.

Sincerely,

A handwritten signature in cursive script, appearing to read "Stanley J. Clapham".

Stanley J. Clapham  
Radiation Safety Officer

SJC/tl

Attachment

cc: Robert Schoenfelder, Weston Solutions, Inc.  
Mark Garcia, Weston Solutions, Inc.

**OVERNIGHT DELIVERY**

# **Radiological Survey and Dose Modeling for Termination of License SUB 1382**

**Prepared for:  
ExxonMobil Refining and Supply Company  
Billings, Montana**

**February 2006**

**Prepared by:**



**3840 Commons Ave., NE  
Albuquerque, New Mexico 87109**

**Mark Garcia, CMP, Technical Manager**

**Document Number: 13014\_010\_D\_019\_06**

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## EXXONMOBIL DOSE MODELING

### 1. INTRODUCTION

This report was prepared by Weston Solutions, Inc. for the ExxonMobil Refining and Supply Co. (ExxonMobil) refinery at Billings, Montana. The work was completed in conjunction with ExxonMobil's decision to terminate its radioactive materials license no. SUB-1382 granted by the U.S. Nuclear Regulatory Commission, Region IV.

#### 1.1 OBJECTIVE

The objective of the dose modeling is to determine if the materials remaining onsite are contaminated with depleted uranium to a level that would result in a dose to an individual in excess of 25 millirem (mrem). The 25 mrem dose limit has been established by the U.S. Nuclear Regulatory Commission (NRC) as the maximum dose to the average member of the critical group resulting from the unrestricted release of a site following license termination.

Depleted uranium (DU) consists of the uranium isotopes U-238, U-235, and U-234 in equilibrium with their associated decay products. Although DU consists of these isotopes, 99% of its mass is from U-238 and therefore, in this report the radionuclides of concern are U-238 and its associated decay products. WESTON defined the following five areas of interest at the facility to be addressed in the license termination:

- The F551 furnace and associated downstream equipment,
- The spent catalyst storage area,
- The mechanical building (garage),
- The F551 Furnace sump, and
- The F551 furnace perimeter.

An average value is determined for each area of interest and used as the source term for the NRC-approved D and D version 2.1.0 computer model to determine if the license may be terminated without restrictions, commonly known as unrestricted release.

Two modeling scenarios were used; one for building occupancy and one for a resident farmer. Although neither scenario is likely to happen, they were selected to provide a set of very conservative assumptions and ensure an over-estimate of the potential doses to the critical groups. The results of the surveying, sample collection, and dose modeling indicate that the residual contamination present at the site would result in a potential dose of 2.13 mrem per year to the resident farmer and 6.55 mrem/yr to the building occupant. These values are well below the 25 mrem per year limit for license termination with unrestricted use.

#### 1.2 SITE HISTORICAL INFORMATION

From 1980 to 1986 the F551 Hydrogen Reformer furnace used 84 furnace tubes that contained a DU catalyst. The furnace tubes were approximately 40 feet long with an outside diameter (OD) of 6 inches, an inside diameter (ID) of 4.5 inches, and a wall thickness of 1.5 inches. Each tube had two 4-inch diameter pigtailed, both located approximately 3 feet from the bottom of the tube. The catalyst support cones, known as "bullets," were placed inside the bottom end of the tubes with the catalyst loaded on top. Although there were three different bullet designs, base dimensions were approximately 3 feet long, with 4.5-inch OD and 4-inch ID, and one end of the bullet was tapered. Each furnace tube had an end cap flange approximately 1 inch thick and 10 inches in diameter at each end.



The DU catalyst was removed from each tube in 1986, shipped off-site, and replaced with a non-radioactive nickel-molybdenum catalyst. A survey of several tubes conducted in 1988 led to the determination that the tubes would be managed as radioactively contaminated material. However, measurements performed in 1995 indicated that a large portion of each furnace tube (approximately 37 feet) was not contaminated above background levels and could have been released with no further concern about radiation levels (free released) and disposed of as industrial waste or recycled.

In February and March of 1995, all furnace tubes were removed for metallurgical inspection. Prior to inspection or disassembly, the furnace tubes were surveyed for fixed and removable radioactivity. Although the results generally demonstrated background levels at tube tops and at pigtails, some furnace tube bottom openings showed elevated levels above background. To remove this residual activity, workers wearing personal protective equipment (PPE) removed and cleaned all blind flanges and catalyst support cones using glove bags.

When surveys showed successful decontamination to a free release limit of less than 5,000 disintegrations per minute per 100 centimeters squared (dpm/100 cm<sup>2</sup>), a confirmatory measurement for total (fixed and removable) contamination and removable contamination was conducted. Survey data from the 1995 tube refurbishment and decontamination indicate that the furnace tubes were all decontaminated to less than 5000 dpm/100 cm<sup>2</sup>, at which time they were internally sandblasted, and no further surveys were conducted to document the final contamination levels. The tubes were placed back into service at that time.

During the 2002 Hydrocracker turnaround, five furnace tubes were removed (furnace tube numbers 62, 77, 81, 82, and 83). Approximately 3-foot sections of tube were cut from the ends of each tube. In addition, 17 catalyst support cones were removed. The end cap flanges from each of the five tube were removed as well. These tubes, cones, and flanges are stored on site in a wooden box within a secured area with appropriate labeling in place. Surveys performed at the time confirmed that contamination levels were less than 5,000 dpm/100 cm<sup>2</sup>.

In 2005, during another Hydrocracker turnaround that included replacement of all the tubes with new ones, ExxonMobil contracted WESTON to provide radiation safety support and perform radiation surveys and monitoring to characterize potentially contaminated equipment and areas, arrange for appropriate transportation and disposal of contaminated materials, and document final conditions to support termination of the NRC license. This report presents the dose modeling results, which are based on data from radiological surveys conducted at the site during this turnaround. Section 2 describes the areas surveyed and presents the results used in the modeling. Section 3 describes the modeling. Section 4 contains the conclusions reached through the modeling.

## 2. RADIOLOGICAL SURVEYS

Instrument surveys conducted during the 2005 turnaround indicated where residual contamination existed and which potentially contaminated areas were clean. Measurements were performed to meet two objectives. First, measurements were taken of potentially impacted areas and accessible sections of process equipment that were to remain in place after the turnaround was completed to provide input data for dose modeling to support license termination and release of the site for unrestricted use, and disposal of the materials cleared for release from the site. Second, measurements were taken of contaminated items for use in characterizing the waste to be disposed at a license radioactive waste disposal site.

During the Hydrocracker turnaround, radiological surveys were performed at the points where each individual furnace tube was attached to other process equipment and where related equipment were accessible to determine if upstream or downstream equipment had been contaminated during the use of radioactive materials. The surface radiological surveys included direct static surveys with handheld



pancake GM survey meters and swipe samples for removable contamination. The swipe samples were analyzed for gross alpha activity.

Once the tubes were removed from the furnace and placed in a remote lay-down area, surveys were performed of the tubes, the equipment that was removed along with the tubes, and the potentially impacted areas where the catalyst was stored or equipment was handled. Survey results were used to segregate the items that would require disposal at a licensed radioactive waste site and to characterize the radioactive contents of the waste. Additional measurements were performed of the tubes, which were to remain at the site as uncontaminated items, for input to the dose models.

## **2.1 SURVEY DESCRIPTION AND RESULTS FOR DOSE MODELING**

WESTON's health physicist reviewed a process flow diagram for the F551 furnace and discussed it with ExxonMobil's process engineer to determine the potential for residual contamination in various parts of the furnace and related process equipment. Parts of the equipment that could reasonably be contaminated were identified and plans were made to access them during the tube removal activities. Surveys were conducted of the accessible internal and external areas.

In addition, four potentially impacted areas of the site were identified based on WESTON's review of the procedures for handling the catalyst and the furnace equipment. Those four areas were monitored for residual contamination on floor surfaces and in surrounding soils.

### **2.1.1 Instrumentation**

The following instruments were used to perform the surveys described above.

Internal tube monitor -- Two pancake Geiger-Mueller (GM) detectors mounted back to back and attached to two data loggers were used to monitor the internal surfaces of the tubes. This unit is 22% efficient for Sr/Y-90, which is similar in energy to the Th-234/Pa-234m decay product of U-238. Instrument efficiency and function tests were performed daily with a Sr/Y90 source.

Surface monitor – Surfaces of equipment were scanned using a handheld pancake GM survey meter. This unit is 22% efficient for Sr/Y-90, with energies similar to Th-234/Pa-234m. Instrument efficiency and function checks were performed daily with a Sr/Y90 source.

Removable contamination monitor – Swipes were counted on a commercial alpha swipe counter with a 37.5% efficiency for U-238 and a 36.3% efficiency for Th-230. Instrument efficiency and function checks performed daily with a Th-230 source.

### **2.1.2 F551 Furnace and Associated Process Equipment**

The furnace tubes that previously contained the uranium catalyst were permanently removed and replaced with new tubes during the turnaround in 2005. However, the rest of the furnace components and other process equipment in the furnace circuit remained in place. WESTON conducted instrument surveys and collected swipe samples while the tubes were removed and the furnace was inoperable, which allowed access to critical areas that cannot be accessed when the furnace is in use. The surveys and sampling activities focused on the following components:

- Top pigtails (curved tubes) that attach each tube to the inlet stream
- Bottom pigtails that attach each tube to the process and draw product from the tubes to a collection basin refractory drum (D503)

- D503 collection basin refractory drum where radiological contamination would pool because the velocity of the system is at its lowest at that point, therefore facilitating deposition of entrained material
- Additional downstream processing equipment with accessible internal surfaces (E523, E526, and T509).

The furnace tube attachment points (pigtailed) and accessible downstream processing equipment (D503, E523, E526 and T509) are shown in Figure 1. Figure 2 demonstrates the technique used for surveying the pigtail attachment points. The furnace tubes have all been removed and relocated to a low background area, known as the catalyst storage area, for surveying. Figure 3 shows the pipe inlet to the D503 refractory drum. A section of the elbow was removed and replaced with a new section. The elbow will be disposed of as radioactive waste.

### Survey Results

Activity detected on the process equipment is conservatively assumed to result from the presence of licensed material. A total of 352 measurements were made on areas of the furnace and associated equipment that were accessible before the new furnace tubes were put in place. Table 1 presents a summary of the monitoring data including minimum, average, and maximum values for subsets of the data. The total activity in these temporarily accessible areas was estimated and an overall average value was derived as a reasonably conservative estimate of the amount of the licensed material that might exist in those components remaining in use at the site after license termination. The overall average value which was used as a dose model input is provided in the table footnote, along with the maximum individual result.

The highest activity measured during the survey was located inside the pipe leading into D503, which is shown in Figure 3. This location was made accessible during the plant shut down when a large section of the pipe was replaced. A new section was put in place after the measurements were taken, and this location is no longer accessible to workers.

**Table 1. Furnace tube attachment points and downstream equipment summary**

	Attachment Points on Tubes 1 thru 20		Attachment Points on Tubes 21 thru 40		Attachment Points on Tubes 41 thru 60		Attachment Points on Tubes 61 thru 80		Attachment Points on Tubes 81 thru 84		Downstream	
	dpm/100cm <sup>2</sup>	pCi	dpm/100cm <sup>2</sup>	pCi	dpm/100cm <sup>2</sup>	pCi	dpm/100cm <sup>2</sup>	pCi	dpm/100cm <sup>2</sup>	pCi	dpm/100cm <sup>2</sup>	pCi
Min. total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max. total	2.02E+03	9.10E-10	2.02E+03	9.10E-10	4.55E+03	2.73E-09	3.03E+03	1.37E-09	4.00E+00	1.80E+00	9.09E+04	4.10E+04
Average total	1.40E+02	6.32E-11	1.65E+02	7.44E-11	3.13E+02	1.41E-10	1.02E+02	4.59E-11	8.13E-01	3.66E-01	8.81E+03	3.97E+03

The average and maximum values for all of the data in the table above that were used in modeling are as follows:

AVERAGE    dpm/100cm<sup>2</sup> = 1.59E+03    pCi= 6.61E+02  
 MAXIMUM    dpm/100cm<sup>2</sup> = 9.09E+04    pCi= 4.10E+04

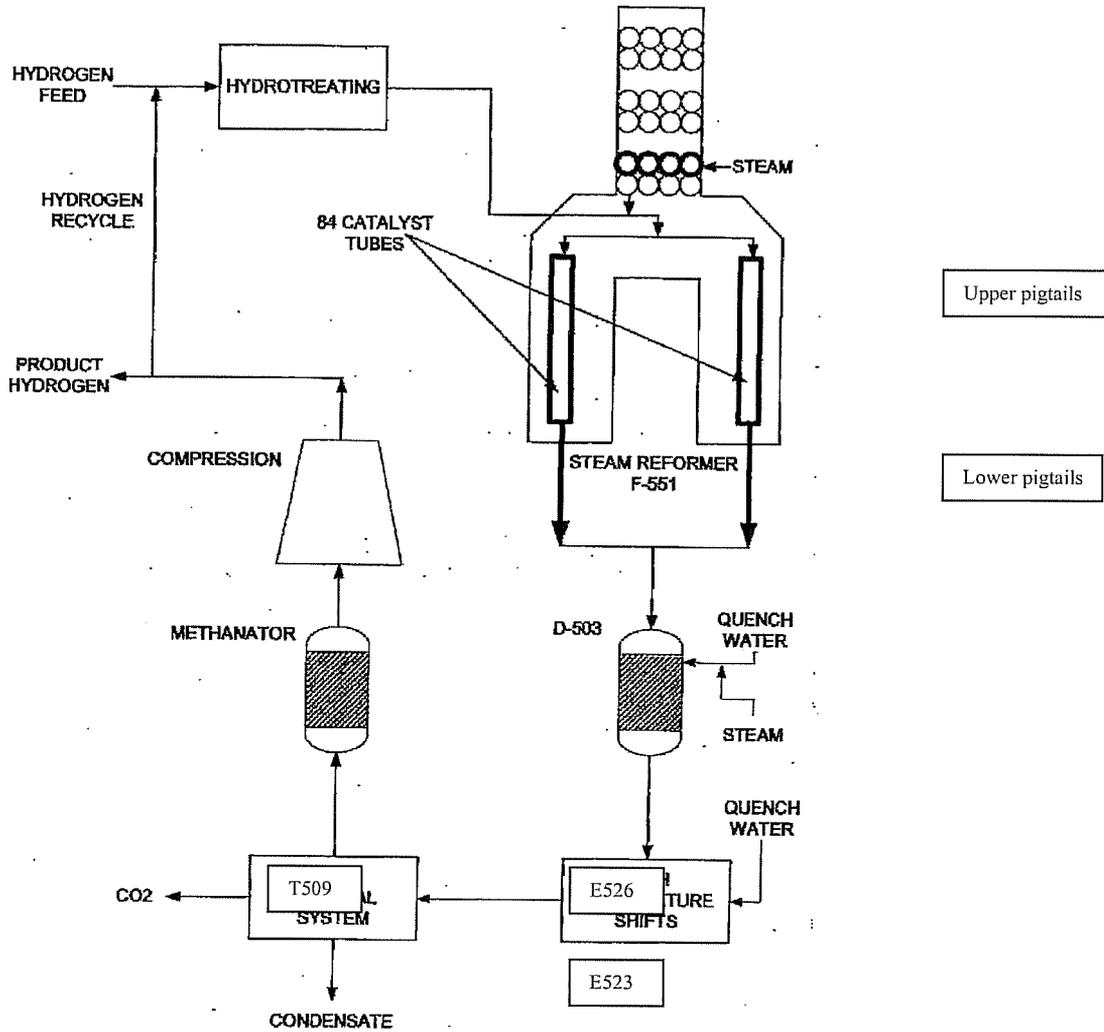
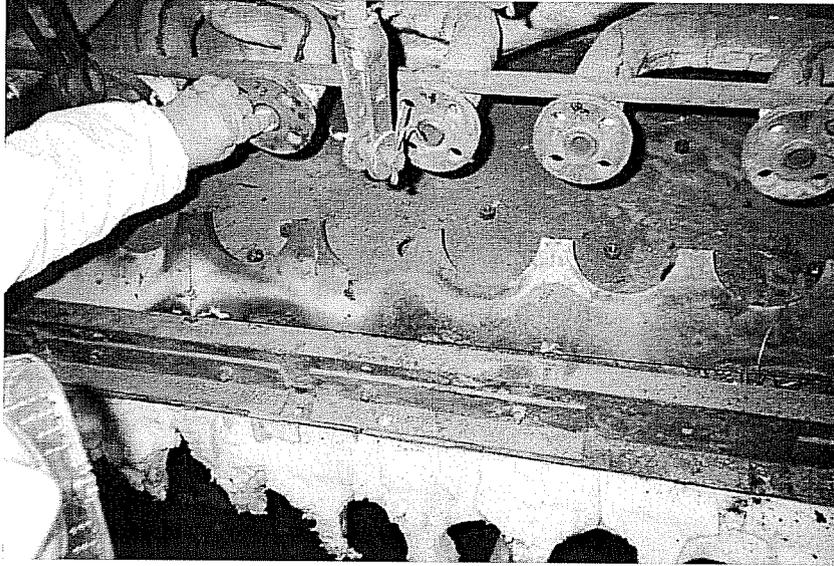
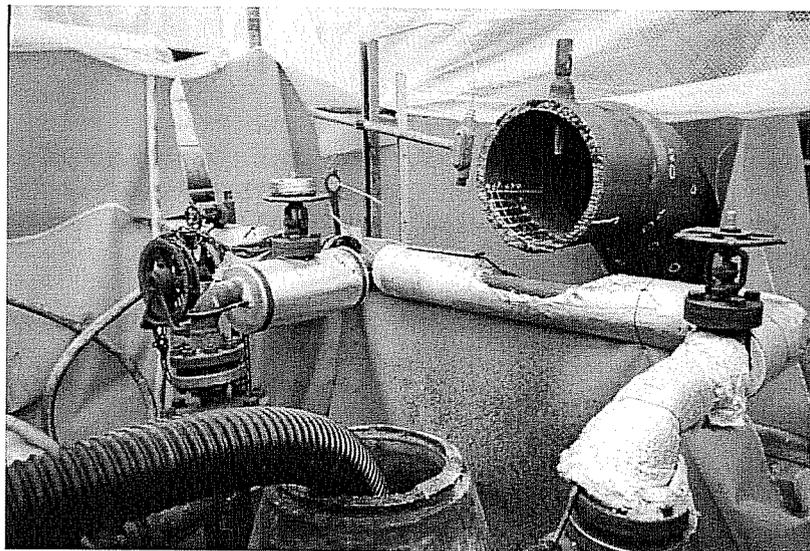


Figure 1. Process Schematic



**Figure 2. Pigtail attachment points**



**Figure 3. Downstream processing equipment - D503**

### 2.1.3 Potentially Impacted Areas

After the removal was complete and all furnace tubes and associated equipment had been surveyed, samples (soil or sediment) were collected at potentially impacted areas. The samples were submitted to an offsite laboratory for gamma spectroscopy analysis. If an area had been previously surveyed, those results may be used to support the final status survey if deemed appropriate. The following areas were designated as potentially impacted and sampled:

- Spent catalyst storage area – sump in the center of the staging area.
- Mechanical building (garage) – sump that runs the length of the garage.
- F551 furnace sump - sump below the furnace.
- F551 furnace perimeter- the perimeter of the foundation
- Background samples – samples collected in the parking lot outside of the fenced area of the plant.

Figures 4 through 9 show the potentially impacted areas of the plant that were surveyed. If radioactive materials were used or stored in an area, it was designated as a potentially impacted area and sampled. The samples were either soil or sediment and submitted to an offsite laboratory for radiochemical analysis.

#### Sample Results for the potentially impacted areas

Table 2 presents results from laboratory analyses of eight samples collected in potentially impacted areas and two samples from background locations. All samples were analyzed for uranium, but results that were below the laboratory detection limit are not shown. Minimum, average, and maximum values are shown at the bottom of the table and were calculated using only samples that had detectable uranium concentrations. The NRC-approved Derived Concentration Guideline Level (DCGL) for U-238 is equal to 1.4E+01 pCi/g.

**Table 2. Results for Samples from Potentially Impacted Areas**

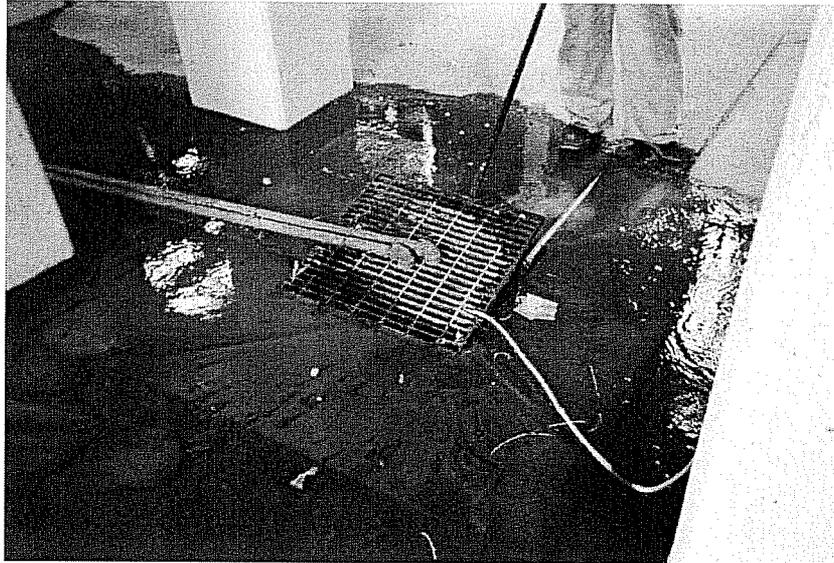
Sample Location	Radionuclide Identified	Laboratory Results	Units	pCi/g	Comments
F551 Sump	Uranium	3	mg/kg	0.9	Metals analysis
F551 Sump	Uranium	3.2	mg/kg	1.1	Metals analysis
Mechanical Garage	U-238	1.1	pCi/g	1.1	Assumed equilibrium with daughters (Pb-214).
	Th-232	1.2	pCi/g		Assumed equilibrium with daughters (Ra-228).
	K-40	19.3	pCi/g		Background value.
Mechanical Garage	U-238	2.3	pCi/g	1.1	Assumed equilibrium with daughters (Th-234).
	Th-232	1.2	pCi/g		Assumed equilibrium with daughters (Pb-212).
	K-40	18	pCi/g		Background value.
F551 Perimeter	U-238	1.3	pCi/g	1.3	Assumed equilibrium with daughters (Pb-214).
	Th-232	1.8	pCi/g		Assumed equilibrium with daughters (Ra-228).
	K-40	21	pCi/g		Background value.
F551 Perimeter	U-238	1.1	pCi/g	1.1	Assumed equilibrium with daughters (Pb-214).
	Th-232	1.9	pCi/g		Assumed equilibrium with daughters (Ra-228).
	K-40	19	pCi/g		Background value.
CSA - Drain	Th-232	1	pCi/g		Assumed equilibrium with daughters (Pb-212).
	K-40	22	pCi/g		Background value.
CSA - Drain	K-40	16.2	pCi/g		Background value.
Background	Th-232	1.2	pCi/g		Assumed equilibrium with daughters (Ra-228).
	K-40	23	pCi/g		Background value.
Background	K-40	23.6	pCi/g		Background value.
		Minimum		0.9	U-238 since it is radionuclide of interest.
		Average		1.1	U-238 since it is radionuclide of interest.
		Maximum		1.3	U-238 since it is radionuclide of interest.



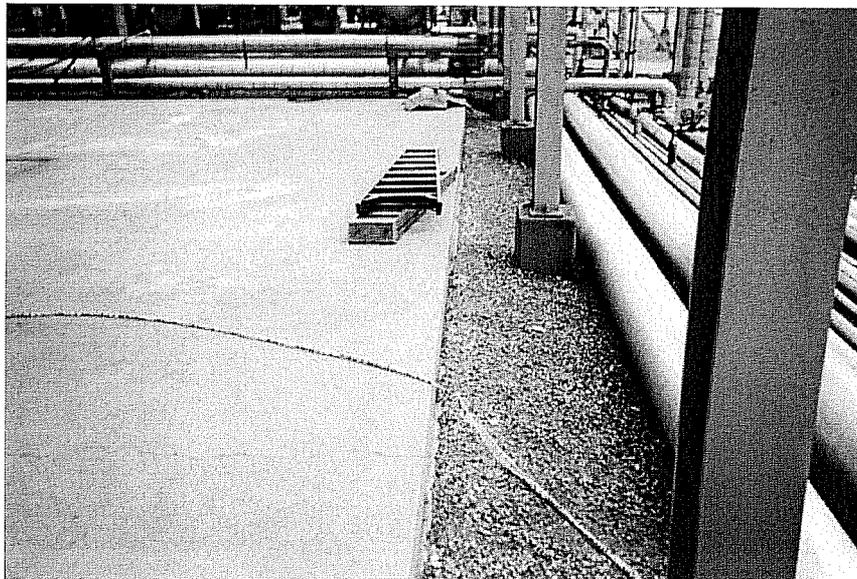
**Figure 4. Spent Catalyst Storage area**



**Figure 5. Mechanical Garage**



**Figure 6. F551 Sump**



**Figure 7. F551 perimeter**



**Figure 8. Background location # 1**



**Figure 9. Background location # 2**

#### **2.1.4 Material Cleared for Release**

The furnace tubes were moved to a low background radiation work area and each tube was surveyed externally and internally to determine the presence of residual radioactive contamination. The external surface was scanned to achieve 100% coverage with a handheld pancake GM survey meter. The inside of the furnace tubes were made accessible by removing the contents (catalyst and catalyst support cones, discussed in Section 2.2) and the upper and lower tube end flanges. The catalyst was removed following ExxonMobil procedure RMP-100-23. Interior surfaces were surveyed using the internal tube monitor described in Section 2.1.1.

The upper and lower tube end flanges and hardware (nuts and bolts) were segregated, placed on pallets, and designated as a survey units. The survey units were scanned to achieve 100% coverage with a hand-held pancake GM detector, followed by collection of swipe samples for removable contamination.

### 2.1.4.1 Furnace Tubes

Once the insides of the furnace tubes were made accessible, the tubes were placed on pipe racks to allow an internal tube monitor to pass through the center. The assembly was passed through the tube, rotated 90 degrees, and pulled back through the tube stopping at 10-cm increments in each direction for static counts. The 10-second static counts made at each stop resulted in 100% static coverage of the inside surfaces and a minimum detectable concentration (MDC) of 2,362/100cm<sup>2</sup> dpm. See Appendix D for MDC calculations.

The internal surfaces of each tube were monitored at 465 locations. A total of 41, 385 measurements were made for all 89 tubes. The minimum, average, and maximum results are presented in Table 3.

**Table 3. Data Summary for Furnace Tubes Removed from F551**

	dpm/100cm <sup>2</sup>	pCi
Minimum	2.02E+02	3.97E+04
Average	8.88E+02	1.75E+05
Maximum	2.12E+03	4.17E+05

Figure 10 shows the furnace tubes positioned on the pipe rack ready for surveying and the internal tube monitor passing through the center of one tube.



**Figure 10. F551 furnace tubes and survey tool**

### 2.1.4.2 Top end flanges (Survey Unit # 1)

The top end flanges were placed on a wooden pallet lined with Herculite. After a single layer was completed, the layer was surveyed for removable and fixed contamination and another layer was placed on top of the first and monitored in the same manner. The process was repeated until all the end flanges

on the pallet were surveyed. The results from the survey were combined, averaged, and reported in dpm/100cm<sup>2</sup> and picocuries.

There were four layers of flanges and 20 measurements were made on each layer for a total of 80 measurements. The minimum, average, and maximum values for each layer are presented in Table 4. The overall average and maximum values are presented in the table footnote.

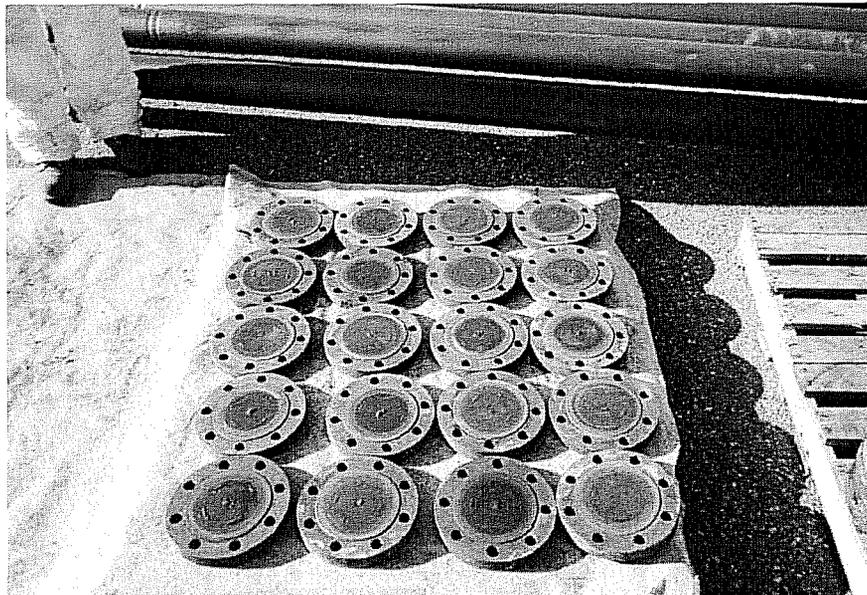
**Table 4. Data Summary for Top End Flanges (Survey Unit #1)**

	1st layer		2nd layer		3rd layer		4th layer	
	dpm/100cm <sup>2</sup>	pCi						
Minimum	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00
Average	5.08E+02	1.16E+03	1.06E+03	2.43E+03	2.54E+02	5.79E+02	2.03E+02	4.64E+02
Maximum	2.03E+03	4.62E+03	2.03E+03	4.62E+03	1.01E+03	2.31E+03	1.01E+03	2.31E+03

The average and maximum values for all of the data in the table above that were used in modeling are as follows:

Average dpm/100cm<sup>2</sup>= 5.07E+02 pCi= 1.16E+03  
 Maximum dpm/100cm<sup>2</sup>= 2.03E+03 pCi= 4.62E+03

Figure 11 shows the first layer of top end flanges positioned on the lined pallet ready for surveying. Each layer was surveyed with a handheld pancake GM, and then swipes were collected. This technique resulted in 100% scan coverage of each layer.



**Figure 11. Top end flanges Survey Unit # 1**

**2.1.4.3 Hardware Nuts and Bolts (Survey Unit # 3)**

The nuts and bolts were placed on a wooden pallet lined with Herculite. After a single layer was completed, the layer was surveyed for removable and fixed contamination. The process was repeated until all the nuts and bolts were on the pallet and surveyed. The results from the survey were combined, averaged, and reported in dpm/100cm<sup>2</sup> and picocuries. In order to determine surface area and report in dpm/100cm<sup>2</sup>, each layer was modeled as a tray with the dimensions of the pallet (4 ft long by 4 ft wide by 4 in. high).

Eight distinct measurements were recorded for the layer of bolts. The minimum, average, and maximum values are presented in Table 5.

**Table 5. Summary Data for Flange Nuts and Bolts (Survey Unit #3)**

	dpm/100cm <sup>2</sup>	pCi
Minimum	0.00E+00	0.00E+00
Average	2.53E+02	3.96E+04
Maximum	1.01E+03	1.58E+05

Figure 12 shows the end flange hardware after the surveying was completed. Layers of the hardware were surveyed using the handheld pancake GM meters, and swipe samples were collected.



**Figure 12. Hardware nuts and bolts Survey Unit # 3**

## 2.2 CONTAMINATED MATERIALS DISPOSAL

### 2.2.1 Bottom end flanges (Survey Unit #2)

The bottom end flanges were placed on a wooden pallet lined with Herculite. After a single layer was completed, the layer was surveyed for removable and fixed contamination and another layer was placed on top of the first and monitored in the same manner. The process was repeated until all the end flanges on the pallet were surveyed. The results from the survey were combined, averaged, and reported in dpm/100cm<sup>2</sup> and picocuries.

Figure 13 shows the first layer of bottom end flanges ready for surveying. After the results were reviewed, it was determined that the bottom end flanges contain detectable amounts of DU and will require disposal at a licensed radioactive waste site.



**Figure 13. Bottom end flanges Survey Unit # 2**

### **Survey results for bottom end flanges**

Bottom end flanges have detectable concentrations of DU and will be disposed of as radiological waste along with the catalyst support cones.

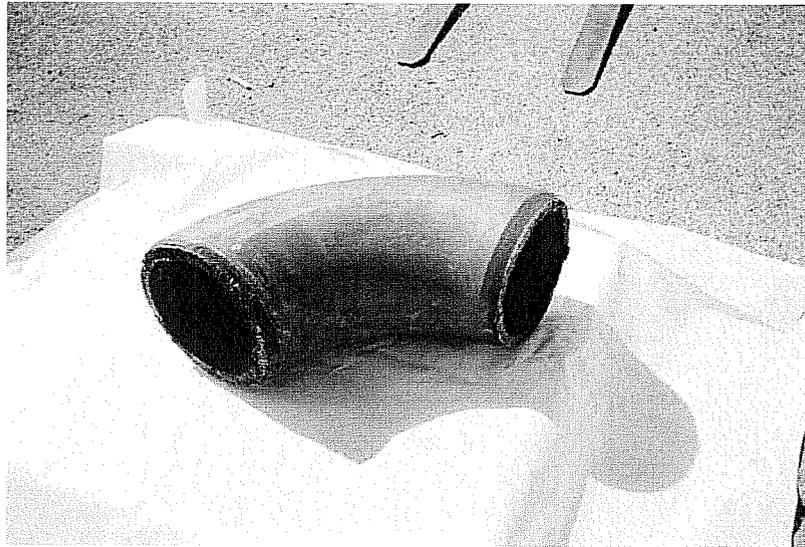
### **2.2.2 Pipe Elbow from D503 (Survey Unit #4)**

A pipe elbow was removed from the D503 process equipment. The section of pipe connects the manifold to the D503 refractory drum. The pipe was surveyed with a handheld GM pancake meter, and a swipe was collected for removable contamination. The section of pipe will be disposed along with the furnace tubes, end flanges, and hardware.

Figure 14 shows the pipe elbow removed from the inlet to D503 refractory drum. After the data were reviewed, results indicated that the elbow contains detectable amounts of DU and will be disposed of as radiological waste along with the catalyst support cones and the bottom end flanges.

### **Survey Results for pipe elbow**

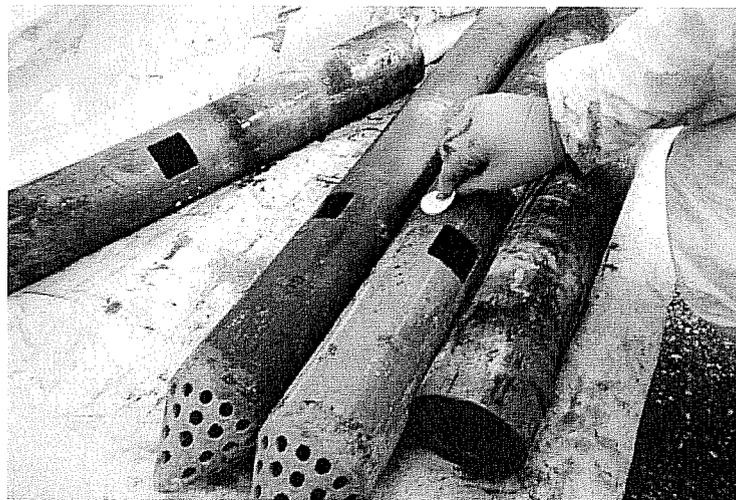
The D503 pipe elbow contains detectable concentrations of DU and will be disposed of as radiological waste along with the catalyst support cones and the bottom end flanges.



**Figure 14. D503 Pipe Elbow Survey Unit # 4**

### **2.2.3 Catalyst Support Cones**

Figures 15 shows wipe surveys being performed for several catalyst support cones removed from the inside of the furnace tubes. The catalyst support cones were surveyed to determine the radionuclide inventory for waste disposal purposes and placed into the radiological waste box as shown in Figure 16 for shipment to the approved waste disposal site.



**Figure 15. Survey of catalyst support cones**



**Figure 16. Catalyst support cones inside radiological waste box**

### 2.2.4 Catalyst Removed from Use

The catalyst had been regularly replaced several times since the uranium catalyst was last used in the 1980's and the current load was not expected to be significantly contaminated based on the negligible levels of loose contamination detected in the tubes. The catalyst was emptied from the tubes into 55-gallon drums and representative samples were collected and delivered to Energy Laboratories in Billings, MT. The samples were analyzed by gamma spectroscopy and the results were reported are provided in Table 6.

**Table 6. Uranium Concentrations in Catalyst Samples**

Sample No.	Radionuclide	Result (pCi/g)	Laboratory reporting Limit (pCi/g)
EM-Tube Catalyst-01	U-238	<1.0	1.0
EM-Tube Catalyst-02	U-238	<1.0	1.0
EM-Tube Catalyst-03	U-238	<1.0	1.0
EM-Tube Catalyst-04	U-238	<1.0	1.0
EM-Tube Catalyst-05	U-238	<1.0	1.0
EM-Tube Catalyst-06	U-238	<1.0	1.0
EM-Tube Catalyst-07	U-238	<1.0	1.0
EM-Tube Catalyst-08	U-238	<1.0	1.0
EM-Tube Catalyst-09	U-238	<1.0	1.0
EM-Tube Catalyst-10	u-238	<1.0	1.0

The results indicated that the spent catalyst is not contaminated with DU and therefore was disposed of as non-radioactive waste following ExxonMobil's Standard Operating Procedures.

## 3. DOSE MODELING

Using the field survey data collected, the potential dose can be determined using the NRC-approved computer model D and D (version 2.1.0). The survey data are converted from field values in counts per minute (cpm) to usable input values, such as disintegrations per minute per 100 centimeters squared (dpm/100cm<sup>2</sup>) and picocuries per gram (pCi/g) when appropriate.



The computer model uses set scenarios to calculate potential dose. The following scenarios were selected for this modeling:

- **Building Occupancy Scenario.** This scenario accounts for exposure to fixed and removable surface contamination on the walls, floor and ceiling of the facility. It assumes that the building may be used for commercial or light industrial (office or warehouse). Exposure pathways are external exposure from building surfaces, inhalation of re-suspended loose contamination, and inadvertent ingestion of removable surface contamination.
- **Resident Farmer Scenario.** This scenario accounts for exposure involving residual radioactivity in the surface soil. A resident farmer obtains some of his or her diet from produce grown on site and uses water from the aquifer beneath the site for drinking water and irrigation. Exposure pathways are external exposure from soil, inhalation of re-suspended soil, ingestion of soil, ingestion of drinking water, ingestion of plant products grown in contaminated soil and using ground water from the site for irrigation, ingestion of animal products grown onsite, and ingestion of fish from pond filled with ground water from the site.

The default parameters provided in the D and D computer model for the building occupancy and resident farmer scenario are used for modeling the furnace tubes, top end flanges, flange nuts and bolts, attachment points, and the downstream processing equipment. The potentially impacted areas were modeled using only the resident farmer scenario since the sample matrix is soil. The attachment points and downstream processing equipment were modeled as one unit because they are connected and one continuous system.

### 3.1 SCENARIO – BUILDING OCCUPANCY

**Critical Group** - In this building occupancy scenario the average member of the critical group is an individual that works in a commercial building. The individuals work conditions are: work area of 10 m<sup>2</sup>, working duration of 45 hrs/wk for 365 days, with an average breathing rate of 1.4 m<sup>3</sup>/hr. The input values are the defaults used in the D and D computer model.

**Source Term** - ExxonMobil is licensed by NRC for the use and storage of DU only. As mentioned in this report DU refers to U-238 and its associated decay products in equilibrium. The collection of data and conversion to dpm/100cm<sup>2</sup> is specific to each survey unit and listed in Table 7.

**Table 7. Survey Data for the Building Occupancy Scenario**

Survey unit	Data source	Input activity to model
Attachment points, upstream and downstream equipment.	Direct static and removable contamination measurements at each attachment point and accessible downstream processing equipment.	Average = 1.59E+03 dpm/100cm <sup>2</sup>
Furnace tubes	Direct static measurements of internal surface 100% scan coverage.	Average = 8.88E+02 dpm/100cm <sup>2</sup>
Top end flanges	Direct static and removable contamination measurements.	Average = 5.07E+02 dpm/100cm <sup>2</sup>
Flange Nuts and Bolts	Direct static and removable contamination measurements.	Average = 2.53E+02 dpm/100cm <sup>2</sup>
Potentially impacted areas	Soil samples analyzed for uranium activity.	Not considered in the building occupancy scenario.

#### 3.1.1 Exposure Pathways Considered

The following exposure pathways in the building occupancy scenario model are defined in NUREG/CR-5512 Volume 1.

- External exposure to penetrating radiation from surface sources,
- Inhalation of resuspended surface contamination, and
- Inadvertent ingestion of surface contamination.

### 3.1.2 D and D General Parameters

The default values provided in D and D version 2.1.0 for the following general input parameters are used with the exception of the resuspension factor for loose contamination (Rfo). This value was modified (constant value of  $9.6E-07 \text{ m}^{-1}$ ) as recommended in NUREG 1720 because the building occupancy scenario is dominated by the inhalation of the single radionuclide (U-238). The use of this modified resuspension factor was deemed appropriate after review of the five studies used in the development of NUREG 1720. The contamination present at this site has similar characteristic to that of the five studies used to re-evaluate the resuspension factor, with the most significant being aged mostly fixed contamination.

### 3.1.3 Building Occupancy Modeling Results

Table 8 provides the results for the building occupancy scenario.

**Table 8. Modeling Results for Building Occupancy Scenario**

Survey unit or description	90 <sup>th</sup> percentile TEDE
Attachment point up and downstream equipment.	3.22E+00 mrem/yr
Individual furnace tubes (89 Total).	1.80E+00 mrem/yr
Top end flanges.	1.03E+00 mrem/yr
End flange nuts and bolts.	5.12E-01 mrem/yr.
Potentially impacted areas	Not modeled in this scenario

## 3.2 SCENARIO – RESIDENT FARMER

**Critical Group** - In the resident farmer scenario the average member of the critical group is an individual who lives on the site where light farming takes place. The individual consumes produce, animal products, and fish from a pond on the site. The groundwater from the site is used as drinking water, irrigation, and to fill the pond. The input values are the defaults used in the D and D computer code.

**Source Term** - ExxonMobil is licensed by NRC for the use and storage of DU only. As mentioned in this report DU refers to U-238 and its associated decay products in equilibrium.

The results from the survey of each survey unit or area of interest were used to calculate the total inventory of U-238 in pCi (assumed to be alpha plus beta/gamma). The total U-238 inventory is assumed to be evenly distributed over a 2,500 m<sup>2</sup> area (as stated in NUREG/CR-5512) at a depth of 0.15 m. The soil activity concentration (pCi/g) is calculated using the area, depth, soil density and activity.

Area = 2500 m<sup>2</sup>  
 Depth = 0.15 m  
 Soil density = 1.6 E06 g/m<sup>3</sup>  
 U-238 activity = Total activity in pCi

Activity concentration (pCi/g) = (Total activity in pCi) ÷ [(2500 m<sup>2</sup>) x (0.15 m) x (1.6 E06 g/m<sup>3</sup>)]

The collection of data and conversion to pCi/g is specific to each area of interest and listed in Table 9.

**Table 9. Survey Data for the Resident Farmer Scenario**

Survey unit	Data source	Input activity to model
Attachment points, upstream and downstream equipment.	Direct static and removable contamination measurements.	1.10E-06 pCi/g
Furnace tubes	Direct static measurements of internal surface 100% scan coverage.	2.92E-04 pCi/g
Top end flanges	Direct static and removable contamination measurements.	1.93E-06 pCi/g
Flange nuts and bolts	Direct static and removable contamination measurements.	6.6E-05 pCi/g
Potentially impacted areas	Soil samples analyzed for uranium activity.	1.10E+00 pCi/g above background at one location F551 sump.

### 3.2.1 Exposure Pathways Considered

The exposure pathways for the residential scenario model are defined in NUREG/CR-5512 Volume 3. The radiation dose results from the exposure by external sources, inhalation, and ingestion of radioactive material.

The exposure pathways considered in the residential scenario are:

- External exposure to penetrating radiation from soil source while outside
- External exposure to penetrating radiation from soil source while inside
- Inhalation exposure to resuspended soil while outside
- Inhalation exposure to resuspended soil while inside
- Inhalation exposure to resuspended surface soils tracked inside
- Direct ingestion of soil
- Inadvertent ingestion of soil tracked inside
- Ingestion of drinking water from ground water
- Ingestion of plant products grown in contaminated soil
- Ingestion of plant products irrigated with contaminated ground water
- Ingestion of animal products grown onsite, and
- Ingestion of fish from a contaminated surface water source.

### 3.2.2 D and D General Parameters

The residential scenario requires the use of 652 input parameters. For the site evaluation all of the default parameters were used. Refer to the attached D and D Residential Scenario Report for a list.

### 3.2.3 Resident Farmer Dose Modeling Results

Table 10 provides the results for the building occupancy scenario.

**Table 10. Modeling Results for Resident Farmer Scenario**

Survey unit or description	90 <sup>th</sup> percentile TEDE
Attachment point up and downstream equipment.	2.13E-06 mrem/yr
Individual furnace tubes (89 Total).	7.60E-04 mrem/yr
Top end flanges.	3.74E-06 mrem/yr
End flange nuts and bolts.	1.28E-04 mrem/yr
Potentially impacted areas	2.13E+00 mrem/yr



#### 4. CONCLUSION

The results of the surveying, sample collection, and dose modeling indicate that the residual contamination present at the site would result in a potential dose of 2.13 mrem per year to the resident farmer and 6.56 mrem/yr to the building occupant. These values are well below the 25 mrem per year limit for license termination with unrestricted use.

The survey location with the highest detected activity was inside the pipe leading into D503 (refer to Figure 1 for a diagram of the process stream and location of D503 in relation to the furnace tubes and to Figure 3 for the actual survey location.) Under normal operating conditions, this location is not accessible to workers and therefore is not considered a radiological hazard requiring remediation.

## 5. REFERENCES

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**APPENDIX A**  
**CALCULATION OF SOURCE TERM INPUTS FOR DOSE MODELING**

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Appendix A contains the spreadsheets used to convert the field data results for each survey unit or area of interest, into the correct input source term values (i.e., counts per minute to disintegrations per minute or picoCuries). The following spreadsheets are contained in Appendix A.

- Attachment point characterization
- Downstream equipment characterization
- Furnace tube characterization
- Survey Unit #1 – Top end flange characterization
- Survey Unit #3 – Nuts and bolts
- Characterization of potentially impacted areas of plant



Item #	Item Information		Swipe Data		Direct Measurement Data		Activity Determination For Each Item			
	Surface area (cm2)	Direct Alpha Net (cpm)	Removable Alpha (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)
11A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11B-upper attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11C-lower attachment, inside	100	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
11D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12A-upper attachment, inside	100	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
12B-upper attachment, outside	100	20	0	4.04E+02	6.08E+02	1.01E+03	4.04E+02	6.08E+02	1.82E-10	2.73E-10
12C-lower attachment, inside	100	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
12D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13A-upper attachment, inside	100	20	0	4.04E+02	6.08E+02	1.01E+03	4.04E+02	6.08E+02	1.82E-10	2.73E-10
13B-upper attachment, outside	100	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
13C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.39E-12	0.00E+00
14B-upper attachment, outside	100	0	3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	6.00E+00	0.00E+00	2.70E-12	0.00E+00
14D-lower attachment, outside	100	0	6	0.00E+00	0.00E+00	0.00E+00	6.00E+00	0.00E+00	0.00E+00	0.00E+00
15A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15B-upper attachment, outside	100	20	2	4.04E+02	6.08E+02	1.01E+03	4.06E+02	6.06E+02	1.83E-10	2.73E-10
15C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15D-lower attachment, outside	100	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
16A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16B-upper attachment, outside	100	0	5	0.00E+00	0.00E+00	0.00E+00	5.00E+00	0.00E+00	2.25E-12	0.00E+00
16C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16D-lower attachment, outside	100	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
17A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17B-upper attachment, outside	100	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
17C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18A-upper attachment, inside	100	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
18B-upper attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18C-lower attachment, inside	100	0	10	0.00E+00	0.00E+00	0.00E+00	1.00E+01	0.00E+00	4.50E-12	0.00E+00
18D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19A-upper attachment, inside	100	0	5	0.00E+00	0.00E+00	0.00E+00	5.00E+00	0.00E+00	2.25E-12	0.00E+00
19B-upper attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19D-lower attachment, outside	100	0	4	0.00E+00	0.00E+00	0.00E+00	4.00E+00	0.00E+00	1.80E-12	0.00E+00
20A-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20B-upper attachment, outside	100	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
20C-lower attachment, inside	100	40	1	8.08E+02	1.21E+03	2.02E+03	8.09E+02	1.21E+03	3.64E-10	5.46E-10
20D-lower attachment, outside	100	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
Total			1,15E+02	4,44E+03	6,87E+03	6,87E+03	4,56E+03	6,87E+03	2,05E-09	3,00E-09
Minimum			0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Average			1,44E+00	5,56E+01	8,33E+01	8,33E+01	5,70E+01	8,33E+01	2,57E-11	3,75E-11
Maximum			1,00E+01	8,08E+02	1,21E+03	1,21E+03	8,09E+02	1,21E+03	3,64E-10	5,46E-10
Std. dev.			2,06	154,07	231,11	231,11	153,86	231,11	0,00	0,00
									Average (pCi)	3,75E+01
									Maximum (pCi)	3,64E+02

Radiological Characterization

F551 furnace tube attachment points "pigtail" attachments upstream and downstream" tubes 21 - 40.

Constants	15	Alpha probe active area (cm2)
	0.33	Alpha efficiency for Depleted Uranium from manufacturer
	15	Beta probe area (cm2)
	0.22	Beta probe efficiency for Sr/Y-90 from manufacturer
Conversions		
	(cpm)/(instrument area)/(instrument efficiency) = dpm/cm2	
	(dpm/cm2)*(total area)/(2.22E12 Ciddpm) = Ci	
	(dpm/f)(100 cm2)/(2.22E12 Ciddpm) = Ci	
	2.22E+12	dpm/Ci

Surface Area Formulas	
Open right circular cylinder SA: (Pi x D x L)	
Closed right circular cylinder SA: (Pi x D x L) + (2*Pi*H*D^2)	
Box Surface Area = LxWx2 + LxHx2 + WxHx2	
Donut Surface Area = (Pi x L) x (Pi x D)	
Disk Surface Area = Pi / 4 x D^2	
Tray Surface Area = LxWx2 + LxHx2 + WxHx2	

Item #	Item Information			Swipe Data		Direct Measurement Data			Activity Determination For Each Item		
	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Direct Alpha Net (cpm)	Removable Alpha (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)
21A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21B-upper attachment, outside	100	0	0	6	0.00E+00	0.00E+00	0.00E+00	6.00E+00	0.00E+00	2.70E-12	0.00E+00
21C-lower attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
21D-lower attachment, outside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
22A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22B-upper attachment, outside	100	0	0	6	0.00E+00	0.00E+00	0.00E+00	6.00E+00	0.00E+00	2.70E-12	0.00E+00
22C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
22D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
23B-upper attachment, outside	100	0	0	4	0.00E+00	0.00E+00	0.00E+00	4.00E+00	0.00E+00	1.80E-12	0.00E+00
23C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23D-lower attachment, outside	100	0	0	6	0.00E+00	0.00E+00	0.00E+00	6.00E+00	0.00E+00	2.70E-12	0.00E+00
24A-upper attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
24B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
24C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
24D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25A-upper attachment, inside	100	20	20	2	4.04E+02	6.06E+02	6.06E+02	1.01E+03	4.06E+02	1.89E-10	2.73E-10
25B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
25C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26A-upper attachment, inside	100	20	20	0	4.04E+02	6.06E+02	6.06E+02	1.01E+03	4.04E+02	1.82E-10	2.73E-10
26B-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26C-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26D-lower attachment, inside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
27A-upper attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
27B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
27C-lower attachment, inside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
27D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
28A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
28B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
28C-lower attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
28D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
29A-upper attachment, inside	100	20	20	0	4.04E+02	6.06E+02	6.06E+02	1.01E+03	4.04E+02	1.82E-10	2.73E-10
29B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
29C-lower attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
29D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
30A-upper attachment, inside	100	20	20	0	4.04E+02	6.06E+02	6.06E+02	1.01E+03	4.04E+02	1.82E-10	2.73E-10
30B-upper attachment, outside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
30C-lower attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
30D-lower attachment, outside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00

Item Information			Swipe Data			Direct Measurement Data			Activity Determination For Each Item					
Item #	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Removable Alpha (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)				
31A-upper attachment, inside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
31B-upper attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
31C-lower attachment, inside	100	40	1	8.08E+02	1.21E+03	2.02E+03	8.09E+02	1.21E+03	3.64E-10	5.46E-10				
31D-lower attachment, outside	100	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00				
32A-upper attachment, inside	100	20	1	4.04E+02	6.06E+02	1.01E+03	4.05E+02	6.06E+02	1.82E-10	2.73E-10				
32B-upper attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
32C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
32D-lower attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
33A-upper attachment, inside	100	20	1	4.04E+02	6.06E+02	1.01E+03	4.05E+02	6.06E+02	1.82E-10	2.73E-10				
33B-upper attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
33C-lower attachment, inside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
33D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
34A-upper attachment, inside	100	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00				
34B-upper attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
34C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
34D-lower attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
35A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
35B-upper attachment, outside	100	20	1	4.04E+02	6.06E+02	1.01E+03	4.05E+02	6.06E+02	1.82E-10	2.73E-10				
35C-lower attachment, inside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
35D-lower attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
36A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
36B-upper attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
36C-lower attachment, inside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
36D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
37A-upper attachment, inside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
37B-upper attachment, outside	100	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00				
37C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
37D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
38A-upper attachment, inside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
38B-upper attachment, outside	100	20	0	4.04E+02	6.06E+02	1.01E+03	4.05E+02	6.06E+02	1.82E-10	2.73E-10				
38C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
38D-lower attachment, outside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
39A-upper attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
39B-upper attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
39C-lower attachment, inside	100	0	3	0.00E+00	0.00E+00	3.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00				
39D-lower attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
40A-upper attachment, inside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
40B-upper attachment, outside	100	20	0	4.04E+02	6.06E+02	1.01E+03	4.05E+02	6.06E+02	1.82E-10	2.73E-10				
40C-lower attachment, inside	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
40D-lower attachment, outside	100	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00				
<b>Total</b>			<b>8.60E+01</b>	<b>5.29E+03</b>	<b>7.88E+03</b>	<b>1.32E+04</b>	<b>5.34E+03</b>	<b>7.88E+03</b>	<b>2.40E-09</b>	<b>3.55E-09</b>				
<b>Minimum</b>			<b>0.00E+00</b>	<b>0.00E+00</b>	<b>0.00E+00</b>	<b>0.00E+00</b>	<b>0.00E+00</b>	<b>0.00E+00</b>	<b>0.00E+00</b>	<b>0.00E+00</b>				
<b>Average</b>			<b>1.08E+00</b>	<b>6.57E+01</b>	<b>9.85E+01</b>	<b>1.65E+02</b>	<b>6.67E+01</b>	<b>9.85E+01</b>	<b>3.01E-11</b>	<b>4.44E-11</b>				
<b>Maximum</b>			<b>6.00E+00</b>	<b>2.02E+03</b>	<b>1.21E+03</b>	<b>2.02E+03</b>	<b>8.09E+02</b>	<b>1.21E+03</b>	<b>3.64E-10</b>	<b>5.46E-10</b>				
<b>Std. dev.</b>			<b>1.38</b>	<b>163.19</b>	<b>244.79</b>	<b>407.85</b>	<b>163.07</b>	<b>244.79</b>	<b>0.00</b>	<b>0.00</b>				
									<b>Average (pCi)</b>	<b>3.01E+01</b>				
									<b>Maximum (pCi)</b>	<b>5.46E+02</b>				

Radiological Characterization

F551 furnace tube attachment points "pigtail attachments upstream and downstream" tubes 41 - 60.

Constants	Alpha probe active area (cm2)
0.33	Alpha efficiency for Depleted Uranium from manufacturer
15	Beta probe area (cm2)
0.22	Beta probe efficiency for Sr/Y-90 from manufacturer
Conversions	
(cpm)/(instrument area)/(instrument efficiency) = dpm/cm2	
(dpm/cm2)*(total area)/(2.22E12 Ci/dpm) = Ci	
(dpm/f)/(100 cm2)/(2.22E12 Ci/dpm) = Ci	
2.22E+12	dpm/Ci

Surface Area Formulas	
Open right circular cylinder SA: (Pi x D x L)	
Closed right circular cylinder SA: (Pi x D x L) + (2*Pi*(D^2)/4)	
Box Surface Area = LxWx2 + LxHx2 + WxHx2	
Donut Surface Area = (Pi x L) x (Pi x D)	
Disk Surface Area = Pi/4 x D^2	
Tray Surface Area = LxWx2 + LxHx2 + WxHx2	

Item #	Item Information			Swipe Data		Direct Measurement Data		Activity Determination For Each Item			
	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Direct Alpha Net (cpm)	Removable Alpha (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)
41A-upper attachment, inside	100	0	0	3	0.00E+00	0.00E+00	3.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
41B-upper attachment, outside	100	0	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
41C-lower attachment, inside	100	20	20	0	4.04E+02	6.06E+02	1.01E+03	4.04E+02	6.06E+02	1.82E-10	2.73E-10
41D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
42A-upper attachment, inside	100	0	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
42B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
42C-lower attachment, inside	100	0	0	6	0.00E+00	0.00E+00	6.00E+00	6.00E+00	0.00E+00	2.70E-12	0.00E+00
42D-lower attachment, outside	100	0	0	3	0.00E+00	0.00E+00	3.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
43A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
43B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
43C-lower attachment, inside	100	0	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
43D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
44D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
45D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
46A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
46B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
46C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
46D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
47A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
47B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
47C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
47D-lower attachment, outside	100	0	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
48A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
48B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
49A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
49B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
49C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
49D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00

Item #	Item Information			Swipe Data		Direct Measurement Data		Activity Determination For Each Item					
	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Direct Alpha Net (cpm)	Removable Alpha (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)	Average (pCi)	Maximum (pCi)
50A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
50B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
50C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
50D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
51A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
51B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
51C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
51D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
52A-upper attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
52B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
52C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
52D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53C-lower attachment, inside	100	140	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
54A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
54B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
54C-lower attachment, inside	100	80	80	3	1.62E+03	2.42E+03	4.04E+03	1.00E+00	1.62E+03	2.42E+03	4.04E+03	7.28E-10	1.09E-09
54D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
55A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
55B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
55C-lower attachment, inside	100	90	90	1	1.82E+03	2.73E+03	4.55E+03	1.00E+00	1.82E+03	2.73E+03	4.55E+03	8.19E-10	1.23E-09
55D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
56A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
56B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
56C-lower attachment, inside	100	80	80	0	1.62E+03	2.42E+03	4.04E+03	1.00E+00	1.62E+03	2.42E+03	4.04E+03	7.28E-10	1.09E-09
56D-lower attachment, outside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
57A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
57B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
57C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
57D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
58A-upper attachment, inside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
58B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
58C-lower attachment, inside	100	80	80	1	1.62E+03	2.42E+03	4.04E+03	1.00E+00	1.62E+03	2.42E+03	4.04E+03	7.28E-10	1.09E-09
58D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
59A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
59B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
59C-lower attachment, inside	100	60	60	0	1.21E+03	1.82E+03	3.03E+03	1.00E+00	1.21E+03	1.82E+03	3.03E+03	5.46E-10	8.19E-10
59D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
60A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
60B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
60C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
60D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
<b>Total</b>				<b>5.70E+01</b>								<b>740.06</b>	<b>9.38E+01</b>
<b>Minimum</b>				<b>0.00E+00</b>								<b>388.46</b>	<b>8.19E+02</b>
<b>Average</b>				<b>7.13E-01</b>									
<b>Maximum</b>				<b>6.00E+00</b>									
<b>Std. dev.</b>				<b>1.02</b>									

Radiological Characterization

F551 furnace tube attachment points "pigtail attachments upstream and downstream" tubes 61 - 80.

Constants	Alpha probe active area (cm2)
0.33	Alpha efficiency for Depleted Uranium from manufacturer
15	Beta probe area (cm2)
0.22	Beta probe efficiency for Sr/Y-90 from manufacturer
Conversions	
	(cpm)/(instrument area)/(instrument efficiency) = dpm/cm2
	(dpm/cm2)/(total area)/(2.22E12 C/dpm) = Ci
2.22E+12	dpm/Ci

Surface Area Formulas	
Open right circular cylinder SA: (Pi x D x L)	
Closed right circular cylinder SA: (Pi x D x L) + (2*Pi*(D/2)^2)	
Box Surface Area = LxWx2 + LxHx2 + WxHx2	
Donut Surface Area = (Pi x L) x (Pi x D)	
Disk Surface Area = Pi / 4 x D^2	
Tray Surface Area = LxWx2 + LxHx2 + WxHx2	

Item #	Item Information			Swipe Data		Direct Measurement Data		Activity Determination For Each Item			
	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Direct Alpha Net (cpm)	Removable Alpha (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)
61A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61C-lower attachment, inside	100	40	40	0	8.08E+02	0.00E+00	2.02E+03	8.09E+02	1.21E+03	3.64E-10	5.46E-10
61D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
62A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
62B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
62C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
62D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
63A-upper attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
63B-upper attachment, outside	100	0	0	5	0.00E+00	0.00E+00	0.00E+00	5.00E+00	0.00E+00	2.25E-12	0.00E+00
63C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
63D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
64A-upper attachment, inside	100	0	0	4	0.00E+00	0.00E+00	0.00E+00	4.00E+00	0.00E+00	1.80E-12	0.00E+00
64B-upper attachment, outside	100	0	0	5	0.00E+00	0.00E+00	0.00E+00	5.00E+00	0.00E+00	2.25E-12	0.00E+00
64C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64D-lower attachment, outside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
65A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65B-upper attachment, outside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
65C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
66B-upper attachment, outside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
66C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
67A-upper attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00
67B-upper attachment, outside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
67C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
67D-lower attachment, outside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	1.35E-12	0.00E+00
68A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
68B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
68C-lower attachment, inside	100	60	60	1	1.21E+03	1.82E+03	3.03E+03	1.21E+03	1.82E+03	5.46E-10	8.19E-10
68D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
69A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	4.50E-13	0.00E+00
69B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
69C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
69D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

70A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
70B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
70C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
70D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
71A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
71B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
71C-lower attachment, inside	100	40	40	2	8.08E+02	1.21E+03	2.02E+03	8.10E+02	1.21E+03	3.69E-10	5.49E-10	0.00E+00
71D-lower attachment, outside	100	0	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	0.00E+00	9.01E-13	0.00E+00
72A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
72B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
72C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
72D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
73A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
73B-upper attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
73C-lower attachment, inside	100	20	20	0	4.04E+02	6.06E+02	1.01E+03	4.04E+02	6.06E+02	1.82E-10	2.73E-10	0.00E+00
73D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
74A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
74B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
74C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
74D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
75A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
75B-upper attachment, outside	100	0	0	3	0.00E+00	0.00E+00	3.00E+00	3.00E+00	0.00E+00	0.00E+00	1.35E-12	0.00E+00
75C-lower attachment, inside	100	0	0	4	0.00E+00	0.00E+00	4.00E+00	4.00E+00	0.00E+00	0.00E+00	1.80E-12	0.00E+00
75D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
76A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
76B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
76C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
76D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
77A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
77B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
77C-lower attachment, inside	100	0	0	3	0.00E+00	0.00E+00	3.00E+00	3.00E+00	0.00E+00	0.00E+00	1.35E-12	0.00E+00
77D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
78A-upper attachment, inside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
78B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
78C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
78D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
79A-upper attachment, inside	100	0	0	4	0.00E+00	0.00E+00	4.00E+00	4.00E+00	0.00E+00	0.00E+00	1.80E-12	0.00E+00
79B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
79C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
79D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00	4.50E-13	0.00E+00
80A-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
80B-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
80C-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
80D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total				7.50E+01	3.23E+03	4.85E+03	8.16E+03	3.31E+03	4.85E+03	1.86E+01	2.73E+01	0.00E+00
Minimum				0.00E+00	0.00E+00	0.00E+00						
Average				9.38E-01	4.04E+01	6.06E+01	1.02E+02	4.13E+01	6.06E+01	1.86E+01	2.73E+01	0.00E+00
Maximum				5.00E+00	1.21E+03	1.82E+03	3.03E+03	1.21E+03	1.82E+03	5.48E+10	8.19E+10	0.00E+00
Std. dev.				1.25	188.53	282.79	471.36	188.57	282.79	0.00	0.00	0.00
										Average (pCi)	1.86E+01	2.73E+01
										Maximum (pCi)	5.48E+02	8.19E+02

F551 furnace tube attachment points "pigtail attachments upstream and downstream" tubes 61 - 84.

15	Alpha probe active area (cm2)
0.33	Alpha efficiency for Depleted Uranium from manufacturer
15	Beta probe area (cm2)
0.22	Beta probe efficiency for SrY-90 from manufacturer
<b>Conversions</b>	
$(\text{cpm})/(\text{instrument area})/(\text{instrument efficiency}) = \text{dpm/cm}^2$	
$(\text{dpm/cm}^2)/(\text{total area})/(\text{2.22E12 Ci/dpm}) = \text{Ci}$	
$(\text{dpm/fi}/100 \text{ cm}^2)/(\text{total area})/(\text{2.22E12 Ci/dpm}) = \text{Ci}$	
dpm/Ci	

<b>Surface Area Formulas</b>	
Open right circular cylinder SA: $(\pi \times D \times L)$	
Closed right circular cylinder SA: $(\pi \times D \times L) + (\pi \times D^2/4 \times D^2)$	
Box Surface Area = $L \times W \times 2 + L \times H \times 2 + W \times H \times 2$	
Donut Surface Area = $(\pi \times L) \times (\pi \times D)$	
Disk Surface Area = $\pi \times L \times D^2$	
Tray Surface Area = $L \times W \times 2 + L \times H \times 2 + W \times H \times 2$	

Item #	Item Information			Swipe Data		Direct Measurement Data			Activity Determination For Each Item					
	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Direct Alpha Net (cpm)	Removable Alpha (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)	Average (pCi)	Maximum (pCi)	
81A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
81B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
81C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
81D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
82A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
82B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
82C-lower attachment, inside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
82D-lower attachment, outside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
83A-upper attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
83B-upper attachment, outside	100	0	0	2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
83C-lower attachment, inside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
83D-lower attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
84A-upper attachment, inside	100	0	0	3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
84B-upper attachment, outside	100	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
84C-lower attachment, inside	100	0	0	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
84D-lower attachment, outside	100	0	0	4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
<b>Total</b>				1.30E+01	0.00E+00	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
<b>Minimum</b>				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
<b>Average</b>				8.13E-01	0.00E+00	0.00E+00	0.00E+00	8.13E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
<b>Maximum</b>				4.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
<b>Std. dev.</b>				1.28	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
<b>Average (pCi)</b>											3.66E-01	0.00E+00		
<b>Maximum (pCi)</b>											1.80E+00	0.00E+00		

F551 furnace downstream processing equipment.

Constants	Alpha probe active area (cm2)	15
0.33	Alpha efficiency for Depleted Uranium from manufacturer	
15	Beta probe area (cm2)	
0.22	Beta probe efficiency for SrY-90 from manufacturer	
Conversions		
(cpm)/(instrument area)/(instrument efficiency) = dpm/cm2		
(dpm/cm2)/(total area)/(2.22E12 C/dpm) = Ci		
2.22E+12	dpm/Ci	
Surface Area Formulas		
Open right circular cylinder SA: (PI x D x L)		
Closed right circular cylinder SA: (PI x D x L) + (2*PI/4*DP <sup>2</sup> )		
Box Surface Area = LxWx2 + LxHx2 + WxHx2		
Donut Surface Area = (PI x L) x (PI x D)		
Disk Surface Area = PI/4 x D <sup>2</sup>		
Tray Surface Area = LxWx2 + LxHx2 + WxHx2		

Item #	Item Information		Swipe Data		Direct Measurement Data		Activity Determination For Each Item				
	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Removable Alpha (dpm/100cm <sup>2</sup> )	Direct Alpha (dpm/100cm <sup>2</sup> )	Direct Beta-Gamma (dpm/100cm <sup>2</sup> )	Total (dpm/100cm <sup>2</sup> )	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)	
D-503 Drum (D503-2)	100	100	3	2.02E+03	3.03E+03	5.05E+03	2.02E+03	3.03E+03	9.11E-10	1.37E-09	
D-503 Contents (D503-1)	100	120	5	2.42E+03	3.64E+03	6.07E+03	2.43E+03	3.64E+03	1.09E-09	1.64E-09	
D-503 pipe (D503-S1)	100	200	1	4.04E+03	6.06E+03	1.01E+04	4.04E+03	6.06E+03	1.82E-09	2.73E-09	
D-503 pipe (D503-S2)	100	150	3	3.03E+03	4.55E+03	7.58E+03	3.03E+03	4.55E+03	1.37E-09	2.05E-09	
D-503 pipe (D503-S3)	100	1800	0	3.64E+04	5.45E+04	9.09E+04	3.64E+04	5.45E+04	1.64E-08	2.46E-08	
D-503 pipe (D503-S4)	100	300	2	6.06E+03	9.09E+03	1.52E+04	6.06E+03	9.09E+03	2.73E-09	4.10E-09	
D-503 pipe (D503-S5)	100	0	5	0.00E+00	0.00E+00	5.00E+00	5.00E+00	0.00E+00	2.25E-12	0.00E+00	
D-503 pipe (D503-S6)	100	0	2	0.00E+00	0.00E+00	2.00E+00	2.00E+00	0.00E+00	9.01E-13	0.00E+00	
D-503 pipe (D503-S7)	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
D-503 pipe (D503-S8)	100	0	6	0.00E+00	0.00E+00	6.00E+00	6.00E+00	0.00E+00	2.70E-12	0.00E+00	
E523-A	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
E523-B	100	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
E526-A	100	20	0	4.04E+02	6.06E+02	1.01E+03	4.04E+02	6.06E+02	1.82E-10	2.73E-10	
E526-B	100	20	0	4.04E+02	6.06E+02	1.01E+03	4.04E+02	6.06E+02	1.82E-10	2.73E-10	
T509-A	100	40	0	8.08E+02	1.21E+03	2.02E+03	8.08E+02	1.21E+03	3.64E-10	5.46E-10	
T509-B	100	40	1	8.08E+02	1.21E+03	2.02E+03	8.08E+02	1.21E+03	3.64E-10	5.46E-10	
Total			2.80E+01	5.64E+04	8.45E+04	1.41E+05	8.45E+04	8.45E+04	2.54E-08	3.81E-08	
Minimum			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Average			1.75E+00	3.52E+03	5.28E+03	8.81E+03	5.28E+03	5.28E+03	1.59E-09	2.38E-09	
Maximum			6.00E+00	3.64E+04	5.45E+04	9.09E+04	3.64E+04	5.45E+04	1.64E-08	2.46E-08	
Std. dev.			2.08	8935.28	13402.93	22337.80	8934.88	13402.93	0.00	0.00	
								Average (pCi)	1.59E+03	2.38E+03	
								Maximum (pCi)	1.64E+04	2.46E+04	

**Furnace Tube Radiological Characterization**

Furnace tubes removed from F551 hydrogen reformer furnace. Tubes once contained depleted uranium catalyst.

Constants	15
Alpha probe active area (cm <sup>2</sup> )	0.33
Alpha efficiency for Depleted Uranium from manufacturer	15
Beta probe area (cm <sup>2</sup> )	0.22
Beta probe efficiency for Sr-90 from manufacturer	

Conversions	(cpm)/(instrument area)/(instrument efficiency) = dpm/cm <sup>2</sup>
	(dpm/cm <sup>2</sup> )/(total area)/(2.22E12 C/dpm) = Ci
	(dpm)/(100 cm <sup>2</sup> )/(total area)/(2.22E12 C/dpm) = Ci
	2.22E+12

Surface Area Formulas	
Open right circular cylinder SA: (Pi x D x L)	
Closed right circular cylinder SA: (Pi x D x L) + (2 x Pi x D <sup>2</sup> /4)	
Box Surface Area = LxWx2 + LxHx2 + WxHx2	
Donut Surface Area = (Pi x L) x (Pi x D)	
Disk Surface Area = Pi / 4 x D <sup>2</sup>	
Tray Surface Area = LxWx2 + LxHx2 + WxHx2	
Tray Dimensions = 30" x 20" x 2"	
NOTE: Multiply by 2 for internal and external contamination.	
Parcel Information	

**Contamination Measurement Data**

**Activity Determination For Each Item**

Item #	Description	Item Modeled AS	Surface Area (cm <sup>2</sup> )	Average Direct Beta-Gamma (net cpm)	Average Direct Alpha (net cpm)	Direct Alpha (dpm/100cm <sup>2</sup> )	Direct Beta-Gamma (dpm/100cm <sup>2</sup> )	Total dpm/100cm <sup>2</sup>	Direct Alpha (dpm)	Direct Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)
Tube 1	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	19	19	3.84E+02	5.76E+02	9.60E+02	1.68E+05	2.51E+05	7.59E-08	1.13E-07
Tube 2	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	22	21	4.44E+02	6.67E+02	1.11E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 3	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	21	21	4.44E+02	6.67E+02	1.11E+03	1.86E+05	2.79E+05	8.35E-08	1.25E-07
Tube 4	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	26	26	5.25E+02	7.88E+02	1.31E+03	2.29E+05	3.44E+05	1.03E-07	1.56E-07
Tube 5	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	18	18	3.64E+02	5.46E+02	9.10E+02	1.59E+05	2.39E+05	7.15E-08	1.07E-07
Tube 6	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	23	23	4.65E+02	6.98E+02	1.16E+03	2.03E+05	3.04E+05	9.14E-08	1.37E-07
Tube 7	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	20	20	4.04E+02	6.06E+02	1.01E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 8	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	22	22	4.44E+02	6.67E+02	1.11E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 9	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	5	5	1.01E+02	1.52E+02	2.53E+02	4.41E+04	6.62E+04	1.98E-08	2.98E-08
Tube 10	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	13	13	2.63E+02	3.95E+02	6.57E+02	1.16E+05	1.72E+05	5.17E-08	7.75E-08
Tube 11	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	15	15	3.03E+02	4.55E+02	7.58E+02	1.32E+05	1.98E+05	5.96E-08	8.94E-08
Tube 12	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	10	10	2.02E+02	3.03E+02	5.05E+02	8.82E+04	1.32E+05	3.97E-08	5.96E-08
Tube 13	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	13	13	2.63E+02	3.95E+02	6.57E+02	1.16E+05	1.72E+05	5.17E-08	7.75E-08
Tube 14	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	18	18	3.64E+02	5.46E+02	9.10E+02	1.59E+05	2.39E+05	7.15E-08	1.07E-07
Tube 15	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	21	21	4.24E+02	6.36E+02	1.06E+03	1.86E+05	2.79E+05	8.35E-08	1.25E-07
Tube 16	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	23	23	4.65E+02	6.98E+02	1.16E+03	2.03E+05	3.04E+05	9.14E-08	1.37E-07
Tube 17	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	17	17	3.43E+02	5.15E+02	8.59E+02	1.50E+05	2.29E+05	6.78E-08	1.01E-07
Tube 18	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	25	25	5.05E+02	7.58E+02	1.26E+03	2.21E+05	3.31E+05	9.94E-08	1.48E-07
Tube 19	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	22	22	4.44E+02	6.67E+02	1.11E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 20	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	26	26	5.25E+02	7.88E+02	1.31E+03	2.29E+05	3.44E+05	1.03E-07	1.56E-07
Tube 21	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	26	26	5.25E+02	7.88E+02	1.31E+03	2.29E+05	3.44E+05	1.03E-07	1.56E-07
Tube 22	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	22	22	4.44E+02	6.67E+02	1.11E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 23	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	20	20	4.04E+02	6.06E+02	1.01E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 24	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	28	28	5.66E+02	8.48E+02	1.41E+03	2.47E+05	3.71E+05	1.11E-07	1.67E-07
Tube 25	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	22	22	4.44E+02	6.67E+02	1.11E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 26	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	19	19	3.84E+02	5.76E+02	9.60E+02	1.68E+05	2.51E+05	7.59E-08	1.13E-07
Tube 27	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	21	21	4.24E+02	6.36E+02	1.06E+03	1.86E+05	2.79E+05	8.35E-08	1.25E-07
Tube 28	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	27	27	5.45E+02	8.18E+02	1.36E+03	2.39E+05	3.57E+05	1.07E-07	1.56E-07
Tube 29	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	13	13	2.63E+02	3.95E+02	6.57E+02	1.16E+05	1.72E+05	5.17E-08	7.75E-08
Tube 30	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	14	14	2.83E+02	4.24E+02	7.07E+02	1.24E+05	1.85E+05	5.56E-08	8.35E-08
Tube 31	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	11	11	2.22E+02	3.33E+02	5.56E+02	9.70E+04	1.46E+05	4.37E-08	6.56E-08
Tube 32	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	18	18	3.64E+02	5.46E+02	9.10E+02	1.59E+05	2.39E+05	7.15E-08	1.07E-07
Tube 33	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	4	4	8.08E+01	1.21E+02	2.02E+02	3.59E+04	5.29E+04	1.59E-08	2.39E-08
Tube 34	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	14	14	2.42E+02	3.64E+02	6.06E+02	1.06E+05	1.59E+05	4.77E-08	7.15E-08
Tube 35	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	12	12	2.42E+02	3.64E+02	6.06E+02	1.06E+05	1.59E+05	4.77E-08	7.15E-08
Tube 36	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	20	20	4.04E+02	6.06E+02	1.01E+03	1.94E+05	2.91E+05	8.74E-08	1.31E-07
Tube 37	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	17	17	3.43E+02	5.15E+02	8.59E+02	1.50E+05	2.25E+05	6.78E-08	1.01E-07
Tube 38	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	24	24	4.85E+02	7.27E+02	1.21E+03	2.12E+05	3.18E+05	9.54E-08	1.43E-07
Tube 39	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	14	14	2.83E+02	4.24E+02	7.07E+02	1.24E+05	1.85E+05	5.56E-08	8.35E-08
Tube 40	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	27	27	5.45E+02	8.18E+02	1.36E+03	2.39E+05	3.57E+05	1.07E-07	1.61E-07
Tube 41	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	6	6	1.21E+02	1.82E+02	3.03E+02	5.29E+04	7.94E+04	2.39E-08	3.59E-08
Tube 42	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	14	14	2.83E+02	4.24E+02	7.07E+02	1.24E+05	1.85E+05	5.56E-08	8.35E-08
Tube 43	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	5	5	1.01E+02	1.52E+02	2.53E+02	4.41E+04	6.62E+04	1.98E-08	2.98E-08

Tube Characterization

Item #	Description	Item Modeled As	Surface Area (cm <sup>2</sup> )	Average Direct Beta-Gamma (net cpm)	Direct Alpha (dpm/100cm <sup>2</sup> )	Direct Beta-Gamma (dpm/100cm <sup>2</sup> )	Total dpm/100cm <sup>2</sup>	Direct Alpha (dpm)	Direct Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)
Tube 44	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	5	1.01E+02	5.72E+02	6.73E+02	4.41E+04	6.62E+04	1.99E-08	2.96E-08
Tube 45	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	18	3.64E+02	5.72E+02	9.36E+02	1.95E+05	4.41E+04	7.15E-08	1.07E-07
Tube 46	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	24	4.85E+02	7.97E+02	1.28E+03	2.12E+05	3.18E+05	1.95E-08	2.96E-08
Tube 47	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	17	3.43E+02	5.15E+02	8.58E+02	1.90E+05	5.56E+05	1.67E-07	2.50E-07
Tube 48	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	42	8.08E+02	8.70E+02	1.68E+03	2.56E+05	3.84E+05	1.15E-07	1.79E-07
Tube 49	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	30	6.08E+02	9.08E+02	1.52E+03	1.90E+05	2.28E+05	6.76E-08	1.01E-07
Tube 50	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	17	3.43E+02	5.15E+02	8.58E+02	1.90E+05	2.28E+05	6.76E-08	1.01E-07
Tube 51	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	17	3.43E+02	5.15E+02	8.58E+02	1.90E+05	2.28E+05	6.76E-08	1.01E-07
Tube 52	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	17	3.43E+02	5.15E+02	8.58E+02	1.90E+05	2.28E+05	6.76E-08	1.01E-07
Tube 53	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	13	2.63E+02	3.94E+02	6.57E+02	1.15E+05	1.72E+05	5.17E-08	7.75E-08
Tube 54	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	21	4.24E+02	6.26E+02	1.05E+03	1.95E+05	2.78E+05	8.35E-08	1.25E-07
Tube 55	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	14	2.82E+02	4.21E+02	7.03E+02	1.24E+05	1.86E+05	5.66E-08	8.35E-08
Tube 56	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	25	5.05E+02	7.68E+02	1.27E+03	2.21E+05	3.31E+05	9.84E-08	1.49E-07
Tube 57	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	20	2.92E+02	4.30E+02	7.22E+02	8.82E+04	1.32E+05	3.87E-08	5.66E-08
Tube 58	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	20	4.04E+02	6.06E+02	1.01E+03	1.76E+05	2.65E+05	7.95E-08	1.19E-07
Tube 59	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	24	4.85E+02	7.97E+02	1.28E+03	2.12E+05	3.18E+05	1.95E-08	2.96E-08
Tube 60	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	12	2.42E+02	3.72E+02	6.14E+02	1.06E+05	1.58E+05	4.77E-08	7.15E-08
Tube 61	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	18	3.64E+02	5.72E+02	9.36E+02	1.95E+05	2.38E+05	7.15E-08	1.07E-07
Tube 62	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	26	5.25E+02	7.90E+02	1.31E+03	2.29E+05	3.44E+05	1.03E-07	1.55E-07
Tube 63	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	19	3.84E+02	5.70E+02	9.54E+02	1.80E+05	2.51E+05	7.55E-08	1.13E-07
Tube 64	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	21	4.24E+02	6.26E+02	1.05E+03	1.85E+05	2.78E+05	8.35E-08	1.25E-07
Tube 65	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	22	4.44E+02	6.67E+02	1.11E+03	1.94E+05	2.91E+05	7.15E-08	1.07E-07
Tube 66	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	16	3.23E+02	4.92E+02	8.15E+02	1.68E+05	2.12E+05	6.36E-08	9.54E-08
Tube 67	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	16	3.23E+02	4.92E+02	8.15E+02	1.68E+05	2.12E+05	6.36E-08	9.54E-08
Tube 68	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	19	3.84E+02	5.70E+02	9.54E+02	1.85E+05	2.38E+05	7.55E-08	1.13E-07
Tube 69	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	19	3.84E+02	5.70E+02	9.54E+02	1.85E+05	2.38E+05	7.55E-08	1.13E-07
Tube 70	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	27	5.45E+02	8.10E+02	1.35E+03	2.38E+05	3.57E+05	1.07E-07	1.61E-07
Tube 71	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	10	2.02E+02	3.03E+02	5.05E+02	1.32E+05	1.72E+05	3.87E-08	5.66E-08
Tube 72	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	13	2.63E+02	3.94E+02	6.57E+02	1.15E+05	1.72E+05	5.17E-08	7.75E-08
Tube 73	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	15	3.03E+02	4.52E+02	7.55E+02	1.99E+05	2.51E+05	5.86E-08	8.64E-08
Tube 74	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	11	2.22E+02	3.35E+02	5.57E+02	1.32E+05	1.99E+05	3.87E-08	5.66E-08
Tube 75	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	5	1.01E+02	1.52E+02	2.53E+02	4.41E+04	6.62E+04	1.99E-08	2.96E-08
Tube 76	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	13	2.63E+02	3.94E+02	6.57E+02	1.15E+05	1.72E+05	5.17E-08	7.75E-08
Tube 77	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	19	3.84E+02	5.70E+02	9.54E+02	1.85E+05	2.38E+05	7.55E-08	1.13E-07
Tube 78	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	16	3.23E+02	4.92E+02	8.15E+02	1.68E+05	2.12E+05	6.36E-08	9.54E-08
Tube 79	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	11	2.22E+02	3.35E+02	5.57E+02	1.32E+05	1.99E+05	3.87E-08	5.66E-08
Tube 80	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	4	8.08E-01	6.06E-01	1.41E+00	3.53E+04	5.29E+04	1.08E-06	1.61E-05
Tube 81	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	22	4.44E+02	6.67E+02	1.11E+03	1.94E+05	2.91E+05	7.15E-08	1.07E-07
Tube 82	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	14	2.82E+02	4.21E+02	7.03E+02	1.24E+05	1.86E+05	5.66E-08	8.35E-08
Tube 83	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	20	4.04E+02	6.06E+02	1.01E+03	1.76E+05	2.65E+05	7.95E-08	1.19E-07
Tube 84	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	7	1.41E+02	2.12E+02	3.54E+02	1.76E+05	2.65E+05	7.95E-08	1.19E-07
Tube 62-02	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	24	4.85E+02	7.97E+02	1.28E+03	2.12E+05	3.18E+05	1.95E-08	2.96E-08
Tube 77-02	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	8	1.82E+02	2.72E+02	4.54E+02	1.08E+05	1.60E+05	4.77E-08	7.15E-08
Tube 81-02	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	4	8.08E-01	6.06E-01	1.41E+00	3.53E+04	5.29E+04	1.08E-06	1.61E-05
Tube 82-02	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	24	4.85E+02	7.97E+02	1.28E+03	2.12E+05	3.18E+05	1.95E-08	2.96E-08
Tube 83-02	Furnace tube 4.5" dia. X 40" Length	Cylinder	43671.1	5	1.01E+02	1.52E+02	2.53E+02	4.41E+04	6.62E+04	1.99E-08	2.96E-08
Total			1.57E+03	1.57E+03	4.74E+04	7.90E+04	1.38E+07	6.22E+06	9.33E+06	2.38E+04	3.97E+04
Minimum			4.00E+00	4.00E+00	8.08E-01	1.21E+02	2.02E+02	5.29E+04	2.33E+05	6.99E-08	1.08E-07
Average			1.76E+01	1.76E+01	3.55E+02	5.33E+02	8.88E+02	1.55E+05	5.56E+05	1.67E-07	2.50E-07
Maximum			4.20E+01	4.20E+01	8.48E+02	1.27E+03	2.12E+03	3.71E+05	9.380579	1.59E+04	2.38E+04
Std. dev.			7.09	7.09	143.20	214.80	358.00	62337.20	93805.79	0.00	0.00
									Minimum	1.59E+04	2.38E+04
									Average (pCi)	6.99E-08	1.08E-07
									Maximum (pCi)	1.67E+05	2.50E+05



Radiological Characterization of Furnace Tube End Flanges "1st Layer"

Removable Contamination Measurement Data Entry

Item #	Swipe Results	Removable Alpha (dpm/100cm2)	Removable Beta (dpm/100cm2)*
Top Flange 1st -1	5/04/05 #1	6.00E+00	NM
Top Flange 1st -1	5/04/05 #1	6.00E+00	NM
Top Flange 1st -1	5/04/05 #1	6.00E+00	NM
Top Flange 1st -1	5/04/05 #1	6.00E+00	NM
Top Flange 1st -2	5/04/05 #2	1.00E+00	NM
Top Flange 1st -2	5/04/05 #2	1.00E+00	NM
Top Flange 1st -2	5/04/05 #2	1.00E+00	NM
Top Flange 1st -2	5/04/05 #2	1.00E+00	NM
Top Flange 1st -3	5/04/05 #3	0.00E+00	NM
Top Flange 1st -3	5/04/05 #3	0.00E+00	NM
Top Flange 1st -3	5/04/05 #3	0.00E+00	NM
Top Flange 1st -4	5/04/05 #4	4.00E+00	NM
Top Flange 1st -4	5/04/05 #4	4.00E+00	NM
Top Flange 1st -4	5/04/05 #4	4.00E+00	NM
Top Flange 1st -4	5/04/05 #4	4.00E+00	NM
Top Flange 1st -5	5/04/05 #5	6.00E+00	NM
Top Flange 1st -5	5/04/05 #5	6.00E+00	NM
Top Flange 1st -5	5/04/05 #5	6.00E+00	NM

Direct Contamination Measurement Data Entry

Item #	Direct Beta-Gamma (net cpm)	Direct Alpha (net cpm)
Top Flange 1st -1	20	20
Top Flange 1st -1	0	0
Top Flange 1st -1	20	20
Top Flange 1st -1	20	20
Top Flange 1st -2	0	0
Top Flange 1st -2	0	0
Top Flange 1st -2	20	20
Top Flange 1st -2	40	40
Top Flange 1st -3	0	0
Top Flange 1st -3	20	20
Top Flange 1st -3	20	20
Top Flange 1st -3	20	20
Top Flange 1st -4	0	0
Top Flange 1st -4	20	20
Top Flange 1st -4	0	0
Top Flange 1st -4	0	0
Top Flange 1st -5	0	0
Top Flange 1st -5	0	0
Top Flange 1st -5	0	0



Radiological Characterization of Furnace Tube End Flanges "2nd Layer"

Removable Contamination Measurement Data Entry

Item #	Swipe Results	Removable Alpha (dpm/100cm <sup>2</sup> )	Removable Beta (dpm/100cm <sup>2</sup> )
Top Flange 2nd -1	5/04/05 #1	6.00E+00	NM
Top Flange 2nd -1	5/04/05 #1	6.00E+00	NM
Top Flange 2nd -1	5/04/05 #1	6.00E+00	NM
Top Flange 2nd -1	5/04/05 #1	6.00E+00	NM
Top Flange 2nd -2	5/04/05 #2	1.00E+00	NM
Top Flange 2nd -2	5/04/05 #2	1.00E+00	NM
Top Flange 2nd -2	5/04/05 #2	1.00E+00	NM
Top Flange 2nd -2	5/04/05 #2	1.00E+00	NM
Top Flange 2nd -3	5/04/05 #3	0.00E+00	NM
Top Flange 2nd -3	5/04/05 #3	0.00E+00	NM
Top Flange 2nd -3	5/04/05 #3	0.00E+00	NM
Top Flange 2nd -4	5/04/05 #4	4.00E+00	NM
Top Flange 2nd -4	5/04/05 #4	4.00E+00	NM
Top Flange 2nd -4	5/04/05 #4	4.00E+00	NM
Top Flange 2nd -4	5/04/05 #4	4.00E+00	NM
Top Flange 2nd -5	5/04/05 #5	6.00E+00	NM
Top Flange 2nd -5	5/04/05 #5	6.00E+00	NM
Top Flange 2nd -5	5/04/05 #5	6.00E+00	NM
Top Flange 2nd -5	5/04/05 #5	6.00E+00	NM

Direct Contamination Measurement Data Entry

Item #	Direct Beta-Gamma (net cpm)	Direct Alpha (net cpm)
Top Flange 2nd -1	0	0
Top Flange 2nd -1	0	0
Top Flange 2nd -1	0	0
Top Flange 2nd -1	20	20
Top Flange 2nd -2	20	20
Top Flange 2nd -2	20	20
Top Flange 2nd -2	40	40
Top Flange 2nd -2	40	40
Top Flange 2nd -3	20	20
Top Flange 2nd -3	40	40
Top Flange 2nd -3	20	20
Top Flange 2nd -3	0	0
Top Flange 2nd -4	20	20
Top Flange 2nd -4	20	20
Top Flange 2nd -4	20	20
Top Flange 2nd -4	40	40
Top Flange 2nd -5	40	40
Top Flange 2nd -5	0	0
Top Flange 2nd -5	40	40



Radiological Characterization of Furnace Tube End Flanges "3rd Layer"

Removable Contamination Measurement Data Entry

Item #	Swipe Results	Removable Alpha (dpm/100cm <sup>2</sup> )	Removable Beta (dpm/100cm <sup>2</sup> )
Top Flange 3rd -1	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -1	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -1	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -1	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -2	5/05/05 #7	2.00E+00	NM
Top Flange 3rd -2	5/05/05 #7	2.00E+00	NM
Top Flange 3rd -2	5/05/05 #7	2.00E+00	NM
Top Flange 3rd -2	5/05/05 #7	2.00E+00	NM
Top Flange 3rd -3	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -3	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -3	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -4	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -4	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -4	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -4	5/05/05 #6	1.00E+00	NM
Top Flange 3rd -5	5/05/05 #10	2.00E+00	NM
Top Flange 3rd -5	5/05/05 #10	2.00E+00	NM
Top Flange 3rd -5	5/05/05 #10	2.00E+00	NM
Top Flange 3rd -5	5/05/05 #10	2.00E+00	NM

Direct Contamination Measurement Data Entry

Item #	Direct Beta- Gamma (net cpm)	Direct Alpha (net cpm)
Top Flange 3rd -1	0	0
Top Flange 3rd -1	0	0
Top Flange 3rd -1	20	20
Top Flange 3rd -1	0	0
Top Flange 3rd -2	20	20
Top Flange 3rd -2	0	0
Top Flange 3rd -2	0	0
Top Flange 3rd -2	20	20
Top Flange 3rd -3	0	0
Top Flange 3rd -3	0	0
Top Flange 3rd -3	0	0
Top Flange 3rd -4	0	0
Top Flange 3rd -4	0	0
Top Flange 3rd -4	0	0
Top Flange 3rd -4	0	0
Top Flange 3rd -5	20	20
Top Flange 3rd -5	20	20
Top Flange 3rd -5	20	20
Top Flange 3rd -5	0	0

Radiochemical Characterization

Characterization of furnace tube top flanges.

Constants	15	Alpha probe active area (cm2)
	0.33	Alpha efficiency
	15	Beta probe area (cm2)
	0.22	Beta probe efficiency
Conversions		
(cpm)/(instrument area)/(instrument efficiency) = dpm/cm2		
(dpm/cm2)(total area)/(2.22E12 C/dpm) = Ci		
(dpm/f)/(100 cm2)/(2.22E12 C/dpm) = Ci		
2.22E+12		dpm/Ci
1.00E-12		pCi/Ci
Surface Area Formulas		
Open right circular cylinder SA: $(P1 \times D \times L) + (P1^2/4 \times D^2)$		
Closed right circular cylinder SA: $(P1 \times D \times L) + (P1^2/4 \times D^2)$		
Box Surface Area = $L \times W \times 2 + L \times H \times 2 + W \times H \times 2$		
Donut Surface Area = $(P1 \times L) \times (P1 \times D)$		
Disk Surface Area = $P1/4 \times D^2$		
Trey Surface Area = $L \times W \times 2 + L \times H \times 2 + W \times H \times 2$		

Item Information

Item #	Description	Item Modeled As	Surface Area (cm2)
Top Flange 4th -1	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -1	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -1	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -1	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -2	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -2	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -2	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -2	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -3	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -3	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -3	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -3	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -4	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -4	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -4	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -4	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -5	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -5	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -5	Top flange - Disk 25.4 cm Dia.	Disk	506.5
Top Flange 4th -5	Top flange - Disk 25.4 cm Dia.	Disk	506.5

Contamination Measurement Data

Item #	Removable Alpha (dpm/100cm2)	Removable Beta (dpm/100cm2)	Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Removable Alpha (dpm)	Removable Beta (dpm)	Direct Alpha (dpm)	Direct Beta-Gamma (dpm)
Top Flange 4th -1	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -1	1.00E+00	NM	4.04E+02	6.06E+02	5.06E+00	NM	2.05E+03	3.07E+03
Top Flange 4th -1	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -1	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -2	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -2	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -2	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -2	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -3	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -3	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -3	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -3	1.00E+00	NM	0.00E+00	0.00E+00	5.06E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -4	4.00E+00	NM	0.00E+00	0.00E+00	2.03E+01	NM	0.00E+00	0.00E+00
Top Flange 4th -4	4.00E+00	NM	4.04E+02	6.06E+02	2.03E+01	NM	2.05E+03	3.07E+03
Top Flange 4th -4	4.00E+00	NM	0.00E+00	0.00E+00	2.03E+01	NM	0.00E+00	0.00E+00
Top Flange 4th -4	4.00E+00	NM	0.00E+00	0.00E+00	2.03E+01	NM	0.00E+00	0.00E+00
Top Flange 4th -5	0.00E+00	NM	0.00E+00	0.00E+00	0.00E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -5	0.00E+00	NM	0.00E+00	0.00E+00	0.00E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -5	0.00E+00	NM	0.00E+00	0.00E+00	0.00E+00	NM	0.00E+00	0.00E+00
Top Flange 4th -5	0.00E+00	NM	0.00E+00	0.00E+00	0.00E+00	NM	0.00E+00	0.00E+00
Minimum	0.00E+00	NM	0.00E+00	0.00E+00	0.00E+00	NM	0.00E+00	0.00E+00
Average	1.20E+00	NM	6.08E+01	1.21E+02	6.08E+00	NM	4.09E+02	6.14E+02
Maximum	4.00E+00	NM	4.04E+02	6.06E+02	2.03E+01	NM	2.05E+03	3.07E+03

Activity Determination For Each Item.

Assigned Activity	dpm/100cm2	pCi
Minimum	0.00E+00	0.00E+00
Average	2.03E+02	4.84E+02
Maximum	1.01E+03	5.14E+03

Removable Contamination Measurement Data Entry

Item #	Swipe Results	Removable Alpha (dpm/100cm2)	Removable Beta (dpm/100cm2) *
Top Flange 4th -1	5/05/05 #11	1.00E+00	NM
Top Flange 4th -1	5/05/05 #11	1.00E+00	NM
Top Flange 4th -1	5/05/05 #11	1.00E+00	NM
Top Flange 4th -1	5/05/05 #11	1.00E+00	NM
Top Flange 4th -2	5/05/05 #12	1.00E+00	NM
Top Flange 4th -2	5/05/05 #12	1.00E+00	NM
Top Flange 4th -2	5/05/05 #12	1.00E+00	NM
Top Flange 4th -2	5/05/05 #12	1.00E+00	NM
Top Flange 4th -3	5/05/05 #13	0.00E+00	NM
Top Flange 4th -3	5/05/05 #13	0.00E+00	NM
Top Flange 4th -3	5/05/05 #13	0.00E+00	NM
Top Flange 4th -3	5/05/05 #13	0.00E+00	NM
Top Flange 4th -4	5/05/05 #14	4.00E+00	NM
Top Flange 4th -4	5/05/05 #14	4.00E+00	NM
Top Flange 4th -4	5/05/05 #14	4.00E+00	NM
Top Flange 4th -4	5/05/05 #14	4.00E+00	NM
Top Flange 4th -5	5/05/05 #15	0.00E+00	NM
Top Flange 4th -5	5/05/05 #15	0.00E+00	NM

Direct Contamination Measurement Data Entry

Item #	Direct Beta-Gamma (net cpm)	Direct Alpha (net cpm)
Top Flange 4th -1	0	0
Top Flange 4th -1	20	20
Top Flange 4th -1	0	0
Top Flange 4th -1	0	0
Top Flange 4th -2	0	0
Top Flange 4th -2	0	0
Top Flange 4th -2	0	0
Top Flange 4th -2	0	0
Top Flange 4th -3	0	0
Top Flange 4th -3	0	0
Top Flange 4th -3	0	0
Top Flange 4th -3	0	0
Top Flange 4th -4	20	20
Top Flange 4th -4	0	0
Top Flange 4th -4	0	0
Top Flange 4th -4	20	20
Top Flange 4th -5	0	0
Top Flange 4th -5	0	0

Radiological Characterization of Furnace Tube End Flanges "4th Layer"

Top Flange 4th - 5	5/05/05 #15	0.00E+00	NM
Top Flange 4th - 5	5/05/05 #15	0.00E+00	NM

Top Flange 4th - 5	0	0
Top Flange 4th - 5	20	20

Radiological Characterization

Flange Nuts and Bolts

Survey Unit # 3 "Nuts and Bolts from Flanges".

Constants	
15	Alpha probe active area (cm2)
0.33	Alpha efficiency for Depleted Uranium from manufacturer
15	Beta probe area (cm2)
0.22	Beta probe efficiency for Sr/Y-90 from manufacturer
Conversions	
$(cpm)/(instrument\ area)/(instrument\ efficiency) = dpm/cm^2$	
$(dpm/cm^2)(total\ area)/(2.22E12\ Ci/dpm) = Ci$	
2.22E+12	$(dpm/f)/(100\ cm^2)(total\ area)/(2.22E12\ Ci/dpm) = Ci$
1.00E-12	dpm/Ci
	pCi/Ci

Surface Area Formulas	
Open right circular cylinder SA: $(\pi \times D \times L)$	
Closed right circular cylinder SA: $(\pi \times D \times L) + (2 \times \pi/4 \times D^2)$	
Box Surface Area = $L \times W \times 2 + L \times H \times 2 + W \times H \times 2$	
Donut Surface Area = $(\pi \times L) \times (\pi \times D)$	
Disk Surface Area = $\pi/4 \times D^2$	
Tray Surface Area = $L \times W \times 2 + L \times H \times 2 + W \times H \times 2$	

Each layer resembles a tray 4ft. L x 4ft. W x 4in. H (122cm x 122cm x 10.2 cm)

Item #	Item Information			Swipe Data Removable Alpha (dpm/100cm2)	Direct Measurement Data		Activity Determination For Each Item			
	Surface area (cm2)	Direct Beta-Gamma Net (cpm)	Direct Alpha Net (cpm)		Direct Alpha (dpm/100cm2)	Direct Beta-Gamma (dpm/100cm2)	Total Alpha (dpm)	Total Beta-Gamma (dpm)	Alpha (Ci)	Beta (Ci)
Nuts and bolts - 1st layer (A)	34,746	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nuts and bolts - 1st layer (B)	34,746	0	0	1	0.00E+00	0.00E+00	3.47E+02	0.00E+00	1.57E-10	0.00E+00
Nuts and bolts - 1st layer (C)	34,746	0	0	2	0.00E+00	0.00E+00	6.95E+02	0.00E+00	3.13E-10	0.00E+00
Nuts and bolts - 2nd layer (D)	34,746	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nuts and bolts - 2nd layer (E)	34,746	20	20	0	4.04E+02	6.06E+02	1.40E+05	2.11E+05	6.32E-08	9.49E-08
Nuts and bolts - 2nd layer (F)	34,746	20	20	1	4.04E+02	6.06E+02	1.41E+05	2.11E+05	6.34E-08	9.49E-08
Nuts and bolts - 3rd layer (G)	34,746	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nuts and bolts - 3rd layer (H)	34,746	0	0	1	0.00E+00	0.00E+00	3.47E+02	0.00E+00	1.57E-10	0.00E+00
			Minimum	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
			Average	6.25E-01	1.52E+02	1.52E+02	3.53E+04	5.26E+04	1.59E-08	2.37E-08
			Maximum	2.00E+00	4.04E+02	6.06E+02	1.41E+05	2.11E+05	6.34E-08	9.49E-08

Assigned Activity		dpm/100cm2	dpm	Ci	pCi
Minimum		0.00E+00	0.00E+00	0.00E+00	0.00E+00
Average		2.53E+02	8.80E+04	3.96E-08	3.96E+04
Maximum		1.01E+03	3.51E+05	1.58E-07	1.58E+05

Characterization of potential impacted areas of plant.xls

Sample Location	Radionuclide Identified	Laboratory Results	Units	pCi/g	Comments
F551 Sump	Uranium	3	mg/kg	0.9	Metals analysis
F551 Sump	Uranium	3.2	mg/kg	1.1	Metals analysis
Mechanical Garage	U-238	1.1	pCi/g	1.1	Assumed equilibrium with daughters (Pb-214).
	Th-232	1.2	pCi/g		Assumed equilibrium with daughters (Ra-228).
	K-40	19.3	pCi/g		Background value.
Mechanical Garage	U-238	2.3	pCi/g	1.1	Assumed equilibrium with daughters (Th-234).
	Th-232	1.2	pCi/g		Assumed equilibrium with daughters (Pb-212).
	K-40	18	pCi/g		Background value.
F551 Perimeter	U-238	1.3	pCi/g	1.3	Assumed equilibrium with daughters (Pb-214).
	Th-232	1.8	pCi/g		Assumed equilibrium with daughters (Ra-228).
	K-40	21	pCi/g		Background value.
F551 Perimeter	U-238	1.1	pCi/g	1.1	Assumed equilibrium with daughters (Pb-214).
	Th-232	1.9	pCi/g		Assumed equilibrium with daughters (Ra-228).
	K-40	19	pCi/g		Background value.
CSA - Drain	Th-232	1	pCi/g		Assumed equilibrium with daughters (Pb-212).
	K-40	22	pCi/g		Background value.
CSA - Drain	K-40	16.2	pCi/g		Background value.
	Th-232	1.2	pCi/g		Assumed equilibrium with daughters (Ra-228).
Background	K-40	23	pCi/g		Background value.
	K-40	23.6	pCi/g		Background value.
			<b>Minimum</b>	<b>0.9</b>	U-238 since it is radionuclide of interest.
			<b>Average</b>	<b>1.1</b>	U-238 since it is radionuclide of interest.
			<b>Maximum</b>	<b>1.3</b>	U-238 since it is radionuclide of interest.



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**APPENDIX B**  
**DOSE MODELING REPORT SUMMARIES FOR –**  
**BUILDING OCCUPANCY SCENARIO**

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Appendix B contains the D and D dose modeling summary reports for each of the survey units and areas of interest evaluated using the building resident scenario. Appendix B has the following dose modeling summary reports attached:

- ExxonMobil Attachment and downstream building occupancy
- ExxonMobil Furnace tube building occupancy
- ExxonMobil Top flange building occupancy
- ExxonMobil Nuts and bolts building occupancy



## D and D Building Occupancy Scenario

**D and D Version:** 2.1.0

**Run Date/Time:** 2/8/2006 8:58:25 AM

**Site Name:** ExxonMobil, Billings Montana

**Description:** Contamination from attachment points and downstream equipment is on the building surface.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\Attachment and Downstream\ExxonMobil Attachment and Downstream Building Occupancy.mcd

### Options:

**Implicit progeny doses included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

### Initial Activities:

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	UNLIMITED	CONSTANT(dpm/100 cm**2)
Justification for concentration: Average activity from survey of attachment points and accessible downstream equipment.		Value 1.59E+03

### Site Specific Parameters:

#### General Parameters:

Parameter Name	Description	Distribution
<b>Rfo:Loose Resuspension Factor</b>	Resuspension factor for loose contamination	CONSTANT(1/m)
Justification for modification: Recommended release fraction from NUREG 1720.		Value 9.60E-07

		Default CONTINUOUS LOGARITHMIC(1/m)	
		Value	Probability
		9.12E-06	0.00E+00
		1.10E-04	7.67E-01
		1.46E-04	9.09E-01
		1.62E-04	9.50E-01
		1.85E-04	9.90E-01
		1.90E-04	1.00E+00

**Correlation Coefficients:**

None

**Summary Results:**

90.00% of the 100 calculated TEDE values are < 3.22E+00 mrem/year .

The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 3.22E+00 to 3.22E+00 mrem/year



### D and D Building Occupancy Scenario

**D and D Version:** 2.1.0

**Run Date/Time:** 9/15/2005 9:39:35 AM

**Site Name:** ExxonMobil Refining and Supply Co. Bilings Montana

**Description:** Surface contamination inside furnace tubes is assumed to be contamination on building surface.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\ExxonMobil Furnace Tube Building Occupancy.mcd

#### Options:

**Implicit progeny doses included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

#### Initial Activities:

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	UNLIMITED	CONSTANT(dpm/100 cm**2)
<u>Justification for concentration:</u> Average value from survey of 89 furnace tubes.		<u>Value</u> 8.88E+02



**Site Specific Parameters:**

**General Parameters:**

Parameter Name	Description	Distribution														
<b>Rfo:Loose Resuspension Factor</b>	Resuspension factor for loose contamination	CONSTANT(1/m)														
<u>Justification for modification:</u> Recommend value from NUREG 1720 site conditions are similar to those used in the study. Aged contamination which is mostly fixed.		<u>Value</u> 9.60E-07														
		Default CONTINUOUS LOGARITHMIC(1/m)														
		<table border="1"> <thead> <tr> <th><u>Value</u></th> <th><u>Probability</u></th> </tr> </thead> <tbody> <tr> <td>9.12E-06</td> <td>0.00E+00</td> </tr> <tr> <td>1.10E-04</td> <td>7.67E-01</td> </tr> <tr> <td>1.46E-04</td> <td>9.09E-01</td> </tr> <tr> <td>1.62E-04</td> <td>9.50E-01</td> </tr> <tr> <td>1.85E-04</td> <td>9.90E-01</td> </tr> <tr> <td>1.90E-04</td> <td>1.00E+00</td> </tr> </tbody> </table>	<u>Value</u>	<u>Probability</u>	9.12E-06	0.00E+00	1.10E-04	7.67E-01	1.46E-04	9.09E-01	1.62E-04	9.50E-01	1.85E-04	9.90E-01	1.90E-04	1.00E+00
<u>Value</u>	<u>Probability</u>															
9.12E-06	0.00E+00															
1.10E-04	7.67E-01															
1.46E-04	9.09E-01															
1.62E-04	9.50E-01															
1.85E-04	9.90E-01															
1.90E-04	1.00E+00															

**Correlation Coefficients:**

None

**Summary Results:**

90.00% of the 100 calculated TEDE values are < 1.80E+00 mrem/year .

The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 1.80E+00 to 1.80E+00 mrem/year



### D and D Building Occupancy Scenario

**D and D Version:** 2.1.0

**Run Date/Time:** 2/8/2006 8:51:55 AM

**Site Name:** ExxonMobil, Billings Montana

**Description:** Contamination from top end flanges is on the building surface.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\Top Flanges\ExxonMobil Top Flange Building Occupancy.mcd

#### Options:

**Implicit progeny doses included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

#### Initial Activities:

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	UNLIMITED	CONSTANT(dpm/100 cm**2)
<u>Justification for concentration:</u> Average activity from survey of top end flanges.		<u>Value</u> 5.07E+02



**Site Specific Parameters:**

**General Parameters:**

Parameter Name	Description	Distribution														
<b>Rfo:Loose Resuspension Factor</b>	Resuspension factor for loose contamination	CONSTANT(1/m)														
<u>Justification for modification:</u> Recommended release fraction from NUREG 1720.		<u>Value</u> 9.60E-07														
		<u>Default</u> CONTINUOUS LOGARITHMIC(1/m)														
		<table> <thead> <tr> <th><u>Value</u></th> <th><u>Probability</u></th> </tr> </thead> <tbody> <tr> <td>9.12E-06</td> <td>0.00E+00</td> </tr> <tr> <td>1.10E-04</td> <td>7.67E-01</td> </tr> <tr> <td>1.46E-04</td> <td>9.09E-01</td> </tr> <tr> <td>1.62E-04</td> <td>9.50E-01</td> </tr> <tr> <td>1.85E-04</td> <td>9.90E-01</td> </tr> <tr> <td>1.90E-04</td> <td>1.00E+00</td> </tr> </tbody> </table>	<u>Value</u>	<u>Probability</u>	9.12E-06	0.00E+00	1.10E-04	7.67E-01	1.46E-04	9.09E-01	1.62E-04	9.50E-01	1.85E-04	9.90E-01	1.90E-04	1.00E+00
<u>Value</u>	<u>Probability</u>															
9.12E-06	0.00E+00															
1.10E-04	7.67E-01															
1.46E-04	9.09E-01															
1.62E-04	9.50E-01															
1.85E-04	9.90E-01															
1.90E-04	1.00E+00															

**Correlation Coefficients:**

None

**Summary Results:**

90.00% of the 100 calculated TEDE values are < 1.03E+00 mrem/year .  
 The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 1.03E+00 to 1.03E+00 mrem/year



### D and D Building Occupancy Scenario

**D and D Version:** 2.1.0

**Run Date/Time:** 9/16/2005 2:12:17 PM

**Site Name:** ExxonMobil, Billings Montana

**Description:** Contamination from flange nuts&bolts is on the building surface.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\ExxonMobil Nuts&Bolts Building Occupancy.mcd

**Options:**

**Implicit progeny doses included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

**Initial Activities:**

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	UNLIMITED	CONSTANT(dpm/100 cm**2)
Justification for concentration: Total activity from survey of flange nuts and bolts.		Value 2.53E+02

**Site Specific Parameters:**

**General Parameters:**

Parameter Name	Description	Distribution
<b>Rfo:Loose Resuspension Factor</b>	Resuspension factor for loose contamination	CONSTANT(1/m)
Justification for modification: Recommended release fraction from 1720.		Value 9.60E-07
		Default CONTINUOUS LOGARITHMIC(1/m)
		Value Probability
		9.12E-06 0.00E+00
		1.10E-04 7.67E-01
		1.46E-04 9.09E-01
		1.62E-04 9.50E-01



	1.85E-04	9.90E-01
	1.90E-04	1.00E+00

**Correlation Coefficients:**

None

**Summary Results:**

**90.00% of the 100 calculated TEDE values are < 5.12E-01 mrem/year .**

**The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 5.12E-01 to 5.12E-01 mrem/year**



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**APPENDIX C**  
**DOSE MODELING REPORT SUMMARIES FOR –**  
**RESIDENT FARMER SCENARIO**

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Appendix C contains the D and D dose modeling summary reports for each of the survey units and areas of interest evaluated using the resident farmer scenario. Appendix C has the following dose modeling summary reports attached:

- ExxonMobil Attachment and downstream residential
- ExxonMobil Furnace tube residential
- ExxonMobil Top flange residential
- ExxonMobil Nuts and bolts residential
- ExxonMobil potentially impacted areas residential



### D and D Residential Scenario

**D and D Version:** 2.1.0

**Run Date/Time:** 2/9/2006 8:36:16 AM

**Site Name:** ExxonMobil, Billings Montana

**Description:** Activity from attachment points and downstream equipment spread over 2500 square meters.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\Attachment and Downstream\ExxonMobil Attachment and Downstream Residential.mcd

#### Options:

**Implicit progeny doses NOT included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

**Agricultural Pathway is ON**

**Drinking Water Pathway is ON**

**Irrigation Pathway is ON**

**Surface Water Pathway is ON**

#### Initial Activities:

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	2500	CONSTANT(pCi/g)
<u>Justification for concentration:</u> Activity determined from survey of attachment points and downstream equipment. Conversion to pCi/g using total area, soil depth, soil density and total U-238 activity. Limited area by default using NUREG/CR-5512.		<u>Value</u> 1.10E-06

#### Site Specific Parameters:



**General Parameters:**

None

**Element Dependant Parameters**

None

**Correlation Coefficients:**

None

**Summary Results:**

**90.00% of the 100 calculated TEDE values are  $< 2.13E-06$  mrem/year .**

**The 95 % Confidence Interval for the 0.9 quantile value of TEDE is  $1.31E-06$  to  $5.87E-06$  mrem/year**



### D and D Residential Scenario

**D and D Version:** 2.1.0

**Run Date/Time:** 10/10/2005 9:30:51 AM

**Site Name:** ExxonMobil Billings, Montana

**Description:** Surface contamination from inside of furnace tubes is spread over 2500 square meters.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\ExxonMobil Furnace Tube Residential.mcd

#### Options:

**Implicit progeny doses NOT included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

**Agricultural Pathway is ON**

**Drinking Water Pathway is ON**

**Irrigation Pathway is ON**

**Surface Water Pathway is ON**

#### Initial Activities:

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	2500	CONSTANT(pCi/g)
Justification for concentration: Activity determined from survey of furnace tubes and conversion to pCi/g using total area, soil depth, soil density and total U-238 activity. Limited area by default using NUREG/CR-5512.		Value 2.92E-04

#### Site Specific Parameters:

#### General Parameters:

None



**Element Dependant Parameters**

None

**Correlation Coefficients:**

None

**Summary Results:**

**90.00% of the 100 calculated TEDE values are < 7.60E-04 mrem/year .**

**The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 3.44E-04 to 3.88E-03 mrem/year**



**D and D Residential Scenario**

**D and D Version:** 2.1.0

**Run Date/Time:** 10/6/2005 2:03:39 PM

**Site Name:** ExxonMobil, Billings Montana

**Description:** Activity from top flanges spread over 2500 square meters.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\ExxonMobil Top Flange Residential.mcd

**Options:**

**Implicit progeny doses NOT included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

**Agricultural Pathway is ON**

**Drinking Water Pathway is ON**

**Irrigation Pathway is ON**

**Surface Water Pathway is ON**

**Initial Activities:**

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	2500	CONSTANT(pCi/g)
<u>Justification for concentration:</u> Activity determined from survey of top end flanges and conversion to pCi/g using total area, soil depth, soil density and total U-238 activity. Limited area by default using NUREG/CR-5512.		<u>Value</u> 1.93E-06

**Site Specific Parameters:**

**General Parameters:**

None



**Element Dependant Parameters**

None

**Correlation Coefficients:**

None

**Summary Results:**

**90.00% of the 100 calculated TEDE values are < 3.74E-06 mrem/year .**

**The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 2.30E-06 to 1.03E-05 mrem/year**



**D and D Residential Scenario**

**D and D Version:** 2.1.0

**Run Date/Time:** 2/9/2006 9:05:01 AM

**Site Name:** ExxonMobil, Billings Montana

**Description:** Activity from end flange nuts and bolts spread over 2500 square meters.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil\ExxonMobil Dose Modeling\Nuts and Bolts\ExxonMobil Nuts&Bolts Residential.mcd

**Options:**

**Implicit progeny doses NOT included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

**Agricultural Pathway is ON**

**Drinking Water Pathway is ON**

**Irrigation Pathway is ON**

**Surface Water Pathway is ON**

**Initial Activities:**

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	2500	CONSTANT(pCi/g)
<u>Justification for concentration:</u> Activity determined from survey of nuts and bolts from end flanges and conversion to pCi/g using total area, soil depth, soil density and total U-238 activity. Limited area by default using NUREG/CR-5512.		<u>Value</u> 6.60E-05

**Site Specific Parameters:**

**General Parameters:**

None



**Element Dependant Parameters**

None

**Correlation Coefficients:**

None

**Summary Results:**

**90.00% of the 100 calculated TEDE values are < 1.28E-04 mrem/year .**

**The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 7.88E-05 to 3.52E-04 mrem/year**



### D and D Residential Scenario

**D and D Version:** 2.1.0

**Run Date/Time:** 9/9/2005 10:06:18 AM

**Site Name:** ExxonMobil, Billings Montana

**Description:** Activity from soil samples collected at potential impacted areas of plant, spread over 2500 square meters.

**FileName:** C:\Documents and Settings\garciam\My Documents\ExxonMobil potential impacted areas Residential.mcd

#### Options:

**Implicit progeny doses NOT included with explicit parent doses**

**Nuclide concentrations are distributed among all progeny**

**Number of simulations:** 100

**Seed for Random Generation:** 8718721

**Averages used for behavioral type parameters**

**External Pathway is ON**

**Inhalation Pathway is ON**

**Secondary Ingestion Pathway is ON**

**Agricultural Pathway is ON**

**Drinking Water Pathway is ON**

**Irrigation Pathway is ON**

**Surface Water Pathway is ON**

#### Initial Activities:

Nuclide	Area of Contamination (m <sup>2</sup> )	Distribution
238U	2500	CONSTANT(pCi/g)
<u>Justification for concentration:</u> Activity determined from collection of soil samples from potential impacted areas of plant. Limited area by default using NUREG/CR-5512.		<u>Value</u> 1.10E+00

#### Site Specific Parameters:

#### General Parameters:

None

#### Element Dependant Parameters



None

**Correlation Coefficients:**

None

**Summary Results:**

**90.00% of the 100 calculated TEDE values are < 2.13E+00 mrem/year .**

**The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 1.31E+00 to 5.87E+00 mrem/year**



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**APPENDIX D**  
**MINIMUM DETECTABLE CONCENTRATION (MDC) CALCULATIONS**

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## APPENDIX D

This appendix contains two calculation worksheets to determine minimum detectable concentrations for the following cases:

- Static measurements using tube survey tool.
- Scanning measurements using handheld pancake GM survey meter.

### Static Minimum Detectable Concentration for Tube Survey Tool

Static Minimum Detectable Concentration (MDC) was calculated using the methodology outlined in NUREG 1761, Radiological Surveys for Controlling Release of Solid Materials.

The minimum detectable concentration is an estimate of the minimum concentration level that can be practically measured with a specific instrument, and sampling and/or measurement technique. For an integrated measurement over a preset time, the MDC for surface activity can be approximated by the following:

#### Weighted efficiency for static measurement with pancake GM survey meter

Radionuclide	Activity fraction	$e_i$	$e_s$	weighted efficiency
U-238	0.998	0.1	0.25	0.02495
Th-234	0.998	0.125	0.25	0.031188
Pa-234m	0.998	0.6	0.5	0.2994
U-234	8.00E-06	0.1	0.25	2.00E-07
U-235	2.00E-03	0.1	0.25	0.00005
Th-231	2.00E-03	0.225	0.25	0.000113
				0.3557

#### Static MDC for pancake GM survey meter

Background (counts) 15

Count time (T) min. 0.1667

Probe area (cm) 15

Static Minimum Detectable Concentration (MDC)

$$\text{MDC} = \frac{(3+4.65(\text{Bkg})^{1/2})}{(\text{weighted efficiency}) (T) (\text{probe area}/100)}$$

**Static MDC =** 2362.121 dpm/100cm<sup>2</sup>

## Scan Minimum Detectable Concentration for Pancake GM survey meter

### Weighted efficiency for scanning with pancake GM meter

Radionuclide	Activity fraction	$e_i$	$e_s$	weighted efficiency
U-238	0.998	0.02	0.25	0.00499
Th-234	0.998	0.02	0.25	0.00499
Pa-234m	0.998	0.12	0.5	0.05988
U-234	8.00E-06	0.02	0.25	4.00E-08
U-235	2.00E-03	0.02	0.25	0.00001
Th-231	2.00E-03	0.045	0.25	2.25E-05
				0.069893

### Scan MDC for pancake GM survey meter

Background (cpm)                    90

Scan interval (sec)                    1

Performance level @

95% true positive

and 25% false

positive = d

2.32

Background counts in scan interval ( $b_i$ ) = (bkg)(Scan interval)(Minutes/seconds)

$b_i$  = 1.5 cps

Minimum detectable counts in scan interval ( $s_i$ ) =  $d(b_i)^{1/2}$

$s_i$  = 2.841408

Minimum Detectable Count Rate (MDCR) = ( $s_i$ )(60/i)

MDCR = 170.4845

Scanning Minimum Detectable Concentration (Scan MDC) = (MDCR)/(p)<sup>1/2</sup> • (Weighted Efficiency)

**Scan MDC =** 3449.602 dpm/100cm<sup>2</sup>