

## **Engineering Design File**

# **Power Burst Facility (PBF) Below and Above Grade Source Terms**

**Idaho  
Cleanup  
Project**

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The purpose of this EDF is to estimate the above grade, grade to 10 feet below grade, and total below grade source terms for the Power Burst Facility (PBF) Reactor Building PER-620.

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# Power Burst Facility (PBF) Below and Above Grade Source Terms

## 1. PURPOSE

The purpose of this EDF is to estimate the above grade, grade to 10 feet below grade, and total below grade source terms for the Power Burst Facility (PBF) Reactor Building PER-620.

## 2. INTRODUCTION

Radiological Characterization of the Power Burst Facility (PBF) Reactor Building (PER-620) was completed in EDF-4697 (Reference 1), "Radiological Characterization of the PBF Reactor for Disposal." Additionally, the current configuration of Building PER-620 is discussed in ICP/EXT-05-00856 (Reference 2), *Power Burst Facility Reactor Building Interim End State Report*. The characterization data and descriptions from these documents are used to estimate the source term of PER-620 relative to grade. The source term values relative to grade are developed to support the CERCLA risk assessment.

## 3. FACILITY INFORMATION (FROM REFERENCE 2)

The Power Burst Facility (PBF) nuclear reactor operated from 1972 to 1985. The reactor building houses the reactor vessel, fuel storage canal, and various process systems that supported reactor operations. The structure is a two-story, steel-framed building that has a steel plate interior with aluminum exterior siding and two block-wall wings (east and west). The building is divided into a main reactor high-bay room, two single-story wings that contain instrumentation and electrical control equipment, various support offices, operational and utility areas, and a two-level basement.

The main floor of the building (see Figure 1) contains the high bay; offices for the shift supervisor, operator training, and radiological control technicians; a decontamination room; a counting room; personal protective equipment (PPE) issue room; a tool crib; bathrooms; and change rooms. The high bay contains the canal (which joins the reactor on the south side) and has hatches giving access to Loop Cubicles 10 and 13 on the level below. Additional support and operational areas include the process control room and the furnace and equipment room. The east wing of the main floor contains the mechanical work area, test loop control room, the experimental instrumentation room, and an electronic work area.

The building has two basement levels, which are connected by a stairwell and floor hatches. The first basement level contains part of the reactor vessel enclosure, Loop Cubicles 10 and 13, process and utility equipment, the experimental loop pipe-access tunnel, and a sampling area. Figure 4 shows the second basement level, which contains the Knockout drum room, Sub-Pile Room, Warm/Hot Waste Room, Poison Injection System Room, additional process and utility equipment, and the Waste Gas Room.

Figure 2 depicts the subfloor chambers shown at the left or on the north side of the basement. The loop cubicle represents three chambers, one behind another. In this view, Cubicle 10 is closest to the viewer. The main function of this chamber was processing the experimental loop coolant. The sampling room is behind it, and, easternmost, Cubicle 13 is behind the sampling room, which houses the Blowdown tank among other functions. Figure 3 shows Cubicles 10 and 13 in plan view. Figure 5 depicts a section view of the PBF reactor vessel.

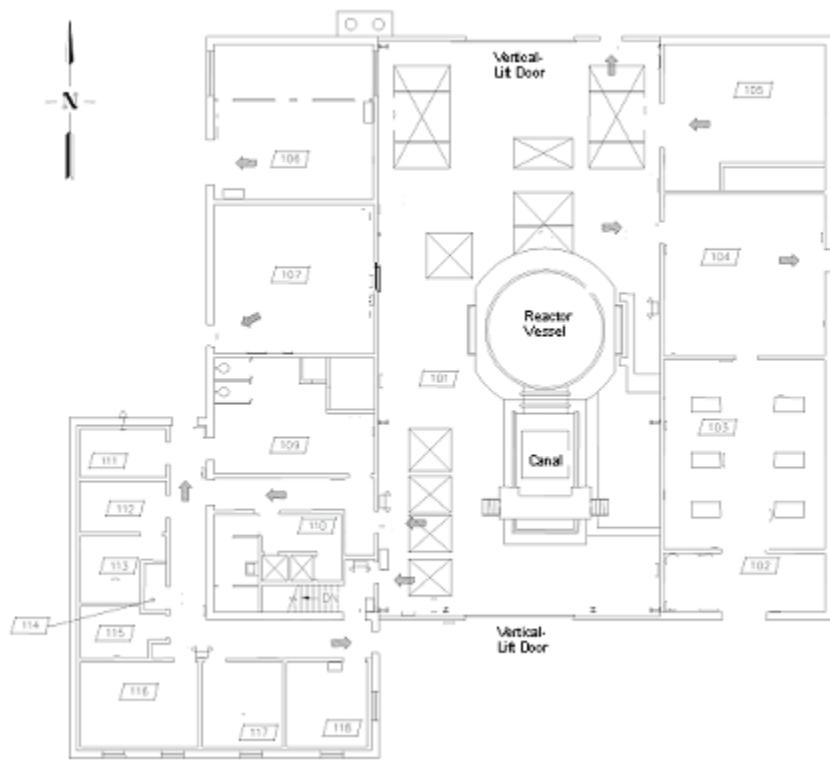


Figure 1. Power Burst Facility reactor building main floor.

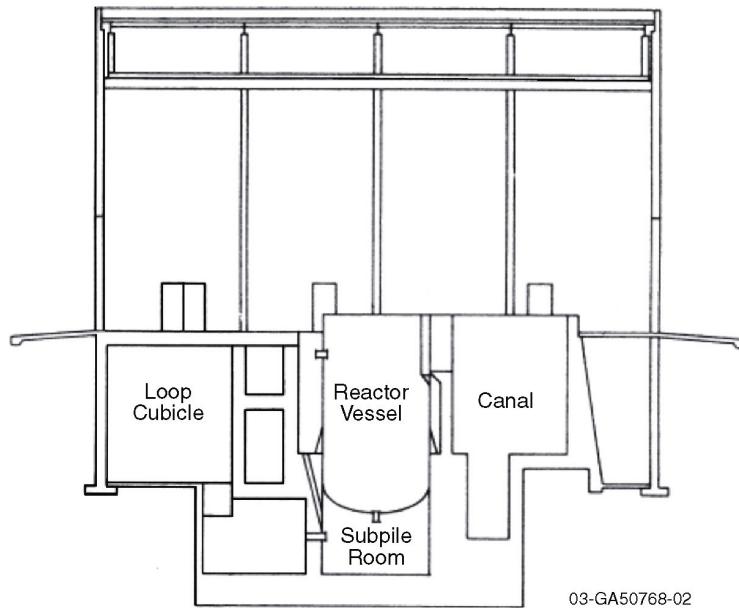


Figure 2. Power Burst Facility reactor building (PER-620) elevation looking east.

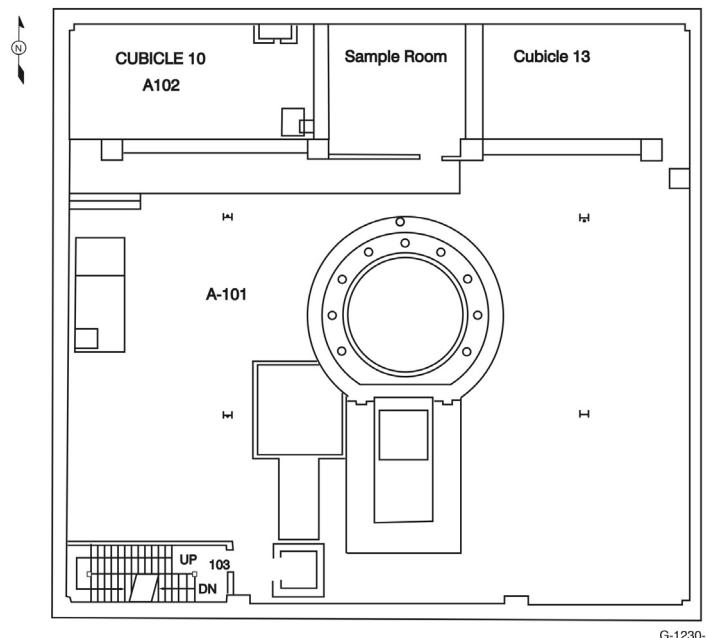


Figure 3. Power Burst Facility reactor building (PER-620) first basement showing Cubicles 10 and 13.

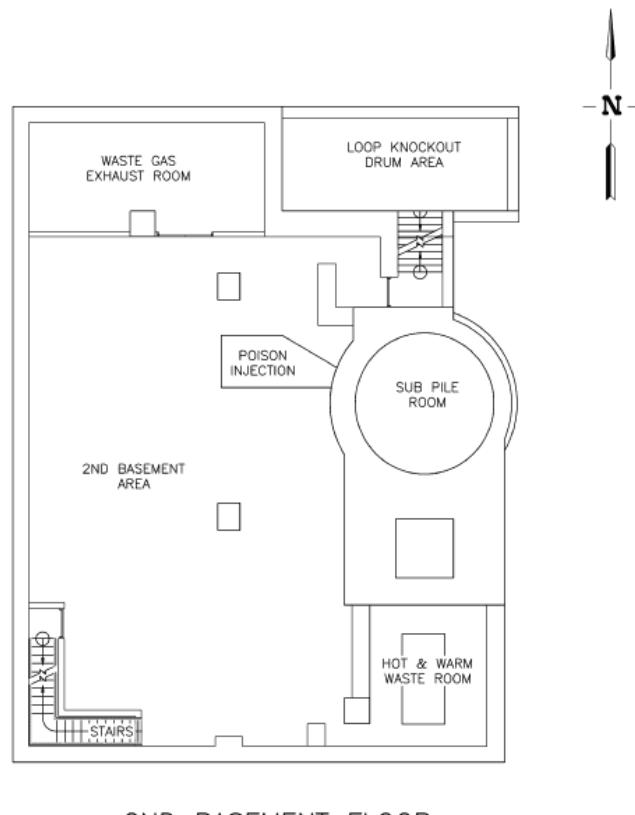


Figure 4. Second basement level.

## 4. SOURCE TERM INFORMATION

Except as noted below, the activity values used for each building are taken from EDF-4697. The methodology used to determine the PBF source term values are well documented in that characterization EDF.

### 1. Reactor

- **Activity:**

**Activation** - Reactor activity values, due to activation, are taken from EDF-4697 and are based on MCNP4C and ORIGEN2 computer codes. The activity results presented in EDF-4697 include the activation of the In Pile Tube which, per reference 2, has been removed. Appendix A presents the activity values used by the authors of EDF-4697 to obtain the total reactor source term and also lists source term values with the contribution made by the In-Pile Tube removed. The total reactor source term (without the In-Pile Tube) is 21.79 Ci.

**Contamination** - Reactor activity values, due to surface contamination, are obtained from Appendix C of EDF-4697. The total reactor source term due to internal contamination is 8.24E-05 Ci and the source term due to external contamination is 1.67E-03 Ci.

- Location Relative to Grade: The locations of the reactor internal components, relative to grade and surface areas, are approximated based on the information contained in Figure 6 of EDF-4697 and is reproduced as Figure 5 below.
- Activity Distribution: The data presented in Appendix A of EDF-4697 demonstrate that only those structures within about 1 m of the core experience significant (in terms of total reactor activity) activation. The locations in the PBF reactor within 1 m of the core are all below the 0 to 10 ft below grade level.

From Figure 5 and Appendix C of EDF-4697, of the 1406.27 ft<sup>2</sup> of contaminated internal surface area and 1515.45 ft<sup>2</sup> of contaminated external surface area, only ~7.8% of the reactor internal surfaces and ~8.9% of the reactor external surfaces (and thus activity) are above grade level and ~ 33.5% of the activity is in the 0 to 10' below grade regions.

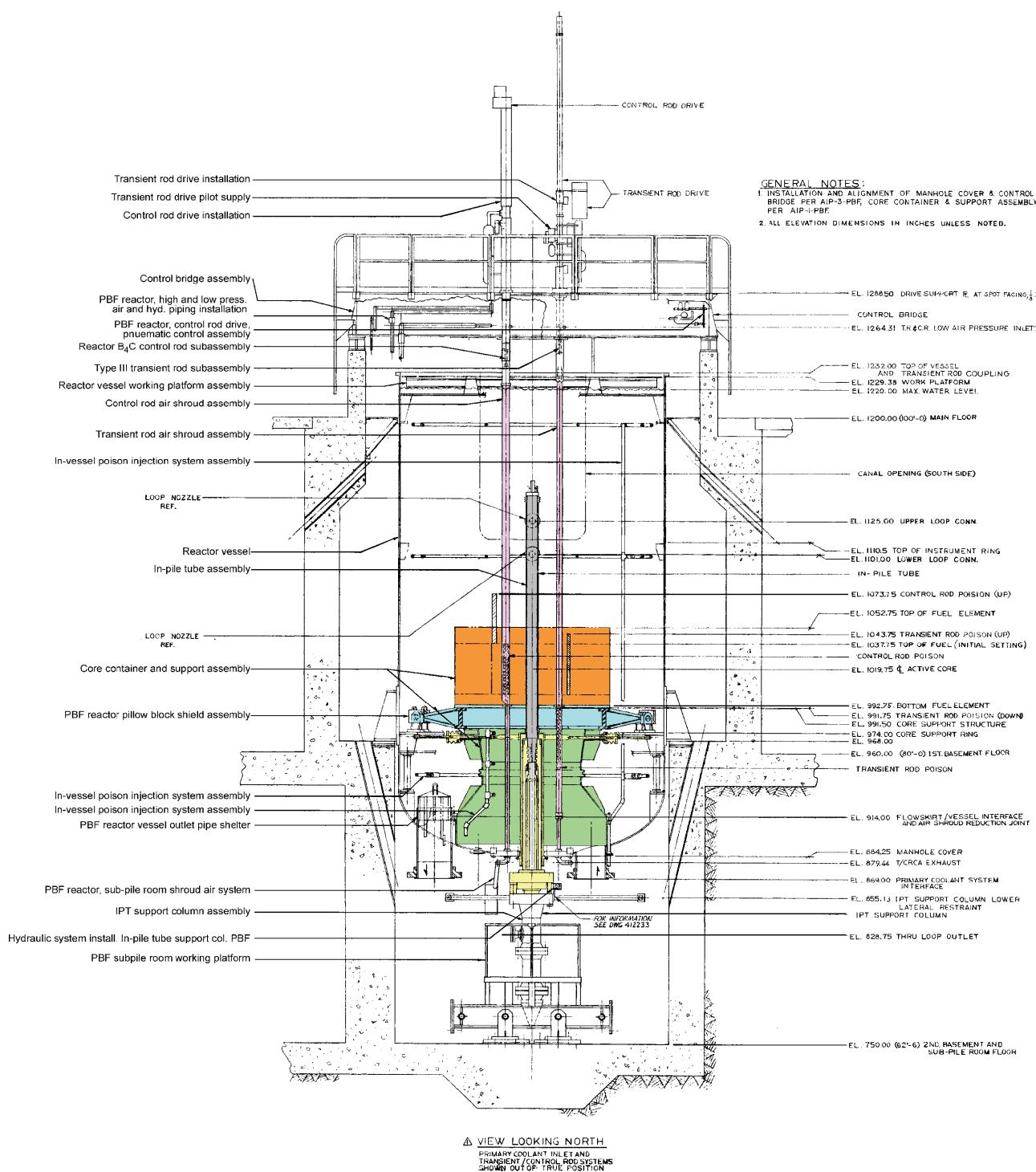
- **Radionuclides:**

**Activation** – See Appendix A

**Contamination** – The radionuclides in the contamination on the internal surfaces of the reactor are assumed to be the same as those radionuclides identified in the primary coolant portable resin beds presented in Table 18 of EDF-4697. Table 1 below shows the resin bed radionuclides, the radionuclide activity scaled to Cs-137, **and** the activity values for the radionuclides. See Appendix B for calculations performed to develop Table 1. The only identified radionuclide in the contamination on the reactor external surfaces, per EDF-4697, is Cs-137.

Table 1. Reactor Internal Surface Contamination Radionuclides, Scaling Factors and Activity Values.

Nuclide	Total Reactor Internal Contamination (Ci)	Above Grade Reactor Internal Contamination (Ci)	0 – 10 ft Below Grade Reactor Internal Contamination (Ci)	Below Grade Reactor Internal Contamination (Ci)
Be-10	4.01E-15	3.13E-16	1.34E-15	3.69E-15
C-14	1.96E-11	1.53E-12	6.55E-12	1.80E-11
Cl-36	3.55E-13	2.77E-14	1.19E-13	3.27E-13
Mn-54	1.51E-13	1.18E-14	5.06E-14	1.39E-13
Ni-59	1.19E-10	9.34E-12	4.00E-11	1.10E-10
Co-60	4.59E-08	3.59E-09	1.54E-08	4.23E-08
Ni-63	3.37E-06	2.64E-07	1.13E-06	3.11E-06
Zn-65	6.27E-11	4.90E-12	2.10E-11	5.78E-11
Sr-90	7.77E-07	6.07E-08	2.60E-07	7.16E-07
Nb-94	3.03E-14	2.37E-15	1.02E-14	2.80E-14
Tc-99	2.16E-06	1.69E-07	7.23E-07	1.99E-06
Ru-106	1.47E-11	1.15E-12	4.93E-12	1.36E-11
Ag-108m	2.45E-18	1.92E-19	8.22E-19	2.26E-18
Ag-110m	5.43E-09	4.25E-10	1.82E-09	5.01E-09
Sb-125	2.33E-08	1.82E-09	7.82E-09	2.15E-08
I-129	2.62E-07	2.05E-08	8.77E-08	2.41E-07
Cs-134	2.99E-07	2.34E-08	1.00E-07	2.76E-07
Cs-137	8.24E-05	6.44E-06	2.76E-05	7.60E-05
Ce-144	1.69E-12	1.32E-13	5.65E-13	1.55E-12
Eu-152	6.55E-08	5.12E-09	2.20E-08	6.04E-08
Eu-154	7.03E-09	5.49E-10	2.35E-09	6.48E-09
Pb-210	2.64E-12	2.07E-13	8.86E-13	2.44E-12
Ra-226	1.25E-11	9.76E-13	4.18E-12	1.15E-11
Ac-227	7.67E-11	6.00E-12	2.57E-11	7.07E-11
Th-228	1.81E-12	1.41E-13	6.06E-13	1.67E-12
Th-229	1.01E-16	7.89E-18	3.38E-17	9.30E-17
Th-230	1.69E-11	1.32E-12	5.65E-12	1.55E-11
Th-232	8.20E-19	6.41E-20	2.75E-19	7.56E-19
Pa-231	2.51E-10	1.96E-11	8.41E-11	2.31E-10
U-232	1.77E-12	1.38E-13	5.92E-13	1.63E-12
U-233	4.40E-14	3.44E-15	1.47E-14	4.05E-14
U-234	7.20E-10	5.63E-11	2.41E-10	6.64E-10
U-235	1.31E-10	1.02E-11	4.39E-11	1.21E-10
U-236	6.78E-10	5.30E-11	2.27E-10	6.25E-10
U-238	3.84E-09	3.01E-10	1.29E-09	3.54E-09
Np-237	6.30E-12	4.92E-13	2.11E-12	5.81E-12
Pu-238	5.61E-10	4.39E-11	1.88E-10	5.17E-10
Pu-239	2.58E-09	2.01E-10	8.63E-10	2.37E-09
Pu-240	2.58E-09	2.01E-10	8.63E-10	2.37E-09
Pu-241	6.92E-13	5.41E-14	2.32E-13	6.38E-13
Pu-242	3.53E-21	2.76E-22	1.18E-21	3.26E-21
Pu-244	3.44E-37	2.69E-38	1.15E-37	3.17E-37
Am-241	7.96E-10	6.22E-11	2.67E-10	7.33E-10
Am-243	5.03E-24	3.93E-25	1.69E-24	4.64E-24
CM-244	3.82E-27	2.98E-28	1.28E-27	3.52E-27
Total =	8.94E-05	6.99E-06	3.00E-05	8.24E-05



2. Cubicle 10

- **Activity:** The activity values and radionuclides in the hot spots, cubicle surfaces, piping (internal and external surfaces) and resin beds are taken from sections 5.2 of EDF-4697. The total activity in Cubicle 10 is 11.73 Ci of which 0.15 Ci is due to surface contamination, 3.19 are contained within the piping or on the piping surfaces, and the remainder of the activity contained within the resin beds
- **Activity Distribution:** All of the contaminated surfaces, equipment, and piping in Cubicle 10 are below grade level. It is estimated, due to the position of the resin beds within the cubicle, that ~37% of the resin bed activity is contained within the 0 – 10' below grade region. It is also estimated, based on the **location** of the piping systems within the cubicle, that ~50% of the piping activity is within the 0 – 10' below grade region. The activity distribution on the wall, floor, and ceiling surfaces of the cubicle is presented in Table 10 of EDF-4697 and is reproduced as Table 2 below.

Table 2. Estimate of radioactivity on the surfaces of Cubicle 10.

Area No.	Description	Extended Area (m <sup>2</sup> )	Cs-137 Activity (nCi/dm <sup>2</sup> )	Cs-137 Activity (Ci)
50	Cubicle 10 Floor	49.0	6.50	3.19E-02
51	Cubicle 10 North Wall	44.6	6.50	2.90E-02
52	Cubicle 10 South Wall	44.6	6.50	2.90E-02
53	Cubicle 10 East Wall	20.9	6.50	1.36E-02
54	Cubicle 10 West Wall	20.9	6.50	1.36E-02
55	Cubicle 10 Ceiling	44.6	6.50	2.90E-02
TOTALS		224.6		1.46E-01

50% of the wall activity and all of the ceiling activity is assumed to exist in the 0 – 10' below grade region.

- **Radionuclides:** From EDF-4697, the only radionuclide identified in the hot spots, surfaces and piping is Cs-137. The **radionuclides** in the resin bed located in Cubicle 10 are shown in Table 3.

Table 3. Cubicle 10 Resin Bed Radionuclides and Activity Values.

Isotope	Cubicle 10 Resin Beds (Ci)	Isotope	Cubicle 10 Resin Beds (Ci)
Be-10	8.04E-11	Pa-231	1.91E-08
C-14	6.74E-09	U-232	4.78E-09
Sr-90	1.24E+00	U-233	6.43E-11
Nb-94	3.21E-11	U-234	8.11E-04
Tc-99	2.36E-05	U-235	3.66E-05
Ru-106	3.18E-09	U-236	7.77E-07
Ag-108m	1.25E-10	U-238	1.06E-05
Ag-110m	1.47E-13	Np-237	1.18E-07
Sb-125	9.03E-04	Pu-238	7.58E-05
I-129	3.28E-06	Pu-239	3.79E-04
Cs-134	2.51E-04	Pu-240	1.10E-04
Cs-137	7.13E+00	Pu-241	1.45E-03
Ce-144	3.22E-11	Pu-242	8.47E-09
Eu-152	5.04E-04	Pu-244	1.84E-17
Eu-154	6.82E-03	Am-241	9.58E-03
Pb-210	2.59E-09	Am-243	4.32E-07
Ra-226	2.62E-09	CM-243	2.34E-07
Ac-227	2.01E-08	CM-244	1.25E-06
Th-228	3.36E-09	CM-245	4.92E-11
Th-229	1.45E-13	CM-246	9.41E-13
Th-230	1.51E-07	CM-247	2.67E-19
Th-232	8.56E-16	CM-248	5.89E-20

### 3. Cubicle 13

- **Activity:** The activity values and radionuclides in the hot spots, cubicle surfaces, piping (internal and external surfaces) and the Blowdown tank are taken from sections 5.3 and 5.11 of EDF-4697. The total activity in Cubicle 13 is 3.69 Ci.
- **Activity Distribution:** All of the contaminated surfaces, equipment, and piping in Cubicle 13 are below grade level. The estimated activity in the 0 – 10' below grade regions using the same methodology/assumptions that was used for Cubicle 10 above is 0.98 Ci. Note: a portion of the Blowdown tank is located in the 0 – 10' below grade region however, this is the top portion of the tank where the dose rates (and thus the assumed activity) is low and is neglected in the 0 – 10' below grade source term.
- **Radionuclides:** The only radionuclide associated with Cubicle 13, per EDF-4697, is Cs-137.

4. Knockout Drum Room

- **Activity:** The activity values and radionuclides in the room surfaces and piping & equipment are taken from sections 5.4 of EDF-4697. The total activity in the Knockout Drum Room is 2.11 Ci.
- **Activity Distribution:** All of the contaminated surfaces, equipment, and piping in the Knockout Drum Room are below grade level at a depth deeper than 10'.
- **Radionuclides:** The only radionuclide associated with this room, per EDF-4697, is Cs-137.

5. Warm/Hot Waste Room

- **Activity:** The activity values and radionuclides in the room surfaces, piping & equipment, tanks, and permanent resin beds are taken from sections 5.5 of EDF-4697. Section 5.5 of that EDF included a discussion of, and an activity calculation for, the portable resin beds located on the Second Basement Level. Per reference 2, the portable resin beds have been removed and disposed of. The total activity remaining in the Warm/Hot Waste Room is 0.66 Ci of which 0.152 Ci are in the permanent resin beds and the remainder in located on piping and room surfaces.
- **Activity Distribution:** All of the activity in this room is located below grade level at a depth deeper than 10' below grade.
- **Radionuclides:** The only radionuclide identified with the Warm/Hot Waste Room piping, components, and room surfaces is Cs-137. The radionuclides contained in the resin beds located in this room are shown in Table 4 below.

Table 4. Radionuclides and Activity Values in the Permanent Resin Bed.

Nuclide	Activity in Resin Bed Pair (Ci)	Nuclide	Activity in Resin Bed Pair (Ci)
Be-10	2.97E-11	Ac-227	5.69E-07
C-14	1.45E-07	Th-228	1.34E-08
Cl-36	2.63E-09	Th-229	7.48E-13
Mn-54	1.12E-09	Th-230	1.25E-07
Ni-59	8.86E-07	Th-232	6.08E-15
Co-60	3.40E-04	Pa-231	1.86E-06
Ni-63	2.50E-02	U-232	1.31E-08
Zn-65	4.65E-07	U-233	3.26E-10
Sr-90	5.76E-03	U-234	5.34E-06
Nb-94	2.25E-10	U-235	9.72E-07
Tc-99	1.60E-02	U-236	5.03E-06
Ru-106	1.09E-07	U-238	2.85E-05
Ag-108m	1.82E-14	Np-237	4.67E-08
Ag-110m	4.03E-05	Pu-238	4.16E-06

Table 4. (continued).

Sb-125	1.73E-04		Pu-239	1.91E-05
I-129	1.94E-03		Pu-240	1.91E-05
Cs-134	2.22E-03		Pu-241	5.13E-09
Cs-137	6.11E-01		Pu-242	2.62E-17
Ce-144	1.25E-08		Pu-244	2.55E-33
Eu-152	4.86E-04		Am-241	5.90E-06
Eu-154	5.21E-05		Am-243	3.73E-20
Pb-210	1.96E-08		CM-244	2.83E-23
Ra-226	9.26E-08			

6. Waste Gas Room

- **Activity:** Activity values due to surface contamination on room surfaces were determined in Section 5.6 of EDF-4697. The total activity remaining in the Waste Gas Room is 0.24 Ci.
- **Activity Distribution:** All of the activity in this room is located below grade level at a depth deeper than 10' below grade.
- **Radionuclides:** The only radionuclide identified with the Waste Gas Room surfaces is Cs-137.

7. Main Floor

- **Activity:** Activity values due to surface contamination on the main floor surfaces were determined in Section 5.7 of EDF-4697. The total activity remaining on the surfaces of this location is 4.98 Ci.
- **Activity Distribution:** The Main Floor is located above grade level thus all of the activity in this location is located above grade level.
- **Radionuclides:** The only radionuclide identified with the Main Floor surfaces is Cs-137.

8. First Basement

- **Activity:** Activity values due to surface contamination on First Basement surfaces were determined in Section 5.7 of EDF-4697. The total activity remaining in this location is 9.99E-03 Ci.
- **Activity Distribution:** The First Basement is located entirely below grade level thus all of the activity in this location is located below grade level. The floor and lower walls of the first basement have been decontaminated and thus there is no source term associated with these surfaces. All of the activity associated with the First Basement surfaces is thus assumed to exist in the 0 – 10' below grade region.
- **Radionuclides:** The only radionuclide identified with the First Basement surfaces is Cs-137.

9. Second Basement

- **Activity:** Activity values due to surface contamination on Second Basement surfaces were determined in Section 5.7 of EDF-4697. The total activity remaining in this location is 5.38E-01 Ci.
- **Activity Distribution:** The Second Basement is located below grade level thus all of the activity in this location is located below grade level at a depth deeper than 10' below grade.
- **Radionuclides:** The only radionuclide identified with the Second Basement surfaces is Cs-137.

10. Sub-Pile Room

- **Activity:** Activity values due to surface contamination on Sub-Pile Room surfaces were determined in Section 5.7 of EDF-4697. The total activity remaining in this location is 1.18 Ci.
- **Activity Distribution:** The Sub-Pile Room is located below grade level thus all of the activity in this location is located below grade level at a depth deeper than 10' below grade
- **Radionuclides:** The only radionuclide identified with the Sub-Pile Room surfaces is Cs-137.

11. Reactor Annulus

- **Activity:** Activity values due to surface contamination on the Reactor Annulus surfaces were determined in Section 5.7 of EDF-4697. The total activity remaining in this location is 2.08E-03 Ci.
- **Activity Distribution:** Of the 163 m<sup>2</sup> contaminated surface area presented in Table 22 of EDF-4697, only 23.4 m<sup>2</sup> (as scaled from figure 6 above) exist above grade level and 56 m<sup>2</sup> exists in the 0 – 10' below grade region. Since the source term for this area is determined from the surface area, 14.26% of the above activity is in the above grade location and 34.36% exists in the 0 – 10' below grade region.
- **Radionuclides:** The only radionuclide identified with the Reactor Annulus surfaces is Cs-137.

12. Miscellaneous Piping and Components Located Throughout the Building

- **Activity:** The total source term of these miscellaneous piping and components, as presented in Section 5.7 of EDF-4697, is 2.04 Ci.
- **Activity Distribution:** Appendix C of EDF-4697 lists the various piping systems throughout the PBF facility. The piping systems in this appendix with external contamination listed as "MH" or "ML" in the "External Contamination" column are located above grade. The total activity value for these above grade piping systems is 0.136 Ci. The remainder (1.904 Ci) is located below grade. The piping systems in the appendix listed as "1H" are located in the upper regions (greater than 8' above the floor) of the first basement and are thus assumed to be in the 0 – 10' below grade region. The activity associated with the 0 – 10' below grade region from these pipes is determined to be 1.37E-01 Ci.
- **Radionuclides:** The only radionuclide identified with these miscellaneous piping systems and components is Cs-137.

## **5. RESULTS**

Table 5. Above grade and below grade source terms.

Location	Item	Surface Area (m <sup>2</sup> )	Total Source Term (Ci)	Above Grade Source Term (Ci)	Below Grade Source Term (Ci)
Reactor	Activated Components	NA	2.18E+01		2.18E+01
	Internal Contamination	130.65	8.94E-05	6.99E-06	8.24E-05
	External Contamination	131.50	1.67E-03	1.49E-04	1.52E-03
	Totals =		2.18E+01	1.56E-04	2.18E+01
Cubicle 10	Resin Beds		8.39E+00		8.39E+00
	Hot Spots		1.01E-03		1.01E-03
	Piping and Components		3.19E+00		3.19E+00
	Cubicle Surfaces	224.6	1.46E-01		1.46E-01
	Total =		1.17E+01		1.17E+01
Cubicle 13	Hot Spots	NA	1.14E+00		1.14E+00
	Cubicle Surfaces	218	7.41E-01		7.41E-01
	Piping and Components		1.24E+00		1.24E+00
	Blowdown Tank		5.70E-01		5.70E-01
	Totals =		3.69E+00		3.69E+00
Knockout Drum Room	Room Surfaces	117	3.98E-01		3.98E-01
	Piping and Components		1.71E+00		1.71E+00
	Totals =		2.11E+00		2.11E+00
Warm/Hot Waste Room	Permanent Resin Beds		1.52E-01		1.52E-01
	Room Surfaces	104.3	4.15E-04		4.15E-04
	Piping and Components		3.50E-01		3.50E-01
	Warm Waste Tank		1.55E-01		1.55E-01
	Totals =		6.58E-01		6.58E-01
Waste Gas Room	Room Surfaces	133.4	2.40E-01		2.40E-01
Main Floor	Room Surfaces	1622.8	4.98E+00	4.98E+00	
First Basement	Room Surfaces	926.7	9.99E-03		9.99E-03
Second Basement	Room Surfaces	707.4	5.38E-01		5.38E-01
Sub-Pile Room	Room Surfaces	73.9	1.18E+00		1.18E+00
Sample Room	Room Surfaces	167.3	4.98E-02		4.98E-02
Annulus	Surfaces	139.6	1.95E-03		1.95E-03
	Above Grade Surfaces	23.4	1.28E-04	1.28E-04	
Piping and Components in remainder of Building			2.04E+00	1.36E-01	1.90E+00
			Above Grade Source Term =	5.11E+00	Ci
			Below Grade Source Term =	4.39E+01	Ci
			Total Source Term =	4.90E+01	Ci

Table 6. Above Grade Radionuclides and Activity Values.

Nuclide	Above Grade Reactor Internal Contamination (Ci)	Above Grade Reactor External Contamination (Ci)	Main Floor Surface Contamination (Ci)	Annulus Surface Contamination (Ci)	Above Grade Piping & Components (Ci)	Total (Ci)
Be-10	2.89E-16					2.89E-16
C-14	1.41E-12					1.41E-12
Cl-36	2.56E-14					2.56E-14
Mn-54	1.09E-14					1.09E-14
Ni-59	8.61E-12					8.61E-12
Co-60	3.30E-09					3.30E-09
Ni-63	2.43E-07					2.43E-07
Zn-65	4.52E-12					4.52E-12
Sr-90	5.60E-08					5.60E-08
Nb-94	2.19E-15					2.19E-15
Tc-99	1.55E-07					1.55E-07
Ru-106	1.06E-12					1.06E-12
Ag-108m	1.77E-19					1.77E-19
Ag-110m	3.92E-10					3.92E-10
Sb-125	1.68E-09					1.68E-09
I-129	1.88E-08					1.88E-08
Cs-134	2.16E-08					2.16E-08
Cs-137	5.94E-06	1.49E-04	4.98E+00	1.28E-04	1.36E-01	5.11E+00
Ce-144	1.21E-13					1.21E-13
Eu-152	4.72E-09					4.72E-09
Eu-154	5.06E-10					5.06E-10
Pb-210	1.90E-13					1.90E-13
Ra-226	9.00E-13					9.00E-13
Ac-227	5.53E-12					5.53E-12
Th-228	1.30E-13					1.30E-13
Th-229	7.27E-18					7.27E-18
Th-230	1.21E-12					1.21E-12
Th-232	5.91E-20					5.91E-20
Pa-231	1.81E-11					1.81E-11
U-232	1.27E-13					1.27E-13
U-233	3.17E-15					3.17E-15
U-234	5.19E-11					5.19E-11
U-235	9.44E-12					9.44E-12
U-236	4.89E-11					4.89E-11
U-238	2.77E-10					2.77E-10
Np-237	4.54E-13					4.54E-13
Pu-238	4.04E-11					4.04E-11
Pu-239	1.86E-10					1.86E-10
Pu-240	1.86E-10					1.86E-10
Pu-241	4.98E-14					4.98E-14
Pu-242	2.55E-22					2.55E-22
Pu-244	2.48E-38					2.48E-38
Am-241	5.73E-11					5.73E-11
Am-243	3.62E-25					3.62E-25
CM-244	2.75E-28					2.75E-28
						Total (Ci) = 5.11E+00

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Table 7. Below Grade Radionuclides and Activity Values

Isotope	Reactor Activated Component Activity w/o In Pile Tube (Ci)	Reactor Internal Surface (Ci)	Reactor External Surface (Ci)	Cubicle 10 Resin Beds (Ci)	Cubicle 13 (Ci)	Knockout Drum Room	Warm/Hot Waste Room Permanent Resin Bed (Ci)	Warm/Hot Waste Room (Ci)	Waste Gas Room, First Basement, Second Basement, Sub-pile Room, and Annulus Surfaces	Piping and Components in remainder of Building	Totals
H-3	9.02E-01										9.02E-01
Be-10	3.89E-06	3.40E-15		8.04E-11			6.81E-12				3.89E-06
C-14	9.88E-03	1.66E-11		6.74E-09			3.32E-08				9.88E-03
Cl-36	2.35E-04	3.01E-13					6.03E-10				2.35E-04
Mn-54	5.13E-06	1.28E-13					2.57E-10				5.13E-06
Ni-59	6.65E-02	1.01E-10					2.03E-07				6.65E-02
Co-60	1.39E-01	3.89E-08					7.79E-05				1.39E-01
Ni-63	6.93E-00	2.86E-06					5.73E-03				6.94E+00
Zn-65	1.40E-09	5.33E-11					1.07E-07				1.08E-07
Sr-90	2.44E-06	6.60E-07		1.24E+00			1.32E-03				1.24E-06
Nb-94	5.33E-04	2.58E-14		3.21E-11			5.16E-11				5.33E-04
Tc-99	1.49E-05	1.83E-06		2.36E-05			3.67E-03				3.71E-03
Ru-106	9.17E-12	1.25E-11		3.18E-09			2.50E-08				2.82E-08
Ag-108m	7.89E-05	2.08E-18		1.25E-10			4.17E-15				7.89E-05
Ag-110m	1.23E-10	4.62E-09		1.47E-13			9.24E-06				9.24E-06
Sb-125	3.84E-04	1.98E-08		9.03E-04			3.97E-05				1.33E-03
I-129	1.48E-12	2.22E-07		3.28E-06			4.45E-04				4.48E-04
Cs-134	7.72E-05	2.54E-07		2.51E-04			5.09E-04				8.37E-04
Cs-137	2.81E-06	7.00E-05	1.52E-03	7.13E+00	3.34E+00	3.69E+00	2.11E-00	1.40E-01	5.06E-01	2.02E+00	1.90E+00
Ce-144	9.13E-13	1.43E-12		3.22E-11			2.87E-09				2.90E-09
Eu-152	1.01E-02	5.57E-08		5.04E-04			1.11E-04				1.07E-02
Eu-154	8.95E-04	5.97E-09		6.82E-03			1.19E-05				7.73E-03
Pb-210	9.28E-13	2.25E-12		2.59E-09			4.49E-09				7.09E-09
Ra-226	3.50E-12	1.06E-11		2.62E-09			2.12E-08				2.39E-08
Ac-227	4.55E-10	6.52E-11		2.01E-08			1.30E-07				1.51E-07
Th-228	2.70E-07	1.53E-12		3.36E-09			3.07E-09				2.76E-07
Th-229	3.27E-10	8.57E-17		1.45E-13			1.71E-13				3.27E-10
Th-230	5.02E-10	1.43E-11		1.51E-07			2.87E-08				1.80E-07

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Table 7. (continued).

Isotope	Reactor Activated Component w/o In Pile Tube (Ci)	Reactor Internal Surface (Ci)	Reactor External Surface (Ci)	Cubicle 10 Resin Beds (Ci)	Cubicle 10 (Ci)	Cubicle 13 (Ci)	Knockout Drum Room	Warm/Hot Waste Room Permanent Resin Bed (Ci)	Warm/Hot Waste Room (Ci)	Waste Gas Room, First Basement, Second Basement, Sub-pile Room, and Annulus Surfaces	Piping and Components in remainder of Building	Totals
Th-232	2.79E-07	6.96E-19		8.56E-16				1.39E-15				2.79E-07
Pa-231	4.55E-10	2.13E-10		1.91E-08				4.26E-07				4.46E-07
U-232	5.12E-10	1.50E-12		4.78E-09				3.00E-09				8.30E-09
U-233	1.50E-07	3.73E-14		6.43E-11				7.47E-11				1.51E-07
U-234	1.72E-06	6.12E-10		8.11E-04				1.22E-06				8.14E-04
U-235	7.82E-08	1.11E-10		3.66E-05				2.23E-07				3.69E-05
U-236	3.74E-11	5.76E-10		7.77E-07				1.15E-06				1.93E-06
U-238	1.70E-06	3.26E-09		1.06E-05				6.53E-06				1.88E-05
Np-237	2.53E-11	5.35E-12		1.18E-07				1.07E-08				1.29E-07
Pu-238	4.09E-10	4.77E-10		7.58E-05				9.54E-07				7.68E-05
Pu-239	4.49E-07	2.19E-09		3.79E-04				4.38E-06				3.84E-04
Pu240	3.15E-09	2.19E-09		1.10E-04				4.38E-06				1.14E-04
Pu-241	4.01E-09	5.88E-13		1.45E-03				1.18E-09				1.45E-03
Pu-242	3.12E-16	3.00E-21		8.47E-09				6.01E-18				8.47E-09
Pu-244	1.08E-27	2.92E-37		1.84E-17				5.85E-34				1.84E-17
Am-241	2.25E-10	6.76E-10		9.58E-03				1.35E-06				9.58E-03
Am-243	1.36E-17	4.27E-24		4.32E-07				8.55E-21				4.32E-07
CM-243	1.81E-17			2.34E-07								2.34E-07
CM-244	4.65E-18	3.24E-27		1.25E-06				6.49E-24				1.25E-06
CM-245	5.51E-24			4.92E-11								4.92E-11
CM-246	2.44E-27			9.41E-13								9.41E-13
CM-247	3.65E-35			2.67E-19								2.67E-19
CM-248	2.54E-37			5.89E-20								5.89E-20
Total =	2.18E-01	7.60E-05	1.52E-03	8.39E+00	3.34E+00	3.69E+00	2.11E-00	1.52E-01	5.06E-01	2.02E+00	1.90E+00	4.39E+01

Table 8. PER-620 Above and Below Grade Radionuclides and Activity Values.

Isotope	Reactor Activated Component Activity w/o In Pile Tube (Ci)	Reactor Internal Surfaces (Ci)	Reactor External Surfaces (Ci)	Cubicle 10 Hot spots Surface, Piping & Equipment (Ci)	Cubicle 13 Hot spots Surface, Piping & Equipment (Ci)	Knockout Drum Room Surfaces Piping & Equipment (Ci)	Warm/Hot Waste Room Permanent Resin Bed (Ci)	Remaining Building Surfaces	Piping and Components in remainder of Building	Totals
H-3	9.02E-01									9.02E-01
Be-10	3.89E-06	4.01E-15		8.04E-11						3.89E-06
C-14	9.88E-03	1.96E-11		6.74E-09						9.88E-03
Cl-36	2.35E-04	3.55E-13								2.35E-04
Mn-54	5.13E-06	1.51E-13								5.13E-06
Ni-59	6.65E-02	1.19E-10								6.65E-02
Co-60	1.39E+01	4.59E-08								1.39E+01
Ni-63	6.93E+00	3.37E-06								6.94E+00
Zn-65	1.40E-09	6.27E-11								1.08E-07
Sr-90	2.44E-06	7.77E-07		1.24E+00						1.24E+00
Nb-94	5.33E-04	3.03E-14		3.21E-11						5.33E-04
Tc-99	1.49E-05	2.16E-06		2.36E-05						3.71E-03
Ru-106	9.17E-12	1.47E-11		3.18E-09						2.82E-08
Ag-108m	7.89E-05	2.45E-18		1.25E-10						7.89E-05
Ag-110m	1.23E-10	5.43E-09		1.47E-13						9.24E-06
Sb-125	3.84E-04	2.33E-08		9.03E-04						1.33E-03
I-129	1.48E-12	2.62E-07		3.28E-06						4.48E-04
Cs-134	7.72E-05	2.99E-07		2.51E-04						8.37E-04
Cs-137	2.81E-06	8.24E-05	1.67E-03	7.13E+00	3.34E+00	3.69E+00	2.11E+00	1.40E-01	5.06E-01	7.00E+00
Ce-144	9.13E-13	1.69E-12		3.22E-11						2.90E-09
Eu-152	1.01E-02	6.55E-08								1.07E-02
Eu-154	8.95E-04	7.03E-09		6.82E-03						7.73E-03
Pb-210	9.28E-13	2.64E-12		2.59E-09						7.09E-09
Ra-226	3.50E-12	1.25E-11		2.62E-09						2.39E-08
Ac-227	4.55E-10	7.67E-11		2.01E-08						1.51E-07
Th-228	2.70E-07	1.81E-12		3.36E-09						2.76E-07
Th-229	3.27E-10	1.01E-16		1.45E-13						3.27E-10
Th-230	5.02E-10	1.69E-11		1.51E-07						1.80E-07

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Table 8. (continued).

Isotope	Reactor Activated Component Activity w/o In Pile Tube (Ci)	Reactor Internal Surfaces (Ci)	Reactor External Surfaces (Ci)	Cubicle 10 Hot spots Surface, Piping & Equipment (Ci)	Cubicle 13 Hot spots Surface, Piping & Equipment (Ci)	Knockout Drum Room Surfaces Piping & Equipment (Ci)	Warm/Hot Waste Room Permanent Resin Bed (Ci)	Remaining Building Surfaces	Piping and Components in remainder of Building	Totals		
Th-232	2.79E-07	8.20E-19		8.56E-16			1.39E-15			2.79E-07		
Pa-231	4.55E-10	2.51E-10		1.91E-08			4.26E-07			4.46E-07		
U-232	5.12E-10	1.77E-12		4.78E-09			3.00E-09			8.30E-09		
U-233	1.50E-07	4.40E-14		6.43E-11			7.47E-11			1.51E-07		
U-234	1.72E-06	7.20E-10		8.11E-04			1.22E-06			8.14E-04		
U-235	7.82E-08	1.31E-10		3.66E-05			2.23E-07			3.69E-05		
U-236	3.74E-11	6.78E-10		7.77E-07			1.15E-06			1.93E-06		
U-238	1.70E-06	3.84E-09		1.06E-05			6.53E-06			1.88E-05		
Np-237	2.53E-11	6.30E-12		1.18E-07			1.07E-08			1.29E-07		
Pu-238	4.09E-10	5.61E-10		7.58E-05			9.54E-07			7.68E-05		
Pu-239	4.49E-07	2.58E-09		3.79E-04			4.38E-06			3.84E-04		
Pu240	3.15E-09	2.58E-09		1.10E-04			4.38E-06			1.14E-04		
Pu-241	4.01E-09	6.92E-13		1.45E-03			1.18E-09			1.45E-03		
Pu-242	3.12E-16	3.53E-21		8.47E-09			6.01E-18			8.47E-09		
Pu-244	1.08E-27	3.44E-37		1.84E-17			5.85E-34			1.84E-17		
Am-241	2.25E-10	7.96E-10		9.58E-03			1.35E-06			9.58E-03		
Am-243	1.36E-17	5.03E-24		4.32E-07			8.55E-21			4.32E-07		
CM-243	1.81E-17			2.34E-07						2.34E-07		
CM-244	4.65E-18	3.82E-27		1.25E-06			6.49E-24			1.25E-06		
CM-245	5.51E-24			4.92E-11						4.92E-11		
CM-246	2.44E-27			9.41E-13						9.41E-13		
CM-247	3.65E-35			2.67E-19						2.67E-19		
CM-248	2.54E-37			5.89E-20						5.89E-20		
Total =	2.18E+01	8.94E-05	1.67E-03	8.39E-00	3.34E+00	3.69E+00	2.11E+00	1.52E-01	5.06E-01	7.00E+00	2.04E+00	4.90E-01

Table 9. Source Term for the 0 – 10 ft Below Grade Region.

Isotope	Reactor Internal Contamination (Ci)	Reactor External Contamination (Ci)	Cubicle 10 Resin Beds (Ci)	Cubicle 10 Surface, Piping & Components (Ci)	Cubicle 13 Surfaces, Piping & Components (Ci)	First Basement Piping	First Basement Misc Surfaces	Reactor Annulus Surfaces	Totals
Be-10	1.34E-15		2.97E-11						2.97E-11
C-14	6.55E-12		2.49E-09						2.50E-09
Cl-36	1.19E-13								1.19E-13
Mn-54	5.06E-14								5.06E-14
Ni-59	4.00E-11								4.00E-11
Co-60	1.54E-08								1.54E-08
Ni-63	1.13E-06								1.13E-06
Zn-65	2.10E-11								2.10E-11
Sr-90	2.60E-07		4.59E-01						4.59E-01
Nb-94	1.02E-14		1.19E-11						1.19E-11
Tc-99	7.23E-07		8.73E-06						9.46E-06
Ru-106	4.93E-12		1.18E-09						1.18E-09
Ag-108m	8.22E-19		4.63E-11						4.63E-11
Ag-110m	1.82E-09		5.44E-14						1.82E-09
Sb-125	7.82E-09		3.34E-04						3.34E-04
I-129	8.77E-08		1.21E-06						1.30E-06
Cs-134	1.00E-07		9.29E-05						9.30E-05
Cs-137	2.76E-05	5.59E-04	2.64E+00	1.67E+00	9.84E-01	1.37E-01	8.78E-03	7.15E-04	5.43E+00
Ce-144	5.65E-13		1.19E-11						1.25E-11
Eu-152	2.20E-08		1.86E-04						1.87E-04
Eu-154	2.35E-09		2.52E-03						2.52E-03
Pb-210	8.86E-13		9.58E-10						9.59E-10
Ra-226	4.18E-12		9.69E-10						9.74E-10
Ac-227	2.57E-11		7.44E-09						7.46E-09
Th-228	6.06E-13		1.24E-09						1.24E-09
Th-229	3.38E-17		5.37E-14						5.37E-14
Th-230	5.65E-12		5.59E-08						5.59E-08
Th-232	2.75E-19		3.17E-16						3.17E-16
Pa-231	8.41E-11		7.07E-09						7.15E-09
U-232	5.92E-13		1.77E-09						1.77E-09
U-233	1.47E-14		2.38E-11						2.38E-11

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Table 9. (continued).

Isotope	Reactor Internal Contamination (Ci)	Reactor External Contamination (Ci)	Cubicle 10 Resin Beds (Ci)	Cubicle 10 Surface, Piping & Components (Ci)	Cubicle 13 Surfaces, Piping & Components (Ci)	First Basement Piping	First Basement Misc Surfaces	First Basement Misc Surfaces	Reactor Annulus Surfaces	Totals
U-234	2.41E-10		3.00E-04							3.00E-04
U-235	4.39E-11		1.35E-05							1.35E-05
U-236	2.27E-10		2.87E-07							2.88E-07
U-238	1.29E-09		3.92E-06							3.92E-06
Np-237	2.11E-12		4.37E-08							4.37E-08
Pu-238	1.88E-10		2.80E-05							2.80E-05
Pu-239	8.63E-10		1.40E-04							1.40E-04
Pu240	8.63E-10		4.07E-05							4.07E-05
Pu-241	2.32E-13		5.37E-04							5.37E-04
Pu-242	1.18E-21		3.13E-09							3.13E-09
Pu-244	1.15E-37		6.81E-18							6.81E-18
Am-241	2.67E-10		3.54E-03							3.54E-03
Am-243	1.69E-24		1.60E-07							1.60E-07
CM-243	1.69E-24		8.66E-08							8.66E-08
CM-244	1.28E-27		4.63E-07							4.63E-07
CM-245	0.00E+00		1.82E-11							1.82E-11
CM-246	0.00E+00		3.48E-13							3.48E-13
CM-247	0.00E+00		9.88E-20							9.88E-20
CM-248	0.00E+00		2.18E-20							2.18E-20
Total =	3.00E-05	5.59E-04	3.10E+00	1.67E+00	9.84E-01	1.37E-01				5.89E+00

## **6. CONCLUSION**

This EDF documents the estimated source term of the PBF PER-620 both above grade level and below grade level (to the bottom of the concrete slab of the lowest level of the building) based on previous characterizations.

Radiological Characterization of the Power Burst Facility (PBF) Reactor Building (PER-620) was completed in EDF-4697 (Reference 1), “Radiological Characterization of the PBF Reactor for Disposal.” Additionally, the current configuration of Building PER-620 is discussed in ICP/EXT-05-00856 (Reference 2), *Power Burst Facility Reactor Building Interim End State Report*.

The source term values relative to grade are developed to support the CERCLA risk assessment.

## **7. REFERENCES**

1. EDF-4697, “Radiological Characterization of the PBF Reactor for Disposal,” 2004, Idaho National Laboratory, Idaho Falls, Idaho.
2. ICP/EXT-05-00856, “Power Burst Facility Reactor Building Interim End State Report,” April 2005, Idaho National Laboratory, Idaho Falls, Idaho.

## **8. APPENDICES**

Appendix A – EDF-4697 Reactor Activation Activity Results

Appendix B – Sample Calculations

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**Appendix A**

**EDF-4697 Reactor Activation Activity Results**

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Table A-1. Reactor Activation Radionuclides and Activity Values by Component.

Isotope	In Pile Tube	In Pile Tube Support	Transient Rod Assembly (4)	Control Rod Assembly (8)	Support Grid	Flow Skirt	Support Structure	Support Structure Arms (8)	Hold Down Assembly	Core Barrel Assembly	Total Activity (CI)	Total Activity w/o In Pile Tube (CI)
H-3	4.21E-08	1.56E-04	8.79E-01	8.86E-09	8.79E-05	8.00E-08	6.05E-04	5.38E-07	2.02E-02	2.24E-03	9.02E-01	9.02E-01
Be-10	1.37E-08	5.95E-11	3.89E-06	1.50E-16	2.59E-13	1.55E-14	1.17E-10	1.04E-13	3.91E-09	4.34E-10	3.90E-06	3.89E-06
C-14	2.68E-03	6.27E-05	5.37E-04	6.03E-15	9.84E-09	3.23E-08	2.44E-04	2.17E-07	8.14E-03	9.01E-04	1.26E-02	9.88E-03
Cl-36	2.99E-05	1.15E-06	3.70E-06	6.02E-05	3.37E-20	5.92E-10	4.47E-06	3.98E-09	1.49E-04	1.65E-05	2.65E-04	2.35E-04
Mn-54	7.66E-06	3.32E-08	1.70E-08	5.32E-07	3.31E-12	1.58E-11	1.20E-07	1.06E-10	3.99E-06	4.41E-07	1.28E-05	5.13E-06
Ni-59	4.07E-01	2.97E-03	5.62E-05	6.08E-03	4.32E-09	2.00E-07	1.51E-03	1.34E-06	5.03E-02	5.57E-03	4.74E-01	6.65E-02
Co-60	1.26E+01	5.94E-01	1.72E-02	1.30E+00	1.72E-06	4.15E-05	3.14E-01	2.79E-04	1.05E+01	1.16E+00	2.64E+01	1.39E+01
Ni-63	4.30E+01	3.09E-01	1.18E-02	6.41E-01	4.28E-06	2.08E-05	1.57E-01	1.39E-04	5.23E+00	5.79E-01	5.00E+01	6.93E+00
Zn-65	2.77E-11	1.77E-12	5.23E-10	6.00E-10	1.46E-11	9.13E-16	6.90E-12	6.13E-15	2.30E-10	2.55E-11	1.43E-09	1.40E-09
Sr-90	6.18E-11	3.71E-16	1.28E-11	3.16E-12	3.51E-20	5.88E-27	2.20E-17	1.18E-25	1.59E-13	2.44E-06	2.44E-06	2.44E-06
Nb-94	1.22E-01	2.56E-04	1.14E-05	3.64E-05	1.14E-09	7.98E-10	6.03E-06	5.36E-09	2.01E-04	2.23E-05	1.23E-01	5.33E-04
Tc-99	1.20E-04	2.34E-06	5.64E-09	1.20E-06	3.07E-13	3.98E-11	3.01E-07	2.68E-10	9.96E-06	1.11E-06	1.34E-04	1.49E-05
Ru-106	0.00E+00	5.87E-38	4.23E-33	4.82E-29	0.00E+00	0.00E+00	2.78E-38	0.00E+00	4.35E-32	9.17E-12	9.17E-12	9.17E-12
Ag-108m	7.82E-04	1.70E-06	5.72E-08	2.65E-05	1.55E-19	8.74E-10	6.61E-06	5.87E-09	1.96E-05	2.44E-05	8.61E-04	7.89E-05
Ag-110m	2.55E-09	7.42E-13	2.50E-14	1.20E-11	1.50E-25	3.82E-16	2.89E-12	2.57E-15	9.62E-11	1.07E-11	2.67E-09	1.23E-10
Sb-125	1.93E-05	1.63E-06	5.70E-05	8.76E-05	5.76E-09	8.41E-10	6.35E-06	5.65E-09	2.08E-04	2.35E-05	4.03E-04	3.84E-04
I-129	2.05E-11	2.91E-31	1.13E-26	6.52E-24	0.00E+00	6.49E-38	3.87E-31	1.30E-36	2.15E-23	1.48E-12	2.20E-11	1.48E-12
Cs-134	5.78E-11	4.72E-07	1.57E-08	7.57E-06	0.00E+00	2.40E-10	1.82E-06	1.62E-09	6.05E-05	6.73E-06	7.72E-05	7.72E-05
Cs-137	3.63E-23	1.55E-26	1.75E-22	3.40E-17	0.00E+00	6.68E-40	2.52E-27	1.24E-37	3.59E-17	2.81E-06	2.81E-06	2.81E-06
Ce-144	0.00E+00	2.76E-20	1.86E-20	6.26E-17	0.00E+00	6.46E-27	3.72E-20	1.26E-25	2.68E-16	9.13E-13	9.13E-13	9.13E-13
Eu-152	0.00E+00	6.32E-05	2.11E-06	9.39E-04	0.00E+00	3.26E-08	2.46E-04	2.19E-07	7.94E-03	9.07E-04	1.01E-02	1.01E-02
Eu-154	0.00E+00	5.42E-06	1.83E-07	8.60E-05	0.00E+00	2.79E-09	2.11E-05	1.88E-08	7.05E-04	7.79E-05	8.95E-04	8.95E-04
Pb-210	0.00E+00	8.65E-14	0.00E+00	2.72E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.15E-13	9.28E-13	9.28E-13	9.28E-13
Ra-226	0.00E+00	3.27E-13	0.00E+00	1.02E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.08E-12	3.50E-12	3.50E-12	3.50E-12
Ac-227	0.00E+00	1.60E-11	0.00E+00	2.18E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E-10	4.55E-10	4.55E-10	4.55E-10
Th-228	0.00E+00	2.52E-08	0.00E+00	7.28E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.37E-07	2.70E-07	2.70E-07	2.70E-07
Th-229	0.00E+00	1.14E-11	0.00E+00	1.58E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-10	3.27E-10	3.27E-10	3.27E-10
Th-230	0.00E+00	4.69E-11	0.00E+00	1.40E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.41E-10	5.02E-10	5.02E-10	5.02E-10
Th-232	0.00E+00	2.62E-08	0.00E+00	7.02E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.46E-07	2.79E-07	2.79E-07	2.79E-07

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Table A-1. (continued).

Isotope	In Pile Tube Support	Transient Rod Assembly (4)	Control Rod Assembly (8)	Support Grid	Flow Skirt	Support Structure Arms (8)	Hold Down Assembly	Core Barrel Assembly	Total Activity (Ci)	Total Activity w/o In Pile Tube (Ci)
									Support Structure Arms (8)	Hold Down Assembly
Pa-231	0.00E+00	3.22E-11	0.00E+00	4.23E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.55E-10	4.55E-10
U-232	0.00E+00	2.67E-13	0.00E+00	4.95E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.12E-10	5.12E-10
U-233	0.00E+00	5.21E-09	0.00E+00	7.34E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.18E-08	1.50E-07
U-234	0.00E+00	1.61E-07	0.00E+00	4.33E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-06	1.72E-06
U-235	0.00E+00	7.33E-09	0.00E+00	1.96E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.89E-08	7.82E-08
U-236	0.00E+00	1.21E-12	0.00E+00	1.88E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E-11	3.74E-11
U-238	0.00E+00	1.59E-07	0.00E+00	4.27E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-06	1.70E-06
Np-237	0.00E+00	8.28E-13	0.00E+00	1.27E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-11	2.53E-11
Pu-238	0.00E+00	1.96E-13	0.00E+00	3.96E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E-11	4.09E-10
Pu-239	0.00E+00	2.74E-08	0.00E+00	4.22E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.72E-11	4.49E-07
Pu-240	0.00E+00	1.50E-12	0.00E+00	3.05E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.72E-11	3.15E-09
Pu-241	0.00E+00	1.31E-14	0.00E+00	4.01E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.56E-12	4.01E-09
Pu-242	0.00E+00	6.58E-24	0.00E+00	3.12E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.03E-20	3.12E-16
Pu-244	0.00E+00	6.73E-44	0.00E+00	1.08E-27	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E-38	1.08E-27
Am-241	0.00E+00	7.40E-16	0.00E+00	2.25E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.14E-13	2.25E-10
Am-243	0.00E+00	2.76E-30	0.00E+00	1.36E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.26E-26	1.36E-17
CM-243	0.00E+00	0.00E+00	0.00E+00	1.81E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.81E-17	1.81E-17
CM-244	0.00E+00	2.97E-36	0.00E+00	4.65E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.54E-31	4.65E-18
CM-245	0.00E+00	0.00E+00	0.00E+00	5.51E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.51E-24	5.51E-24
CM-246	0.00E+00	0.00E+00	0.00E+00	2.44E-27	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E-27	2.44E-27
CM-247	0.00E+00	0.00E+00	0.00E+00	3.65E-35	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.65E-35	3.65E-35
CM-248	0.00E+00	0.00E+00	0.00E+00	2.54E-37	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.54E-37	2.54E-37
Total	5.61E+01	9.06E-01	9.09E-01	1.95E+00	9.39E-05	6.26E-05	4.73E-01	4.21E-04	1.58E+01	7.79E+01

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### **Appendix B**

### **Sample Calculations**

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## SAMPLE CALCULATIONS

### Reactor Internal Contamination

The activity results presented in EDF-4697, Table 25, did not specifically address the reactor internal surfaces. The reactor internal activity was included in this table under the “Piping and Tanks – Internal” column. Appendix C of EDF-4697 presented the data used to estimate the activity of these internal surfaces based on an assumed representative activity value and the surface area. The results for the reactor internal surfaces presented in Appendix C listed only the activity value of Cs-137. The reactor internal surfaces were in contact with the same water purified by the primary coolant ion exchangers thus it can be reasonably assumed that the reactor internal surfaces are contaminated by the same radionuclides in the same relative ratios identified in the ion exchangers. The following methodology was used to determine the activity values for the various radionuclides based on the Cs-137 activity.

Given:

Cs-137 activity value on the reactor internal surfaces presented in Appendix C of EDF-4697:  
8.24E-05 Ci

The first step in determining the activity values for the remaining radionuclide was to determine the scaling factors of these radionuclides to the activity of Cs-137. These scaling factors are determined by dividing the activity of each radionuclide identified in the ion exchanger resin bed by the Cs-137 value. The resin bed activity values are taken from table 18 of EDF-4697. The results of these calculations are presented in the Table below.

Table B-1. Radionuclide activity scaled to Cs-137.

Nuclide	Activity in Resin Bed Pair (Ci)	Activity Scaled to Cs-137 (Ci/Ci)	Nuclide	Activity in Resin Bed Pair (Ci)	Activity Scaled to Cs-137 (Ci/Ci)
Be-10	2.97E-11	4.86E-11	Ac-227	5.69E-07	9.31E-07
C-14	1.45E-07	2.37E-07	Th-228	1.34E-08	2.19E-08
Cl-36	2.63E-09	4.30E-09	Th-229	7.48E-13	1.22E-12
Mn-54	1.12E-09	1.83E-09	Th-230	1.25E-07	2.05E-07
Ni-59	8.86E-07	1.45E-06	Th-232	6.08E-15	9.95E-15
Co-60	3.40E-04	5.56E-04	Pa-231	1.86E-06	3.04E-06
Ni-63	2.50E-02	4.09E-02	U-232	1.31E-08	2.14E-08
Zn-65	4.65E-07	7.61E-07	U-233	3.26E-10	5.34E-10
Sr-90	5.76E-03	9.43E-03	U-234	5.34E-06	8.74E-06
Nb-94	2.25E-10	3.68E-10	U-235	9.72E-07	1.59E-06
Tc-99	1.60E-02	2.62E-02	U-236	5.03E-06	8.23E-06
Ru-106	1.09E-07	1.78E-07	U-238	2.85E-05	4.66E-05
Ag-108m	1.82E-14	2.98E-14	Np-237	4.67E-08	7.64E-08
Ag-110m	4.03E-05	6.60E-05	Pu-238	4.16E-06	6.81E-06
Sb-125	1.73E-04	2.83E-04	Pu-239	1.91E-05	3.13E-05
I-129	1.94E-03	3.18E-03	Pu-240	1.91E-05	3.13E-05
Cs-134	2.22E-03	3.63E-03	Pu-241	5.13E-09	8.40E-09
Cs-137	6.11E-01	1.00E+00	Pu-242	2.62E-17	4.29E-17
Ce-144	1.25E-08	2.05E-08	Pu-244	2.55E-33	4.17E-33
Eu-152	4.86E-04	7.95E-04	Am-241	5.90E-06	9.66E-06
Eu-154	5.21E-05	8.53E-05	Am-243	3.73E-20	6.10E-20
Pb-210	1.96E-08	3.21E-08	CM-244	2.83E-23	4.63E-23
Ra-226	9.26E-08	1.52E-07			

The total activity value for each radionuclide is then determined by multiplying the radionuclide's scaling factor by the Cs-137 activity. For example, the Be-10 activity is determined as follows:

$$Be10 = 8.24 \times 10^{-5} Ci(Cs137) * \frac{4.86 \times 10^{-11} Ci}{Ci(Cs137)} = 4.01 \times 10^{-15} Ci$$

Since it was previously determined that only 7.82% of the contaminated surface area is above grade, the above grade source term for each radionuclide is determined by multiplying the total calculated source term by 7.82%. The remained of the activity is located below grade with the 0 – 10 ft below grade activity being determined by the same methodology as the above grade source term.