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Characterization of Ventilation Ductwork in Building K-31 at the Oak Ridge K-25 Site

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
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Chemical Technology Division

CHARACTERIZATION OF VENTILATION DUCTWORK IN BUILDING K-31 AT THE OAK RIDGE K-25 SITE

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ABSTRACT

An extensive sampling and analysis program was initiated in mid-August 1992 to characterize the ductwork of Building K-31 at the Oak Ridge K-25 Site. This building, 15 acres under roof, contains approximately 4000 ft of main exhaust ducts (plenums), not including the side laterals, which are extensive. A large number of hexane-moistened wipe samples were taken from randomly selected locations within the seven main plenums and the side lateral ducts. Some samples were taken from the air-intake ducts as well. Three wipes were taken from each location and were analyzed for polychlorinated biphenyls (PCBs), uranium, and technetium. These samples were augmented with ten metal coupon samples (cut from the ducts) that were analyzed for radionuclides and subjected to Toxicity Characteristic Leaching Procedure analyses for toxic metals, base/neutral/acid compounds, and volatile organic compounds.

Based on the wipe analyses (with 95% confidence), 95% of the contamination levels in the ductwork are as follows. PCB levels are <200, <760, and <96 μg/100 cm^2 for the main plenums, side lateral ducts, and air-intake ducts respectively; uranium levels are <1390, <8430, and <340 μg/100 cm^2 for the main plenums, side lateral ducts, and air-intake ducts respectively; and technetium levels are <3130, <167,000, and <2570 pCi/100 cm^2 for the main plenums, side lateral ducts, and air-intake ducts respectively. These values are higher than the contamination limits for the respective contaminants.

1. INTRODUCTION

Complete characterization of the interior of the ventilation ductwork in Building K-31 at the Oak Ridge K-25 Site would be a rather massive and costly undertaking. The building itself is large, with dimensions of 1122 by 574 ft, or a total of 15 acres, under roof. The ventilation ductwork consists of seven main plenums, each 574 ft long (a total length of 4000 ft). Five of the main plenums in the center of the building expand from about a 190-ft length by 8-ft width in the center to an approximately 200-ft length of plenum that is originally 14 ft wide but gradually increases to a width of about 38 ft at the exhaust. The two plenums on the west and east sides are smaller in diameter (4 ft) and slightly shorter (530 ft) than the plenums in the center. These two plenums are vented to the west and east respectively. A large number of side laterals intersect each main plenum. One typical main plenum was intersected by 38 lateral ducts, each being approximately 2 ft in diameter, primarily covering about an 80- by 574-ft area on each side of the main plenum. A sampling plan to determine the general level and worst-case contamination for Building K-31 was designed by the Sampling and Environmental Support Department at the Oak Ridge K-25 Site.

1.1 Sampling and Analysis Plan

The sampling plan divided the ductwork for the building into two distinct sampling areas—the main plenums and the lateral ducts. Approximately half the samples for Building K-31 were taken from each area. Sixty areas were sampled in the main plenums, and another 60 areas were sampled in the side laterals. The number of samples (60) taken from each area was based on a statistical determination that, with a 95% confidence level, 95% of a large population of samples would yield analytical results which would not exceed the maximum analysis found within the sample population of 60.

In the original sampling plan, each of the designated locations would be sampled by rubbing a hexane-moistened wipe. The wipe would then be divided in three parts, and the thirds analyzed for uranium, technetium, and polychlorinated biphenyls (PCBs) respectively. However, after completing the sampling in Building K-33, it was decided to collect three wipes at each location for Building K-31. Each wipe was rubbed over a 100-cm^2 area, from the "arm-reachable area" (arm-reachable through a 12- by 12-in. hole cut into the side of the

duct) on the bottom of the duct at the designated sampling point. Other samples to be taken were the actual metal coupons (originally 12 by 12 in. but cut to 10 by 10 cm for the sample) that were cut from the lower side of the duct to allow hand entry for sampling. Bulk portions of material were to be collected if, in the sampler's judgment, they equaled or exceeded a total of 100 g. The coupon openings were randomly alternated between the two sides of a duct whenever possible.

The sampler scanned the interior of the duct through the 12- by 12-in. opening and recorded in a log appropriate comments concerning the surface conditions. All samples were subjected to careful identification and logging, packaging, chain of custody, and archiving requirements immediately after sampling as detailed in the sampling plan. The three wipes from each sampling location, representing 100 cm^2 of interior duct surface area (per wipe), were submitted to the Quality and Technical Services Division (K-25 Site) for analysis of PCBs, uranium, and technetium. A random selection of 100-cm^2 pieces of metal coupons was subjected to analysis for radionuclides and to Toxicity Characteristic Leaching Procedure (TCLP) analyses; see 40 CFR Part 261, Appendix II) for toxic metals, base/neutral/acid (BNA) compounds, and volatile organic compounds (VOA).

Sixty sampling locations were selected for the main plenums, and the same number of locations was selected for the side lateral ductwork. The locations were labeled as specific column numbers within K-31 and were randomly generated. During the course of the actual sampling process, 25 of the initially selected locations for the main plenums and 31 locations for the side laterals were found to be inaccessible for sampling. Alternative locations were selected on the same major plenum; for the side laterals, a nearby lateral attached to the same major plenum was chosen. Nearly half (28) of the samples collected on the side laterals were collected on air-supply lines.

Tables 1 and 2 in this report contain the column location data, with the alternative sampling location shown for each inaccessible location. The layout of the K-31 duct system may be seen in Fig. 1.* As in noted in the figure, all column numbers of the building are shown in respect to the main plenums and side laterals. A complete listing of the sample ID numbers (as recorded by the K-25 Analytical Chemistry Department) may be found in Appendix A.

*Drawing M1E706020-A001—reproduced in reduced form as Fig. 1.

Table 1. Sampling locations in main plenums of Building K-31

Sample no.	Column no.	Alternate location[a]	Sample no.	Column no.	Alternate location[a]
1	C-9		31	O-41	N-41
2	C-25	D-26	32	P-2	
3	D-2		33	P-9	P-10
4	D-33		34	P-17	N-18
5	D-41		35	P-33	
6	D-49	E-49	36	Q-9	
7	E-17	D-17	37	Q-17	
8	E-33		38	Q-25	
9	F-2		39	Q-41	
10	F-17		40	Q-49	S-49
11	F-41		41	R-2	
12	G-9		42	R-17	
13	G-33		43	R-33	R-34
14	H-9		44	R-49	
15	H-41		45	S-41	
16	I-9	J-9	46	T-41	
17	I-33	H-33	47	U-25	T-25
18	J-17		48	V-2	
19	J-33		49	V-9	R-9
20	K-41	K-42	50	X-17	DD-19
21	L-2		51	X-49	Z-49
22	L-17		52	Y-9	DD-9
23	L-49	M-49	53	Y-17	DD-17
24	M-9		54	Y-25	S-26
25	M-33		55	AA-17	BB-17
26	M-41		56	AA-25	R-26
27	M-49		57	AA-33	AA-34
28	N-33		58	AA-41	
29	N-49	G-49	59	BB-9	CC-10
30	O-25	P-26	60	CC-25	

[a]If the planned sampling location was inaccessible, the alternate location is listed.

Table 2. Sampling locations in side lateral ducts of Building K-31

Sample no.	Column no.	Alternate location[a]	Sample no.	Column no.	Alternate location[a]
1	B-17	D-17	31	N-46	L-47
2	B-40	C-40	32	O-24	M-24
3	C-24	D-24	33	O-31	N-31[b]
4	D-18		34	O-44	R-44
5	D-41		35	O-45	L-43[b]
6	E-27[b]		36	P-19	
7	F-10[b]		37	P-36	L-36
8	H-3		38	P-45	Q-47
9	H-13[b]		39	Q-36	
10	H-16[b]		40	R-2	S-2
11	H-23	H-22[b]	41	R-4[b]	
12	H-37[b]		42	S-24	
13	I-10	H-10	43	S-38	S-39
14	I-13	J-13[b]	44	T-7[b]	
15	I-35	F-36[b]	45	T-27	
16	I-38	H-39[b]	46	T-30[b]	
17	I-46	H-46[b]	47	T-47[b]	
18	J-30	H-31[b]	48	U-31	T-31[b]
19	J-48		49	W-14	Y-15[b]
20	K-15	K-16	50	W-19[b]	
21	K-22[b]		51	W-38	W-39
22	K-27[b]		52	Y-32	Y-34
23	K-29[b]		53	Z-38	
24	L-11		54	AA-17	BB-17
25	M-10		55	AA-26	BB-21
26	M-14	N-15[b]	56	AA-28	Z-28[b]
27	M-16	N-17[b]	57	BB-3	
28	M-34		58	BB-4	CC-3[b]
29	N-23[b]		59	BB-25	BB-28
30	N-25		60	CC-29[b]	

[a]If the planned sampling location was inaccessible, the alternate location is listed.
[b]This location is on an air-supply line.

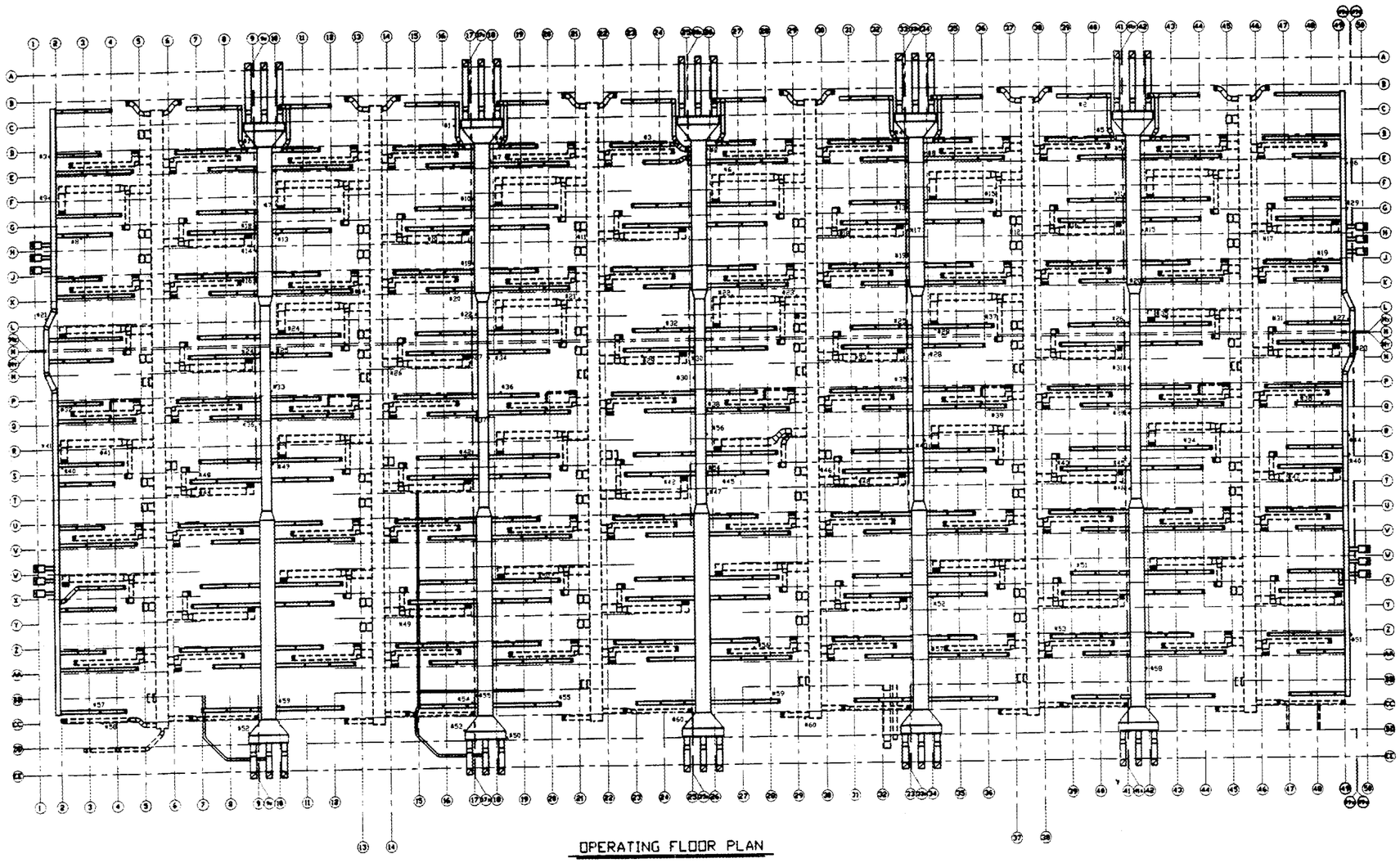

Fig. 1. Layout of main plenums and side laterals in Building K-31, showing column numbers and sampling locations.

1.2 Sampling the Ductwork of Building K-31

Sampling of the ductwork of Building K-31 began on August 13, 1992, and was completed on October 6, 1992. During this period, 132 wipe samples were taken, of which 12 were duplicates. Each wipe sample consisted of three wipes. The wipe samples were analyzed for PCBs, uranium, and technetium (one analysis per wipe) according to the methods listed in the sampling plan. Ten metal coupon samples were taken and submitted for radionuclide and TCLP analysis (see Sect. 1.1).

The procedure required to sample the ductwork involved five people and at least three departments, including Sampling and Environmental Support, Health Physics (HP), and Maintenance. A Veri-lift was utilized to position the individuals adjacent to the duct for the actual sampling. HP technicians surveyed the exterior where the opening was to be made prior to actually cutting into the duct. The external survey of the duct was discontinued after a survey of the first eight sampling areas revealed no external contamination in these areas. A 12- by 12-in. template was used to mark the duct, and a transparent glove bag containing cutting tools and equipment to perform the actual sampling was duct-taped to the metal around the area to be cut. Holes were drilled around the periphery of the marked area, and nippers were employed to complete the opening.

The glove bag and the size of the opening tended to restrict the view of the interior of the duct by the sampling technicians. Their reports concerning the appearance of the duct generally indicated a layer of dust. In some instances, an oily-appearing dust with occasional brown surface crust was noted, especially close to the flange gaskets. At no point were enough deposits present to warrant the collection of bulk samples. Thus, it must be concluded that the interior of the ductwork was relatively clear of particulate matter, except for dust. Several interesting items were noticed inside the ductwork—a large piece of sheet metal, a flashlight, a bag, a milk carton, and a leather glove.

After completion of the sampling event, tools and samples were bagged from the duct by twisting the glove bag around them. Following the HP survey, which indicated that the samples were safe to remove, the samples were bagged and tagged. The HP technician again surveyed the area around the opening, after which it was taped shut.

2. ANALYTICAL DATA FOR BUILDING K-31 DUCT SAMPLES

A number of hexane-moistened wipe samples (132), including 12 duplicates taken from the ductwork of Building K-31, were analyzed. Each wipe sample consisted of three wipes for the three assays (PCBs, uranium, and technetium); the reported analyses were thus based on a wipe area of 100 cm^2. Ninety-seven metal coupons (100 cm^2) were taken, of which ten were analyzed for radionuclides and for toxic metals, base/neutral/acid (BNA) compounds, and volatile organic compounds (VOA) by TCLP.

An appreciation for the variability in the samples can be gained by reviewing the results for duplicate wipe samples in Appendix B.

2.1 Wipe Samples from Main Plenums

The analytical data (PCBs, uranium, and technetium) obtained for the wipe samples from the main plenums of K-31 are listed in Table 3. The data are separated and listed for each of the seven main plenums in K-31 with the mean value ($\bar{x}$) and sample standard deviation (s) listed in bold. In Table 4, these data are summarized as mean values of analysis $\pm$ tolerance limits for each main plenum, together with the number of samples taken from the particular plenum. Tolerance limits were calculated based on the equation $\bar{x} \pm ks$, where $\bar{x}$ is the mean, s is the sample standard deviation, and k may be found in statistical tables.

The ranges (tolerance interval) for all main plenums in K-31 are listed in Table 5, together with the highest measured concentrations of PCBs, uranium, and technetium in each main plenum.

2.2 Wipe Samples from Side Laterals

The assays of PCBs, uranium, and technetium for hexane-moistened wipes from the side lateral ductwork of Building K-31 are listed in Table 6. The results are grouped by major duct to which the side lateral is attached, and the mean values ($\bar{x}$) and sample standard deviations (s) are listed in bold.

Table 3. Results of analyses of wipe samples from main plenums in Building K-31

Column no.	Analysis: PCB (μg/100 cm^2)	Analysis: Uranium (μg/100 cm^2)	Analysis: Technetium (pCi/100 cm^2)
D-2	3.1	230	1110 ± 320
F-2	3.1	200	1250 ± 300
L-2	2.4	460	5450 ± 420
P-2	1.4	58	1310 ± 340
R-2	1.1	96	1470 ± 330
	$\bar{x}$ = 2.2 s = 0.9	$\bar{x}$ = 209 s = 157	$\bar{x}$ = 2118 s = 1867
C-9	0.4	59	1.43 ± 1.4
G-9	3	145	12.9 ± 1.7
H-9	0.8	120	6.52 ± 1.5
J-9	0.94	52	1770 ± 550
M-9	0.86	110	1420 ± 490
P-10	0.87	60	880 ± 510
Q-9	1.6	77	1030 ± 390
V-2	52	1600	5520 ± 280
R-9	3.4	111	716 ± 1400
DD-9	0.48	62	2190 ± 1400
CC-10	0.73	63	1040 ± 240
	$\bar{x}$ = 5.9 s = 15.3	$\bar{x}$ = 224 s = 458	$\bar{x}$ = 1326 s = 1565
D-17	4	78	4.04 ± 1.5
F-17	6.6	34	14.4 ± 1.8
J-17	0.59	63	3.13 ± 1.4
L-17	3.2	52	3.59 ± 1.5
N-18	10	50	645 ± 1400
Q-17	1.4	76	4.8 ± 1.5
R-17	50	48	1.51 ± 1.4
DD-19	200	36	578 ± 1400
DD-17	1.1	260	0 ± 3300
BB-17	470	575	12.7 ± 1.7
	$\bar{x}$ = 74.7 s = 151.9	$\bar{x}$ = 127 s = 171	$\bar{x}$ = 127 s = 256
D-26	1.7	21	124 ± 850
P-26	0.81	18	0 ± 590
Q-25	0.42	25	0 ± 590
T-25	0.51	9.8	0 ± 590
S-26	0.33	18	0 ± 840

Table 3 (continued)

Column no.	Analysis: PCB (μg/100 cm^2)	Analysis: Uranium (μg/100 cm^2)	Analysis: Technetium (pCi/100 cm^2)
R-26	45	88	1000 ± 1400
CC-25	47	13	477 ± 1400
	$\bar{x}$ = 13.7 s = 22.1	$\bar{x}$ = 28 s = 27	$\bar{x}$ = 229 s = 382
D-33	0	13	3.74 ± 1.6
E-33	0.5	27	3.28 ± 1.6
G-33	0.84	24	2.26 ± 1.6
H-33	0.3	26	3.21 ± 1.6
J-33	13	39	3.62 ± 3.62
M-33	24	32	2.45 ± 1.6
N-33	0.57	72	3.07 ± 1.6
P-33	1.6	96	3.69 ± 1.6
R-34	0.89	41	5 ± 1.7
AA-34	7.8	83	4.49 ± 1.6
	$\bar{x}$ = 5.0 s = 7.9	$\bar{x}$ = 45 s = 28	$\bar{x}$ = 3 s = 1
D-41	4.8	200	0 ± 1300
F-41	7.1	150	0 ± 580
H-41	1.1	110	0 ± 1300
K-42	2.9	700	0 ± 1300
M-41	3.9	1800	648 ± 1400
N-41	1.1	280	933 ± 1400
Q-41	1.9	190	0 ± 1300
S-41	0.65	200	0 ± 1300
T-41	270	92	699 ± 1400
AA-41	53	567	209 ± 1400
	$\bar{x}$ = 34.6 s = 84.2	$\bar{x}$ = 528 s = 548	$\bar{x}$ = 249 s = 366
E-49	3.8	110	511 ± 1400
M-49	1.9	350	0 ± 1300
M-49	1800	2700	590 ± 1400
G-49	790	800	2440 ± 1400
S-49	1.5	520	0 ± 1400
R-49	8.2	630	0 ± 1300
Z-49	8.6	650	0 ± 1400
	$\bar{x}$ = 373.4 s = 693.8	$\bar{x}$ = 823 s = 858	$\bar{x}$ = 506 s = 892

Table 4. Mean values of analyses for PCB, uranium, and technetium in main plenums of Building K-31

Main plenum no.	Mean value of analyses and range[a] PCB (μg/100 cm^2)		Uranium (μg/100 cm^2)		Technetium (pCi/100 cm^2)	
2	2.2 ± 4.8	(5)[b]	209 ± 799	(5)	2118 ± 9483	(5)
9	5.9 ± 49.9	(11)	224 ± 1491	(11)	1326 ± 5101	(11)
17	74.7 ± 513.4	(10)	127 ± 577	(10)	127 ± 865	(10)
26	13.7 ± 88.5	(7)	28 ± 109	(7)	229 ± 1532	(7)
33	5.0 ± 26.8	(10)	45 ± 95	(10)	3 ± 3	(10)
41	34.6 ± 284.5	(10)	528 ± 1851	(10)	249 ± 1235	(10)
49	373.4 ± 2780.0	(7)	823 ± 3437	(7)	506 ± 3573	(7)

[a]Range indicated is according to a tolerance interval so that one can assert, with 95% confidence, that the given limits will contain at least 95% of all measurements.
[b]Number of samples collected for this plenum.

Table 5. Ranges[a] and highest[b] analytical values for PCB, uranium, and technetium in main plenums of Building K-31

Main plenum no.	Range and highest level PCB (μg/100 cm^2)	Highest value	Uranium (μg/100 cm^2)	Highest value	Technetium (pCi/100 cm^2)	Highest value
2	0–7.0	3.1	0–1,008	460	0–11,601	5,450
9	0–55.8	52	0–1,715	1,600	0–6,427	5,520
17	0–588.1	470	0–704	575	0–992	645
26	0–102.2	47	0–136	88	0–1,760	1,000
33	0–31.7	24	0–141	96	1–6	5
41	0–319.2	270	0–2,379	1,800	0–1,484	933
49	0–3,153.5	1,800	0–4,260	2,700	0–4,079	2,440

[a]Range of values is mean value ± the tolerance interval. When the low-range value is negative, it is set to zero.
[b]Highest value on analysis in units per 100 cm^2, for the indicated main plenum.

Table 6. Results of analyses of wipe samples from side laterals in Building K-31 (grouped by main duct)

Column no.	Analysis: PCB ($\mu g/100\ cm^2$)	Analysis: Uranium ($\mu g/100\ cm^2$)	Analysis: Technetium ($pCi/100\ cm^2$)
H-3	14	14,000	9,660 ± 530
S-2	1.1	25	3,470 ± 310
BB-3	1.4	570	2,580 ± 390
	$\bar{x} = 5.5$ $s = 7.4$	$\bar{x} = 4{,}865$ $s = 7{,}916$	$\bar{x} = 5{,}237$ $s = 3{,}856$
H-10	5.3	530	6,070 ± 620
L-11	10	600	346,000 ± 3,000
M-10	3.2	530	4,800 ± 590
	$\bar{x} = 6.2$ $s = 3.5$	$\bar{x} = 553$ $s = 40$	$\bar{x} = 118{,}957$ $s = 196{,}626$
D-16	22	155	1.04 ± 1.4
D-18	7.3	1,094	15.5 ± 1.8
K-16	4.3	17	2.12 ± 1.4
P-19	4.5	191	3.93 ± 1.5
BB-17	2.4	138	2,140 ± 1,400
BB-21	15	99	1,380 ± 1,400
	$\bar{x} = 9.3$ $s = 7.7$	$\bar{x} = 282$ $s = 402$	$\bar{x} = 590$ $s = 937$
D-24	3.6	260	573 ± 610
N-25	0.17	101	78.5 ± 1.43
M-24	130	276	1,780 ± 600
S-24	1.9	320	782 ± 620
T-27	290	1,900	4,310 ±1,500
BB-28	8.9	1,600	9,830 ± 1,700
	$\bar{x} = 72.4$ $s = 118.0$	$\bar{x} = 743$ $s = 789$	$\bar{x} = 2{,}892$ $s = 3{,}718$
H-37	2.4	190	2,900 ± 540
M-34	2.7	176	3.64 ± 1.6
L-36	42	963	2,920 ± 770
Q-36	130	648	9,260 ± 950
Y-34	3.7	238	4.15 ± 1.6
	$\bar{x} = 36.2$ $s = 55.1$	$\bar{x} = 443$ $s = 350$	$\bar{x} = 3{,}018$ $s = 3{,}780$

Table 6 (continued)

Column no.	Analysis: PCB (μg/100 cm^2)	Analysis: Uranium (μg/100 cm^2)	Analysis: Technetium (pCi/100 cm^2)
C-40	3.8	370	62.2 ± 1,400
D-41	21	150	0 ± 1,400
R-44	11	970	1,250 ± 1,400
S-39	4.5	657	5,160 ± 830
W-39	0.64	53	805 ± 700
Z-38	10	639	0 ± 1,400
	$\bar{x}$ = 8.5	$\bar{x}$ = 473	$\bar{x}$ = 1,213
	s = 7.3	s = 346	s = 2,001
J-48	9.3	4,300	7,280 ± 890
L-47	8.6	8,600	1,300 ± 500
Q-47	71	430	636 ± 1,400
	$\bar{x}$ = 29.6	$\bar{x}$ = 4,443	$\bar{x}$ = 3,072
	s = 35.8	s = 4,087	s = 3,659
E-27	0.86	37	59 ± 600
F-10	2	83	1.83 ± 1.4
H-13	1.9	230	13.8 ± 1.8
H-16	0	51	1.11 ± 1.4
H-22	0.63	27	0 ± 8,400
J-13	0.5	46	0.61 ± 1.4
F-36	0.49	45	311 ± 460
H-39	0.6	23	1,060 ± 710
H-46	2	89	206 ± 460
H-31	0.3	8	0 ± 1,300
K-22	0.47	18	138 ± 850
K-27	9.2	40	0 ± 1,300
K-29	0.26	20	0 ± 1,300
N-15	1.3	37	1.32 ± 1.4
N-17	0.45	141	1.7 ± 1.4
N-23	15	16	28.9 ± 590
N-31	0.39	48	401 ± 1,400
L-43	5.9	390	185 ± 1,400
R-4	1.8	113	1,240 ± 1,400
T-7	1.9	390	296 ± 310
T-30	0.4	98	0 ± 1,300
T-47	1.5	81	0 ± 1,400
T-31	0.48	87	0 ± 1,300
Y-15	1.9	168	1,750 ± 1,400
W-19	0.77	34	135 ± 1,400
Z-28	180	42	89.1 ± 1,400

Table 6 (continued)

Column no.	Analysis: PCB (μg/100 cm^2)	Analysis: Uranium (μg/100 cm^2)	Analysis: Technetium (pCi/100 cm^2)
CC-3	2.3	90	4,030 ± 270
CC-29	0.6	101	990 ± 1,400
	$\bar{x}$ = 8.4	$\bar{x}$ = 91	$\bar{x}$ = 391
	s = 33.8	s = 98	s = 842

During the sampling campaign, a large number of samples were taken from the air-supply ducts rather than from the exhaust ducts. Of the 60 samples collected, only 32 samples were taken from exhaust ducts. Analytical results for samples taken in the air-supply ducts are listed as the last entries in Table 6. The mean values of the analyses, the number of samples, the ranges (tolerance intervals), and the highest values for each of the three constituents have been grouped as described above and summarized in Tables 7 and 8 respectively.

2.3 Metal Coupon Samples from Main Plenums and Side Laterals

Ninety-seven metal coupon samples (area, 100 cm^2) were obtained from the ductwork of Building K-31. Ten coupon samples were submitted for analysis; the remaining samples were archived. As mentioned before, the coupon samples were analyzed for radionuclides and by TCLP for toxic metals, BNA compounds, and VOA. Five samples were taken from main plenums, and the remaining five were taken from the side laterals. The results of the radiological analyses are listed in Tables 9 and 10 for the main plenums and side lateral ducts respectively.

3. DISCUSSION

As noted in Table 5, the estimated range of PCB surface contamination exceeds 10 μg/100 cm^2, the Martin Marietta Energy Systems, Inc., mandated cleanliness standard for either high- or low-contact PCB-contaminated surfaces for six of the seven major plenums. The highest surface contamination was found in plenum number 49 (at location M-49), where the contamination was 1800 μg/100 cm^2. The sampling crew did not notice anything unusual when sampling at this location.

Table 7. Mean values of analyses for PCB, uranium, and technetium in side laterals of Building K-31 (grouped by main duct)

Main plenum no.	Mean value of analyses and range[a] PCB ($\mu g/100\ cm^2$)		Uranium ($\mu g/100\ cm^2$)		Technetium ($pCi/100\ cm^2$)	
2	5.5 ± 73.0	(3)[b]	4,865 ± 78,493	(3)	5,237 ± 38,241	(3)
9	6.2 ± 34.5	(3)	553 ± 401	(3)	118,957 ± 1,949,747	(3)
17	9.3 ± 33.8	(6)	282 ± 1,775	(6)	590 ± 4,137	(6)
26	72.4 ± 520.9	(6)	743 ± 3,484	(6)	2,892 ± 16,413	(6)
33	36.2 ± 280.0	(5)	443 ± 1,777	(5)	3,018 ± 19,199	(5)
41	8.5 ± 32.1	(6)	473 ± 1,529	(6)	1,213 ± 8,831	(6)
49	29.6 ± 355.3	(3)	4,443 ± 40,526	(3)	3,072 ± 36,286	(3)
Intake	8.4 ± 87.2	(28)	91 ± 254	(28)	391 ± 2,174	(28)

[a]Range indicated is according to a tolerance interval so that one can a assert, with 95% confidence, that the given limits will contain at least 95% of all measurements.

[b]Number of samples collected for this plenum.

Table 8. Ranges[a] and highest[b] analytical values for PCB, uranium, and technetium in side laterals of Building K-31 (grouped by main duct)

Main plenum no.	Range and highest value PCB ($\mu g/100\ cm^2$)	Highest value	Uranium ($\mu g/100\ cm^2$)	Highest value	Technetium ($pCi/100\ cm^2$)	Highest value
2	0 - 78.5	14	0 - 83,358	14,000	0 - 43,478	9,660
9	0 - 40.7	10	152 - 954	600	0 - 2,068,703	346,000
17	0 - 43.1	22	0 - 2,057	1,094	0 - 4,728	2,140
26	0 - 593.3	290	0 - 4,227	1,900	0 - 19,305	9,830
33	0 - 316.1	130	0 - 2,220	963	0 - 22,217	9,260
41	0 - 40.6	21	0 - 2,002	970	0 - 10,044	5,160
49	0 - 384.9	71	0 - 44,969	8,600	0 - 39,358	7,280
Intake	0 - 95.6	180	0 - 345	390	0 - 2,565	4,030

[a]Range of values is mean value ± the tolerance interval. When the low-range value is negative, it is set to zero.

[b]Highest value on analysis in units per 100 cm^2, for the indicated main plenum.

Table 9. Analyses of metal coupons[a] from main plenums in Building K-31
(All values are picocuries per liter)

Analysis	Location (column no.)				
	E-33	M-9	S-49	R-17	R-9
Alpha activity	114 ± 130	<0	<0	<0	28.4 ± 200
Beta activity	<0	148 ± 270	<0	499 ± 290	<0
Gamma activity	NA	NA	NA	NA	NA
Protactinium	12,300 ± 17,000	NA	17,500 ± 18,000	NA	8,330 ± 16,000
Protactinium-234	NA	18,000 ± 21,000	NA	NA	NA
Uranium alpha activity	3.28 ± 11	NA	10.4 ± 12	NA	24.3 ± 18
Uranium-234	NA	<0	NA	<0	NA
Uranium-238	NA	<0	NA	<0	NA
Cesium-137	<0	NA	38.8 ± 89	<0	3.41 ± 95
Technetium-99	<0	1,520 ± 5,500	1,330 ± 2,700	2,170 ± 5,500	491 ± 2,700
Neptunium-237	15.5 ± 22	11.7 ± 23	0 ± 86	12.3 ± 17	<0
Plutonium-238	7.77 ± 27	53.8 ± 62	122 ± 120	263 ± 140	67.2 ± 95
Plutonium-239	0 ± 14	17.9 ± 36	0 ± 110	35.1 ± 50	0 ± 120
Thorium-228	6.57 ± 9.3	<0	0 ± 33	<0	2,740 ± 4,100
Thorium-230	0 ± 9.3	<0	0 ± 27	<0	<0
Thorium-232	3.28 ± 6.6	0 ± 9.8	0 ± 33	0 ± 9.8	0 ± 32
Thorium-234	<0	2,180 ± 540	<0	<0	0± 120
Total activity	<0	8.3 ± 820	<0	610 ± 810	<0

[a]Coupon size was 10 by 10 cm.

TCLP tests for the following toxic metals were also performed (detection limits are listed within parentheses): arsenic (0.50 mg/L), barium (1.0 mg/L), cadmium (0.030 mg/L), chromium (0.10 mg/L), lead (0.50 mg/L), nickel (0.50 mg/L), selenium (0.50 mg/L), and silver (0.070 mg/L).

TCLP tests for the following BNA compounds were also performed (detection limits are listed within parentheses): pyridine (40 μg/L), 1,4-dichlorobenzene (40 μg/L), 1,2-dichlorobenzene (40 μg/L), 2-methylphenol (40 μg/L), 4-methylphenol (40 μg/L), hexachloroethane (40 μg/L), nitrobenzene (40 μg/L), hexachlorobutadiene (40 μg/L), 2,4,6-trichlorophenol (40 μg/L), 2,4,5-trichlorophenol (1200 μg/L), 2,4-dinitrotoluene (40 μg/L), hexachlorobenzene (40 μg/L), pentachlorophenol (200 μg/L), and 2,3,4,6-tetrachlorophenol (40 μg/L). In addition, coupon samples from locations R-17 and M-9 were tested for 3-methylphenol (40 μg/L), phenol (30 μg/L), and bis(2-chloroethyl)ether (30 μg/L), and a sample from location E-33 was tested for 3-methylphenol (40 μg/L).

TCLP tests for the following VOA compounds were also performed (detection limits are listed within parentheses): vinyl chloride (10 μg/L), 1,1-dichloroethene (5 μg/L), chloroform (5 μg/L), 1,2-dichloroethane (5 μg/L), 2-butanone (100 μg/L), carbon tetrachloride (5 μg/L), trichloroethene (5 μg/L), benzene (5 μg/L), tetrachloroethene (5 μg/L), and chlorobenzene (5 μg/L). In addition, coupon samples from locations R-17 and M-9 were tested for acetone (100 μg/L), benzene (5 μg/L), carbon disulfide (100 μg/L), ethylbenzene (5 μg/L), methylene chloride (5 μg/L), 1,1,1-trichloroethane (5 μg/L), 1,1,2-trichloroethane (5 μg/L), and xylene (5 μg/L).

Results from TCLP tests are given in the main text.

Table 10. Analyses of metal coupons[a] from side lateral ducts in Building K-31
(All values are picocuries per liter)

Analysis	Location (column no.)				
	C-40	H-13[b]	T-27	R-4[b]	BB-28
Alpha activity	170 ± 140	56.5 ± 170	283 ± 160	<0	70.8 ± 120
Beta activity	262 ± 270	441 ± 290	1,400 ± 330	51 ± 270	229 ± 270
Cesium-137	47.8 ± 74	0 ± 44	<0	12.8 ± 7	<0
Gamma activity	NA	NA	NA	NA	NA
Protactinium	<0	NA	4,120 ± 9,300	5,630 ± 13,000	NA
Protactinium-234	NA	<0	NA	NA	NA
Uranium alpha activity	17.4 ± 18	NA	78.8 ± 33	16.4 ± 15	<0
Uranium-234	NA	3.8 ± 27	NA	NA	NA
Uranium-238	NA	<0	NA	NA	NA
Technetium-99	<0	<0	1,190 ± 2,100	1,810 ± 2,700	827 ± 2,100
Neptunium-237	0 ± 28	14.3 ± 20	0 ± 24	0 ± 81	7.59 ± 15
Plutonium-238	<0	144 ± 100	20.6 ± 31	115 ± 110	0 ± 21
Plutonium-239	0 ± 16	144 ± 100	4.32 ± 8.6	28.6 ± 57	13 ± 15
Thorium-228	10.4 ± 12	<0	0 ± 11	0 ± 30	0 ± 12
Thorium-230	3.47 ± 12	<0	0 ± 9,300	<0	<0
Thorium-232	0 ± 12	<0	3.28 ± 6.6	0 ± 30	0 ± 12
Thorium-234	2,230 ± 750	<0	1.03 ± 760	2,500 ± 750	<0
Total activity	<0	841 ± 820	2,050 ± 860	<0	285 ± 810

[a]Coupon size was 10 by 10 cm.
[b]This sample was taken on an air-inlet duct.

TCLP tests for the following toxic metals were also performed (detection limits are listed within parentheses): arsenic (0.50 mg/L), barium (1.0 mg/L), cadmium (0.030 mg/L), chromium (0.10 mg/L), lead (0.50 mg/L), nickel (0.50 mg/L), selenium (0.50 mg/L), and silver (0.070 mg/L).

TCLP tests for the following BNA compounds were also performed (detection limits are listed within parentheses): pyridine (40 μg/L), 1,4-dichlorobenzene (40 μg/L), 1,2-dichlorobenzene (40 μg/L), 2-methylphenol (40 μg/L), 4-methylphenol (40 μg/L), hexachloroethane (40 μg/L), nitrobenzene (40 μg/L), hexachlorobutadiene (40 μg/L), 2,4,6-trichlorophenol (40 μg/L), 2,4,5-trichlorophenol (1200 μg/L), 2,4-dinitrotoluene (40 μg/L), hexachlorobenzene (40 μg/L), pentachlorophenol (200 μg/L), and 2,3,4,6-tetrachlorophenol (40 μg/L). In addition, coupon samples from locations T-17, C-40, and H-13 were tested for 3-methylphenol (40 μg/L), and a sample from location H-13 was tested for phenol (30 μg/L) and bis(2-chloroethyl)ether (30 μg/L).

TCLP tests for the following VOA compounds were also performed (detection limits are listed within parentheses): vinyl chloride (10 μg/L), 1,1-dichloroethene (5 μg/L), chloroform (5 μg/L), 1,2-dichloroethane (5 μg/L), 2-butanone (100 μg/L), carbon tetrachloride (5 μg/L), trichloroethene (5 μg/L), benzene (5 μg/L), tetrachloroethene (5 μg/L), and chlorobenzene (5 μg/L). In addition, a coupon sample from location M-13 was tested for acetone (100 μg/L), benzene (5 μg/L), carbon disulfide (100 μg/L), ethylbenzene (5 μg/L), methylene chloride (5 μg/L), 1,1,1-trichloroethane (5 μg/L), 1,1,2-trichloroethane (5 μg/L), and xylene (5 μg/L).

Results from TCLP tests are given in the main text.

Plenums having the highest estimated range of PCB surface contamination also contained the highest levels of uranium and technetium. Plenum number 2, which is located along the west side of the building, had a maximum surface contamination of 2700 μg uranium/100 cm^2, and plenum number 49 (east side of K-31) had a maximum surface contamination of 5450 pCi technetium/100 cm^2. Assuming that all contamination was removable and that the uranium was natural uranium, the highest detected levels of uranium (in plenum 2) and technetium (in plenum 49) are equivalent to 4000 disintegrations/min (dpm) alpha and 12,100 dpm beta respectively. It should be noted that the removable contamination of uranium and technetium was fairly low in main plenum number 33 (see Table 5). There was no obvious relationship between the uranium and technetium analyses. The levels of radiological contamination found would classify the main duct as a contamination area according to Energy Systems' standards for radiation protection* and its interpretation of Attachment 2 of DOE Order 5480.11.

Mean levels of surface contamination for PCB in side laterals, shown in Table 7, were similar to the levels found in the main plenums. In fact the overall mean for the analyses shown in Table 6 (excluding the samples taken on air-intake ducts) is 28.4 μg PCB/100 cm^2 (s = 258.9) compared with 65.5 μg PCB/100 cm^2 (s = 58.1) for main plenums in Table 3. Generally, uranium contamination of the side laterals was higher than that found in the main plenums. The mean level (from Table 6) in the side laterals was 1275 μg/100 cm^2 (s = 2834) compared with 274 μg/100 cm^2 (s = 479) in the main plenums (based on data in Table 3). Technetium levels were also higher in the side laterals than in the main plenums. The mean level for technetium in Table 6 is 13,283 pCi/100 cm^2 (s = 60,788), while the mean for the main plenums in Table 3 is 569 pCi/100 cm^2 (s = 1099).

The samples taken from the air-inlet duct indicate that the PCB contamination was similar to that found in the main plenums and side laterals and that the uranium and technetium levels were lower than in the exhaust ducts (see Tables 7 and 8). This was expected since the main source for PCB contamination is the gasket type used in both intake and exhaust ducts. The mean values (see Table 7) are below the Martin Marietta Energy Systems, Inc., PCB cleanliness standard and within the Energy Systems' HP levels for alpha

*The alpha transferable (smear) level in a contamination area is greater than 200 dpm/100 cm^2. Beta, gamma transferable level in a contamination area is greater than 2000 dpm/100 cm^2.

and beta activities in regulated areas.* However, the maximum values listed in Table 8 are above the cleanliness standard and within limits for contamination areas.

Based on the wipe analyses, the following overall tolerance limits for Building K-31 may be set so that one can say, with 95% confidence, that 95% of the contamination levels in the ductwork fall within these limits.**

	Main plenums	Side lateral ducts	Air-intake ducts
PCB (μg/100 cm^2)	0 - 200	0 - 760	0 - 96
Uranium (μg/100 cm^2)***	0 - 1,390	0 - 8,430	0 - 340
Technetium (pCi/100 cm^2)****	0 - 3,130	0 - 167,000	0 - 2,570

The above-listed ranges are based on the equation

$$\bar{x} \pm ks ,$$

where $\bar{x}$ is the mean, s is the sample standard deviation, and k may be found in statistical tables.

The radiological analyses of the ten coupon samples did not reveal surprising results. The highest activity detected was from the sample collected on a side lateral at location T-27, where the total activity was measured as 2050 pCi/L in the extract. Location T-27 also had the highest uranium concentration among the wipe samples taken from side laterals attached to main plenum 26 (see Table 6).

The TCLP tests indicated concentrations of metals as follows: 0.10 mg/L cadmium and 0.64 mg/L lead in side lateral at T-27 and 0.84 mg/L chromium and 0.65 mg/L nickel in the air-supply duct at R-4. The TCLP/BNA testing revealed no detectable BNA compounds in

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*Standards for activities are as shown: 20 dpm/100 cm^2 < alpha transferable < 200 dpm/100 cm^2; 200 dpm/100 cm^2 < beta, gamma transferable < 2000 dpm/100 cm^2.

**J. K. Taylor, *Statistical Techniques for Data Analysis*, Lewis Publishers, Inc., Chelsea, Mich., p. 70 (1990).

***Assuming the uranium was present as natural uranium, the upper values listed compare with 2100, 12,500, and 500 dpm α/100 cm^2 for the main, side lateral, and air-inlet ducts respectively.

****The upper values listed of technetium correspond to 6950, 371,000, and 6370 dpm β/100 cm^2 in the main, side lateral, and air-inlet ducts respectively.

any of the coupon samples. Results from the TCLP/VOA assays indicated that an estimated 2 μg/L of trichloroethene was present in the sample from the side lateral at BB-28, and an estimated 23 μg/L of 2-butanone was present in the sample from the side lateral at T-27. An estimated 1-μg/L concentration of toluene was reported in the sample from the main plenum at location R-17. No other compounds were detected in the coupon samples.

NOTE: All negative values listed on analytical reports for technetium levels have been listed in this report as zero. This principle also applies to all statistical techniques performed.

Appendix A

SAMPLE ID NUMBERS

Table A.1. Sample ID numbers

Sample no.	Sample ID as recorded by K-25's Analytical Chemistry Department		Sample no.	Sample ID as recorded by K-25's Analytical Chemistry Department	
	Main plenum sample	Side lateral duct sample		Main plenum sample	Side lateral duct sample
1	K31M-C9W	K31S-B17W	31	K31M-O41W	K31S-N46W
2	K31M-C25W	K31S-B40W	32	K31M-P2W	K31S-O24W
3	K31M-D2W	K31S-C24W	33	K31M-P9W	K31S-O31W
4	K31M-D33[a]	K31S-D18W	34	K31M-P17W	K31S-O44W
5	K31M-D41W	K31S-D41W	35	K31M-P33[a]	K31S-O45W
6	K31M-D49W	K31S-E27W	36	K31M-Q9W	K31S-P19W
7	K31M-E17W	K31S-F10W	37	K31M-Q17W	K31S-P36W
8	K31M-E33[a]	K31S-H3W	38	K31M-Q25W	K31S-P45W
9	K31M-F2W	K315-H13W[a]	39	K31M-Q41W	K31S-Q36W
10	K31M-F17W	K31S-H16W	40	K31M-Q49W	K315R2W[a]
11	K31M-F41W	K31S-H23W	41	K31M-R2W	K31S-R4W
12	K31M-G9W	K31S-H37W	42	K31M-R17W	K31S-S24W
13	K31M-G33[a]	K31S-I10W	43	K31M-R33[a]	K31S-S38W
14	K31M-H9W	K315-I13W[a]	44	K31M-R49W	K315T7W[a]
15	K31M-H41W	K31S-I35W	45	K31M-S41W	K31S-T27W
16	K31M-I9W	K31S-I38W	46	K31M-T41W	K31S-T30W
17	K31M-I33[a]	K31S-I46W	47	K31M-U25W	K31S-T47W
18	K31M-J17W	K315-J30W[a]	48	K31MV2W[a]	K31S-U31W
19	K31M-J33[a]	K31S-J48W	49	K31M-V9W	K31S-W14W
20	K31M-K41W	K31S-K15W	50	K31M-X17W	K31S-W19W
21	K31M-L2W	K31S-K22W	51	K31M-X49W	K31S-W38W
22	K31M-L17W	K315-K27W[a]	52	K31M-Y49W[a]	K31S-Y32[a]
23	K31M-L49W-D[a]	K315-K29W[a]	53	K31M-Y17W	K31M-Z38W[a]
24	K31M-M9W	K31S-L11W	54	K31M-S25W	K31S-AA17W
25	K31M-M33[a]	K31S-M10W	55	K31M-AA17W	K31M-AA26W[a]
26	K31M-M41W	K31S-M14W	56	K31M-AA25W	K31S-AA28W
27	K31M-M49W-D[a]	K31S-M16W	57	K31M-AA33[a]	K315-BB3W
28	K31M-N33[a]	K31S-M34[a]	58	K31M-AA41W	K315-BB4W[a]
29	K31M-N49W-D[a]	K31S-N23W	59	K31M-BB9W	K31S-BB25W
30	K31M-O25W	K31S-N25W	60	K31M-CC28W[a]	K31S-CC29W

[a]The listed ID does not match exactly the ID number listed in the field logbook.

Appendix B

RESULTS OF DUPLICATE WIPE ANALYSES IN BUILDING K-31

Table B.1. Results of duplicate wipe analyses in Building K-31

	Analysis					
	PCB ($\mu g/100\ cm^2$)		Uranium ($\mu g/100\ cm^2$)		Technetium ($pCi/100\ cm^2$)	
	Original	Duplicate	Original	Duplicate	Original	Duplicate
			Main plenum location			
E-33	0.5	0.55	27	30	3.28	2.18
H-41	1.1	0.72	1100	700	0	0
M-9	0.86	1.2	110	48	1420	1670
S-49	1.5	2.3	520	290	0	465
R-17	50	1.2	48	18	1.51	1.34
R-9	3.4	1.5	111	201	716	3000
			Side lateral location			
C-40	3.8	5.8	370	920	62.2	169
J-48	9.3	14	4300	1600	7280	4740
T-27	290	16	1900	1400	4310	3370
BB-28	8.9	2.7	1600	125	9830	54100
			Air-intake location			
H-13	1.9	3.6	230	115	13.8	10.6
R-4	1.8	3.7	113	36	1240	0
	$s_p = 56.8^a$		$s_p = 654$		$s_p = 9070$	

[a]The standard deviation listed is the pooled standard deviation [J. K. Taylor, *Statistical Techniques for Data Analysis*, Lewis Publishers, Inc., Chelsea, Mich., p. 46 (1990)].

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