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**Characterization of Ventilation
Ductwork in Building K-29 at the
Oak Ridge K-25 Site**

K. T. Klasson
S. L. Corder

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Chemical Technology Division

**CHARACTERIZATION OF VENTILATION DUCTWORK IN BUILDING K-29
AT THE OAK RIDGE K-25 SITE**

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ABSTRACT

An extensive sampling and analysis program was initiated in mid-October 1992 to characterize the ductwork of Building K-29 at the Oak Ridge K-25 Site. This building, 4 acres under roof, contains approximately 1500 feet of main exhaust ducts (plenums), not including the side laterals. A large number of hexane-moistened wipe samples were taken from randomly selected locations within the four main plenums and the side lateral ducts. Three wipes were taken from each location and were analyzed for polychlorinated biphenyls (PCBs), uranium, and technetium. These samples were augmented with 12 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 $< 16,200$ and $< 2300 \mu\text{g}/100 \text{ cm}^2$ for the main plenums and side lateral ducts respectively; uranium levels are < 910 and $< 6770 \mu\text{g}/100 \text{ cm}^2$ for the main plenums and side lateral ducts respectively; and technetium levels are $< 16,100$ and $< 65,000 \text{ pCi}/100 \text{ cm}^2$ for the main plenums and side laterals respectively. The levels of radiological contamination found would classify the main and side lateral ducts as contamination areas according to Energy Systems' standards for radiation protection and its interpretation of Attachment 2 of DOE Order 5480.11.

1. INTRODUCTION

Complete characterization of the interior of the ventilation ductwork in Building K-29 at the Oak Ridge K-25 Site would be a rather massive and costly undertaking. The building itself is large, with dimensions of 405 by 435 ft, or a total of 4 acres, under roof. The ventilation ductwork consists of four main plenums, each 367 ft long (a total length of 1500 ft). The two main plenums in the center of the building are about 6 ft wide, and the remaining two plenums on the east and west side of the building are about 4 ft wide. A large number of side laterals intersect each main plenum. Each of the center plenums has approximately 42 lateral ducts, and each of the other plenums has 20 lateral ducts. Each side lateral duct is approximately 2 to 4 ft in diameter, and the lateral ductwork on each side of the main plenums covers about a 60- by 360-ft area. A sampling plan to determine the general level and worst-case contamination for Building K-29 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-29 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 on the inside surface of a duct. 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-29. Each wipe was rubbed over a different 100-cm² 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 logbook 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 and analysis plan. The three wipes from each sampling location, representing 100 cm² 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-cm² pieces of metal coupons was subjected to analysis for radionuclides and to Toxicity Characteristic Leaching Procedure (TCLP; see 40 CFR Part 261, Appendix II) for toxic metals, base/neutral/acid compounds (BNAs), and volatile organic compounds (VOAs).

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-29 and were randomly generated. During the course of the actual sampling process, 14 of the initially selected locations for the main plenums and 16 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. 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-29 duct system may be seen in Fig. 1*. As is 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 M1E705020-A001 — reproduced in reduced form as Fig. 1.

Fig. 1. Layout of main plenums and :

de laterals in Building K-29, showing column numbers and sampling locations.

Table 1. Sampling locations in main plenums of Building K-29

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

^aIf the planned sampling location was inaccessible, the alternate location is listed.

Table 2. Sampling locations in side lateral ducts of Building K-29

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

^aIf the planned sampling location was inaccessible, the alternate location is listed.

1.2 Sampling the Ductwork of Building K-29

Sampling of the ductwork of Building K-29 began on October 12, 1992, and was completed on December 16, 1992. During this period, 131 wipe samples were taken, of which 11 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 and analysis plan. Twelve metal coupon samples and one composite bulk sample were taken and submitted for radionuclide and TCLP analyses (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 couple of sampling areas revealed no external contamination. 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, a heavy, oily-appearing dust with brown "gravel" or debris was noted. A bulk sample of this substance was collected as a composite sample from three locations. 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-29 DUCT SAMPLES

A number of hexane-moistened wipe samples (132), including 11 duplicates taken from the ductwork of Building K-29, 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 cm². One hundred nineteen metal coupons (100 cm²) were taken, of which 12 were analyzed for radionuclides and for toxic metals, base/neutral/acid compounds (BNAs), and volatile organic compounds (VOAs) by TCLP. One composite bulk sample was also taken and analyzed for radionuclides and by TCLP for toxic metals, BNAs, and VOAs.

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-29 are listed in Table 3. The data are separated and listed for each of the seven main plenums in K-29 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 intervals for each main plenum, together with the number of samples taken from the particular plenum. Tolerance intervals 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 tolerance limit was chosen to encompass 95% of all measurements with 95% confidence.

The ranges (tolerance intervals) for all main plenums in K-29 are listed in Table 5, together with the highest measured concentrations of PCBs, uranium, and technetium in each main plenum. Note that the highest actual measured concentration may be less than or greater than the statistically-derived tolerance limit.

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-29 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. The mean values of the analyses, 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

One hundred nineteen metal coupon samples (area of 100 cm² each) were obtained from the ductwork of Building K-29. Twelve 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, BNAs, and VOAs. Six samples were taken from main plenums, and the remaining six 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.

2.4 Bulk Sample

One composite bulk sample was collected by gathering loose deposits inside the side lateral ducts at locations W-15, E-3, and B-5. The materials were combined into one composite sample and analyzed for radionuclides and by TCLP for toxic metals, BNAs, and VOAs. The results of the analyses are listed in Table 11.

Table 3. Results of analyses of wipe samples from main plenums in Building K-29

Column no.	Analysis		
	PCB ($\mu\text{g}/100\text{ cm}^2$)	Uranium ($\mu\text{g}/100\text{ cm}^2$)	Technetium (pCi/100 cm^2)
C-2	85	290	1,980 $\pm$ 600
D-2	18	890	1,960 $\pm$ 650
F-2	14	470	875 $\pm$ 700
G-2	16	880	1,500 $\pm$ 630
H-2	11	440	1,900 $\pm$ 650
J-2	32	840	6,100 $\pm$ 770
K-2	23	740	3,450 $\pm$ 690
M-2	7	690	5,390 $\pm$ 700
L-2	2.8	280	1,870 $\pm$ 2,800
R-2	8.2	600	4,130 $\pm$ 2,800
V-2	51	440	6,530 $\pm$ 870
R-2	36	450	10,000 $\pm$ 820
S-2	26	170	1,050 $\pm$ 570
T-17	73	440	2,930 $\pm$ 630
V-2	79	290	2,690 $\pm$ 620
X-2	51,000	1,200	6,360 $\pm$ 730
	$\bar{x} = 3,217.6$ $s = 12,742.0$	$\bar{x} = 569$ $s = 281$	$\bar{x} = 3,670$ $s = 2,552$
H-9	6.6	820	549 $\pm$ 560
H-9	22	220	1,350 $\pm$ 490
K-9	5	570	2,860 $\pm$ 500
L-9	15	220	2,780 $\pm$ 490
M-9	3.3	280	5,090 $\pm$ 560
N-9	2.2	160	2,710 $\pm$ 530
F-9	10	590	6,350 $\pm$ 2,200
P-9	4.3	170	3,470 $\pm$ 560
Q-9	2.3	130	2,120 $\pm$ 520
R-9	17	170	5,430 $\pm$ 610
S-9	35	160	8,230 $\pm$ 680
T-9	9.3	210	4,490 $\pm$ 580
V-9	33	150	4,450 $\pm$ 580
X-9	9.4	105	3,700 $\pm$ 560
	$\bar{x} = 12.5$ $s = 10.8$	$\bar{x} = 283$ $s = 216$	$\bar{x} = 3,827$ $s = 2,037$

Table 3 (continued)

Column no.	Analysis		
	PCB ($\mu\text{g}/100\text{ cm}^2$)	Uranium ($\mu\text{g}/100\text{ cm}^2$)	Technetium ($\text{pCi}/100\text{ cm}^2$)
B-17	1.6	190	$2,990 \pm 2,100$
C-17	50	480	$17,000 \pm 2,600$
D-17	3.4	150	$5,710 \pm 2,200$
E-17	3.7	140	$4,780 \pm 2,200$
F-17	77	120	$3,150 \pm 780$
G-17	1.1	170	$6,270 \pm 1,600$
H-17	1.6	110	$2,480 \pm 760$
K-17	4	390	$4,330 \pm 810$
J-17	61	200	$4,640 \pm 820$
M-17	2.7	160	$3,310 \pm 1,100$
N-17	40	310	$13,400 \pm 1,400$
P-17	40	130	$12,800 \pm 1,400$
Q-17	3.9	38	$6,600 \pm 1,200$
R-17	5	99	$8,690 \pm 1,300$
T-17	3.4	61	$4,970 \pm 1,200$
U-17	18	130	$12,900 \pm 1,400$
V-17	4.5	140	$5,470 \pm 700$
	$\bar{x} = 18.9$	$\bar{x} = 178$	$\bar{x} = 7,029$
	$s = 24.7$	$s = 115$	$s = 4,356$
H-25	2.1	91	$240 \pm 2,700$
E-25	21	210	$4,310 \pm 1,500$
D-25	16	470	$3,000 \pm 1,400$
G-25	9.7	560	$7,300 \pm 1,600$
H-25	3.9	400	$5,860 \pm 1,500$
M-25	91	140	$5,550 \pm 1,500$
L-25	2.2	59	$1,270 \pm 2,700$
L-25	3.2	100	$2,670 \pm 2,800$
P-25	1.9	99	$21,800 \pm 2,000$
Q-25	3.9	76	$16,000 \pm 1,800$
R-25	3.6	120	$17,400 \pm 1,800$
T-25	2.2	96	$7,230 \pm 2,900$
V-25	3.1	220	$9,760 \pm 3,000$
	$\bar{x} = 12.6$	$\bar{x} = 203$	$\bar{x} = 7,876$
	$s = 24.3$	$s = 166$	$s = 6,645$

Table 4. Mean values of analyses for PCB, uranium, and technetium in main plenums of Building K-29

Main plenum no.	Mean value of analyses and range ^a					
	PCB ($\mu\text{g}/100\text{ cm}^2$)		Uranium ($\mu\text{g}/100\text{ cm}^2$)		Technetium ($\text{pCi}/100\text{ cm}^2$)	
2	3,217.6 $\pm$ 36,990.0	(16) ^b	569 $\pm$ 817	(16)	3,670 $\pm$ 7,407	(16)
9	12.5 $\pm$ 32.6	(14)	283 $\pm$ 651	(14)	3,827 $\pm$ 6,137	(14)
17	18.9 $\pm$ 70.5	(17)	178 $\pm$ 328	(17)	7,029 $\pm$ 12,450	(17)
25	12.6 $\pm$ 74.9	(13)	203 $\pm$ 512	(13)	7,876 $\pm$ 20,474	(13)

^aRange 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.

^bNumber within parentheses indicates how many samples were taken and analyzed.

Table 5. Ranges and highest analytical values for PCB, uranium, and technetium in main plenums of Building K-29

Main plenum no.	Range ^a and highest ^b level					
	PCB ($\mu\text{g}/100\text{ cm}^2$)	Highest value	Uranium ($\mu\text{g}/100\text{ cm}^2$)	Highest value	Technetium ($\text{pCi}/100\text{ cm}^2$)	Highest value
2	0-40,208	51,000	0-1,387	1,200	0-11,077	10,000
9	0-45.1	35	0-933	820	0-9,964	8,230
17	0-89.4	77	0-505	480	0-19,479	17,000
25	0-87.5	91	0-715	560	0-28,350	21,800

^aRange of values is mean value $\pm$ the tolerance interval. When the low-range value is negative, it is set to zero.

^bHighest 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-29
(grouped by main duct)**

Column no.	Analysis		
	PCB ($\mu\text{g}/100\text{ cm}^2$)	Uranium ($\mu\text{g}/100\text{ cm}^2$)	Technetium (pCi/100 cm^2)
C-3	24	700	1,590 $\pm$ 500
B-5	110	830	3,200 $\pm$ 640
C-2	9	1,000	8,560 $\pm$ 780
E-3	310	2,400	11,100 $\pm$ 890
G-2	29	1,900	1,020 $\pm$ 710
G-4	5.4	52	1,170 $\pm$ 620
H-5	14	1,300	4,330 $\pm$ 720
J-2	71	1,600	3,920 $\pm$ 800
K-4	280	1,500	6,180 $\pm$ 860
L-2	11	170	6,130 $\pm$ 720
M-5	31	360	15,300 $\pm$ 820
P-5	53	520	21,900 $\pm$ 940
R-6	100	400	35,100 $\pm$ 1100
S-4	66	180	9,770 $\pm$ 710
T-4	74	260	5,760 $\pm$ 620
U-4	52	480	11,600 $\pm$ 750
V-4	3	200	2,700 $\pm$ 530
	$\bar{x} = 73.1$ $s = 89.8$	$\bar{x} = 815$ $s = 695$	$\bar{x} = 8,784$ $s = 8,754$
C-7	17	1,600	11,200 $\pm$ 890
E-13	180	19,000	26,400 $\pm$ 2,800
H-12	64	3,800	12,200 $\pm$ 860
H-9	6.6	170	3,180 $\pm$ 640
J-12	16	1,000	5,560 $\pm$ 570
J-13	120	1,100	10,900 $\pm$ 2400
J-10	1.4	610	9,630 $\pm$ 810
J-11	164	1,700	36,200 $\pm$ 1,300
K-12	98	670	7,090 $\pm$ 740
L-14	61	570	9,350 $\pm$ 950
M-11	92	230	908 $\pm$ 440
N-8	4.5	290	5,580 $\pm$ 610
Q-9	2.3	270	9,200 $\pm$ 700
V-10	2.7	30	1,020 $\pm$ 480
	$\bar{x} = 59.3$ $s = 62.7$	$\bar{x} = 2,217$ $s = 4,928$	$\bar{x} = 10,601$ $s = 9,672$

Table 6 (continued)

Column no.	Analysis		
	PCB ($\mu\text{g}/100\text{ cm}^2$)	Uranium ($\mu\text{g}/100\text{ cm}^2$)	Technetium (pCi/100 cm^2)
C-15	45	240	15,500 $\pm$ 3,200
D-18	1,400	370	15,600 $\pm$ 1,100
E-15	260	760	51,800 $\pm$ 4,100
G-16	50	2,100	14,600 $\pm$ 1,800
G-18	11	1,500	7,980 $\pm$ 1,600
H-14	8.8	520	14,300 $\pm$ 3,100
J-18	1.2	150	3,580 $\pm$ 790
K-15	64	1,400	47,100 $\pm$ 2,500
K-18	33	280	14,900 $\pm$ 1,800
L-19	8.3	1,100	18,100 $\pm$ 1,900
N-16	68	270	7,540 $\pm$ 1,200
N-17	57	450	6,120 $\pm$ 1,200
P-18	5.1	420	11,100 $\pm$ 1,300
Q-19	4	270	8,640 $\pm$ 1,300
R-20	14	980	16,300 $\pm$ 1,800
R-14	8.3	140	19,000 $\pm$ 1,200
S-20	30	1,500	36,400 $\pm$ 1,500
V-14	1,100	26	6,240 $\pm$ 860
W-15	6,800	240	10,600 $\pm$ 830
X-16	28	750	32,000 $\pm$ 1,200
	$\bar{x} = 499.8$ $s = 1,530.4$	$\bar{x} = 673$ $s = 575$	$\bar{x} = 17,870$ $s = 13,497$
D-23	46	890	11,600 $\pm$ 2,400
E-23	200	250	10,400 $\pm$ 2,400
K-22	19	480	9,190 $\pm$ 1,600
Q-23	40	89	18,300 $\pm$ 1,900
S-25	7.8	230	25,500 $\pm$ 1,300
T-24	62	87	36,700 $\pm$ 1,500
U-22	0.66	34	3,830 $\pm$ 790
V-22	70	820	152,000 $\pm$ 2,800
X-22	5.9	380	9,890 $\pm$ 960
	$\bar{x} = 50.2$ $s = 61.5$	$\bar{x} = 362$ $s = 314$	$\bar{x} = 30,823$ $s = 46,536$

Table 7. Mean values of analyses for PCB, uranium, and technetium in side lateral ducts in Building K-29

Main plenum no.	Mean analyses and range ^a					
	PCB ($\mu\text{g}/100\text{ cm}^2$)		Uranium ($\mu\text{g}/100\text{ cm}^2$)		Technetium (pCi/100 cm^2)	
2	73.1 $\pm$ 256.6	(17)	815 $\pm$ 1,986	(17)	8,784 $\pm$ 25,018	(17)
9	59.3 $\pm$ 188.8	(14)	2,217 $\pm$ 14,842	(14)	10,601 $\pm$ 29,133	(14)
17	499.8 $\pm$ 4,211.7	(20)	673 $\pm$ 1,582	(20)	17,870 $\pm$ 37,145	(20)
25	50.2 $\pm$ 217.3	(9)	362 $\pm$ 1,110	(9)	30,823 $\pm$ 164,366	(9)

^aRange 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.

^bNumber within parentheses indicates how many samples were taken and analyzed.

Table 8. Ranges and highest analytical values for PCB, uranium, and technetium in main plenums of Building K-29

Main plenum no.	Range ^a and highest ^b value					
	PCB ($\mu\text{g}/100\text{ cm}^2$)	Highest value	Uranium ($\mu\text{g}/100\text{ cm}^2$)	Highest value	Technetium (pCi/100 cm^2)	Highest value
2	0-329.7	310	0-2,801	2,400	0-33,802	35,100
9	0-248.0	180	0-17,059	19,000	0-39,734	36,200
17	0-4,711.5	6,800	0-2,256	2,100	0-55,015	51,800
25	0-267.5	200	0-1,472	890	0-195,189	152,000

^aRange of values is mean value $\pm$ the tolerance interval. When the low-range value is negative, it is set to zero.

^bHighest 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-29
(All values are picocuries per liter)

Analysis	Location (column no.)				
	F-17	H-25	K-2	L-25	R-9 R-17
Alpha activity	201 ± 160	230 ± 170	159 ± 170	14.5 ± 130	29 ± 140
Beta activity	1,250 ± 340	476 ± 270	<0	638 ± 280	<0
Cesium-137	<0	5.83 ± 32	<0	1.48 ± 38	14.1 ± 51
Gamma activity	NA	NA	NA	NA	NA
Protactinium	3,060 ± 8,400	<0	10,100 ± 17,000	2,590 ± 6,500	654 ± 11,000
Uranium alpha activity	13.7 ± 20	30.8 ± 46	68.4 ± 120	0 ± 30	0 ± 86
Uranium-235	NA	34.9 ± 63	NA	<0	NA
Technetium-99	4,150 ± 2,800	2,080 ± 14,000	1,360 ± 2,700	4,130 ± 17,000	3,130 ± 2,800
Neptunium-237	<0	57 ± 66	<0	34.6 ± 49	<0
Plutonium-238	<0	0 ± 66	0 ± 130	0 ± 60	0 ± 120
Plutonium-239	<0	0 ± 66	36.5 ± 73.1	0 ± 60	0 ± 120
Thorium-228	0 ± 16	<0	<0	<0	<0
Thorium-230	<0	0 ± 75	<0	91.2 ± 91	<0
Thorium-232	0 ± 16	21.7 ± 43	0 ± 79	45.6 ± 64	0 ± 75
Thorium-234	<0	<0	<0	<0	<0
Total activity	2,260 ± 860	669 ± 820	<0	230 ± 800	2,700 ± 880

^a Coupon size was 10 by 10 cm.

TCLP tests for the following toxic metals were also performed: arsenic, barium, cadmium, chromium, lead, nickel, selenium, and silver.

TCLP tests for the following BNA compounds were also performed: pyridine, 1,4-dichlorobenzene, 1,2-dichlorobenzene, 2-methylphenol, 4-methylphenol, hexachloroethane, nitrobenzene, hexachlorobutadiene, 2,4,6-trichlorophenol, 2,4,5-trichlorophenol, 2,4-dinitrotoluene, hexachlorobenzene, pentachlorophenol, and 2,3,4,6-tetrachlorophenol.

TCLP tests for the following VOA compounds were also performed: vinyl chloride, 1,1-dichloroethene, chloroform, 1,2-dichloroethane, 2-butanone, carbon tetrachloride, trichloroethene, benzene, tetrachloroethane, and chlorobenzene.

Results from TCLP tests are given in the main text.

Table 10. Analyses of metal coupons^a from side lateral ducts in Building K-29
(All values are picocuries per liter)

Analysis	Location (column no.)					
	G-16	M-5	M-11	R-20	R-14	X-16
Alpha activity	355 ± 190	113 ± 190	42.3 ± 180	231 ± 170	159 ± 160	57.5 ± 150
Beta activity	1,550 ± 360	744 ± 300	1,090 ± 320	1,307 ± 320	1,580 ± 330	2,570 ± 460
Cesium-137	<0	2.07 ± 56	<0	<0	<0	<0
Gamma activity	NA	NA	NA	NA	NA	NA
Protactinium	<0	<0	306 ± 9,500	1,460 ± 8,500	3,790 ± 7,200	2,050 ± 14,000
Uranium alpha activity	45.9 ± 30	<0	<0	10.8 ± 37	21.7 ± 43	<0
Uranium-235	NA	NA	NA	<0	21.7 ± 70	NA
Technetium-99	1,240 ± 2,700	39.6 ± 2,000	2,170 ± 2,100	3,960 ± 14,000	<0	4,640 ± 2,800
Neptunium-237	0 ± 19	0 ± 98	<0	17.4 ± 35	32.8 ± 46	<0
Plutonium-238	<0	34.6 ± 69	0 ± 130	34.7 ± 49	0 ± 57	33.4 ± 67
Plutonium-239	<0	104 ± 120	0 ± 130	17.4 ± 35	0 ± 57	0 ± 120
Thorium-228	0 ± 14	1,430 ± 1,700	0 ± 79	<0	<0	<0
Thorium-230	<0	64.9 ± 75	0 ± 79	41.7 ± 59	21.6 ± 43	<0
Thorium-232	0 ± 14	0 ± 75	0 ± 79	0 ± 72	0 ± 75	0 ± 72
Thorium-234	<0	<0	293 ± 760	862 ± 360	<0	2,250 ± 730
Total activity	2,180 ± 850	1,330 ± 840	1,740 ± 850	2,080 ± 860	1,180 ± 840	2,990 ± 880

^a Coupon size was 10 by 10 cm.

TCLP tests for the following toxic metals were also performed: arsenic, barium, cadmium, chromium, lead, nickel, selenium, and silver.

TCLP tests for the following BNA compounds were also performed: pyridine, 1,4-dichlorobenzene, 1,2-dichlorobenzene, 2-methylphenol, 4-methylphenol, hexachloroethane, nitrobenzene, hexachlorobutadiene, 2,4,6-trichlorophenol, 2,4,5-trichlorophenol, 2,4-dinitrotoluene, hexachlorobenzene, pentachlorophenol, and 2,3,4,6-tetrachlorophenol.

TCLP tests for the following VOA compounds were also performed: vinyl chloride, 1,1-dichloroethene, chloroform, 1,2-dichloroethane, 2-butanone, carbon tetrachloride, trichloroethene, benzene, tetrachloroethane, and chlorobenzene.

Results from TCLP tests are given in the main text.

Table 11. Analyses of composite bulk sample taken from side lateral duct at locations W-15, E-3, and B-5 in Building K-29

Analysis	Detected Amount
<i><u>Radionuclides (pCi/g)</u></i>	
Alpha Activity	315 ± 17
Beta Activity	1170 ± 22
Gamma Activity	NA
Protactinium	0.527 ± 0.19
Uranium Alpha Activity	955 ± 46
Technetium-99	1410 ± 210
Neptunium-237	<0 ± 3.6
Plutonium-238	1.82 ± 2.6
Plutonium-239	0 ± 2.6
Thorium-228	<0 ± 3.9
Thorium-230	36.3 ± 14
Thorium-232	6.8 ± 6.4
Total Activity	2460 ± 47
<i><u>TCLP/Metals (mg/L)</u></i>	
Arsenic	<0.50
Barium	<1.0
Cadmium	1.1
Chromium	0.24
Lead	<0.50
Nickel	1.6
Selenium	<0.50
Silver	<0.070

Table 11 (continued)

Analysis	Detected Amount
<u>TCLP/BNAs ($\mu\text{g/L}$)</u>	
Pyridine	U*
4-Dichlorobenzene	U
1,2-Dichlorobenzene	U
2-Methylphenol	U
4-Methylphenol	U
Hexachloroethane	U
Nitrobenzene	U
Hexachlorobutadiene	U
2,4,6-Trichlorophenol	U
2,4,5-Trichlorophenol	U
2,4-Dinitrotoluene	U
Hexachlorobenzene	U
Pentachlorophenol	13
2,3,4,6-Tetrachlorophenol	U
<u>TCLP/VOAs ($\mu\text{g/L}$)</u>	
Vinyl chloride	U
1,1-Dichloroethene	U
Chloroform	U
1,2-Dichloroethane	U
2-Butanone	75
Carbon tetrachloride	U
Trichloroethene	U
Benzene	U
Tetrachloroethane	U
Chlorobenzene	U

*U = undetected

3. DISCUSSION

As noted in Table 5, the estimated range of PCB surface contamination exceeds 10 $\mu\text{g}/100\text{ cm}^2$, the Martin Marietta Energy Systems, Inc., mandated cleanliness standard for either high- or low-contact PCB-contaminated surfaces for all of the major plenums. The highest surface contamination was found in plenum number 2 (at location X-2), where the contamination was 51,000 $\mu\text{g}/100\text{ cm}^2$. The sampling crew noticed a thin layer of oil inside the duct close to the gasket at this location.

Main plenum number 2 with the highest estimated range of PCB surface contamination also contained the highest estimated range of uranium. Plenum number 2 (at location X-2), which is located along the west side of the building, had a maximum surface contamination of 1200 μg uranium/100 cm^2 , and plenum number 25 (east side of K-29) had a maximum surface contamination of 21,800 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 25) are equivalent to 1800 dpm (disintegrations/min) alpha and 48,400 dpm beta respectively. There was no obvious relationship between the uranium and technetium analyses. The levels of radiological contamination found would classify the main ducts (see Table 4) as contamination areas 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 lower than the levels found in the main plenums. The overall mean for the analyses shown in Table 6 is 209 μg PCB/100 cm^2 ($s = 895$) compared with 869 μg PCB/100 cm^2 ($s = 6580$) for the 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 1030 $\mu\text{g}/100\text{ cm}^2$ ($s = 2460$) compared with 312 $\mu\text{g}/100\text{ cm}^2$ ($s = 256$) 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 15,500 pCi/100 cm^2 ($s = 21,200$), while the mean for the main plenums in Table 3 is 5570 pCi/100 cm^2 ($s = 4490$).

The mean values in the side laterals (see Table 7) are above the Martin Marietta Energy Systems, Inc., PCB cleanliness standard, and the mean radiological levels in the side laterals would classify these as contamination areas based on alpha and beta activities according to the Energy Systems' listed levels.

Based on the wipe analyses, the following overall tolerance limits for Building K-29 may be set so that one can say, with 95% confidence, that 95% of the contamination levels in the ductwork fall within these limits.*

	<u>Main plenums</u>	<u>Side lateral ducts</u>
PCB ($\mu\text{g}/100\text{ cm}^2$)	0-16,200	0-2,300
Uranium ($\mu\text{g}/100\text{ cm}^2$)**	0-910	0-6,770
Technetium (pCi/100 cm^2)***	0-16,100	0-65,000

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 12 coupon samples did not reveal surprising results. The highest activity detected was from the sample collected on a side lateral at location X-16, where the total activity was measured as 2990 pCi/L in the extract. In general, the side laterals appeared to be more contaminated, with all of the coupons samples having significant (above-error) total activity.

The TCLP tests indicated concentrations of metals as follows: 0.032 mg/L cadmium and 0.38 mg/L nickel in the side lateral at X-16, and 0.032 mg/L cadmium in the main plenum at R-17. The TCLP/BNA testing revealed no detectable BNA compounds in any of the coupon samples. Results from the TCLP/VOA assays indicated that an estimated 17 $\mu\text{g}/\text{L}$ of 2-butanone was present in the sample from side lateral at G-16, and an estimated 19 $\mu\text{g}/\text{L}$ of 2-butanone was present in the samples from the main plenum at K-2, R-9, and R-17. Samples from the side

*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 1350 and 10,000 dpm $\alpha/100\text{ cm}^2$ for the main and side lateral ducts respectively.

***The upper values listed of technetium correspond to 35,700 and 144,000 dpm $\beta/100\text{ cm}^2$ in the main and side lateral ducts respectively.

lateral at M-11 and X-16 and a sample from the main plenum at location M-25 revealed 20 $\mu\text{g/L}$ of 2-butanone. No other compounds were detected in the coupon samples.

Analyses of the composite bulk sample revealed a total activity of 2460 pCi/g. Cadmium, chromium, and nickel were found in the bulk sample in concentrations of 1.2, 0.24, and 1.6 mg/L respectively. Also found in the bulk sample were 13 $\mu\text{g/L}$ pentachlorophenol and 75 $\mu\text{g/L}$ 2-butanone.

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 ID as recorded by K-25's Analytical Chemistry Department			Sample ID as recorded by K-25's Analytical Chemistry Department		
Sample no.	Main plenum sample	Side lateral duct sample	Sample no.	Main plenum sample	Side lateral duct sample
1	K29-B17W	K29S-B3W	31	K29M-N9W	K29S-L2W
2	K29-B25W	K29S-B5W	32	K29M-N17W	K29S-L14W
3	K29M-C2W	K29S-C2W	33	K29M-N25W	K29S-L19W
4	K29M-C17W	K29S-C7W	34	K29M-O2W	K29S-M5W
5	K29M-C25W	K29S-C15W	35	K29M-O9W	K29S-M11W
6	K29M-D2W	K29S-D18W	36	K29M-O17W	K29S-N8W
7	K29M-D17W	K29S-D23W	37	K29M-O25W	K29S-N16W
8	K29M-D25W	K29S-E3W	38	K29M-P2W	K29S-N17W
9	K29M-E17W	K29S-E13W	39	K29M-P9W	K29S-O18W
10	K29M-F2W	K29S-E15W	40	K29M-P25W	K29S-Q4W
11	K29M-F17W	K29S-E23W	41	K29M-Q9W	K29S-Q9W
12	K29M-G2W	K29S-G2W	42	K29M-Q17W	K29S-Q19W
13	K29M-G17W	K29S-G4W	43	K29M-Q25W	K29S-Q22W
14	K29M-G25W	K29S-G16W	44	K29M-R2W	K29S-Q23W
15	K29M-H2W	K29S-G18W	45	K29M-R9W	K29S-R6W
16	K29M-H9W	K29S-H5W	46	K29M-R17W	K29S-S6W
17	K29M-H17W	K29S-H12W	47	K29M-R25W	K29S-S14W
18	K29M-I9W	K29S-H14W	48	K29M-S2W	K29S-S25W
19	K29M-I17W	K29S-I9W	49	K29M-S9W	K29S-T6W
20	K29M-I25W	K29S-I12W	50	K29M-T2W	K29S-T21W
21	K29M-J2W	K29S-I13W	51	K29M-T9W	K29S-T24W
22	K29M-J17W	K29S-J2W	52	K29M-T17W	K29S-U6W
23	K29M-K2W	K29M-J10W*	53	K29M-T25W	K29S-U14W
24	K29M-K9W	K29S-J11W	54	K29M-U17W	K29S-U22W
25	K29M-L9W	K29S-J18W	55	K29M-U25W	K29S-V4W
26	K29M-M2W	K29S-K4W	56	K29M-V2W	K29S-V10W
27	K29M-M9W	K29S-K12W	57	K29M-V9W	K29S-V22W
28	K29M-M17W	K29S-K15W	58	K29M-V17W	K29S-W15W
29	K29M-M25W	K29S-K18W	59	K29M-X2W	K29S-W16W
30	K29M-N2W	K29S-K22W	60	K29S-X4W*	K29S-X21W

*The listed ID does not exactly match the ID number listed in the field logbook.

Appendix B— RESULTS OF DUPLICATE WIPE ANALYSES IN BUILDING K-29

Table B.1. Results of duplicate wipe analyses in Building K-29

Column no.	Analysis					
	PCB ($\mu\text{g}/100\text{ cm}^2$)		Uranium ($\mu\text{g}/100\text{ cm}^2$)		Technetium (pCi/100cm ²)	
	Original	Duplicate	Original	Duplicate	Original	Duplicate
<i>Main plenums</i>						
H-25	2.1	1.6	91	100	240	2670
F-17	77	170	120	140	3,150	2710
K-2	23	8.1	740	1,100	3,450	3770
M-25	91	51	140	200	5,550	5020
R-9	17	17	170	160	5,430	6930
R-17	5	5.5	99	70	8,690	5590
<i>Side lateral ducts</i>						
G-16	50	30	2,100	660	14,600	11,400
M-5	31	14	360	350	15,300	35,300
M-11	92	73	230	270	908	264
R-20	14	15	980	830	16,300	8,960
R-14	8.3	16	140	300	19,000	12,100
sp^a=33.9			sp=472		sp=6,949	

^aThe 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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