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VERIFICATION SURVEY OF
BUILDING 200 HOT CELLS

by

C. M. Sholeen

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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**VERIFICATION SURVEY
OF
BUILDING 200
HOT CELLS**

**ARGONNE
NATIONAL LABORATORY
ARGONNE, ILLINOIS**

Prepared by
C. M. Sholeen

Environment Safety and Health Division
Health Physics Section
Argonne National Laboratory
Argonne, IL 60439

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EXECUTIVE SUMMARY

At the start of this D&D project, the decontamination goals were set at 1) reducing the stack emissions to 10% of the 1991 emissions; 2) reducing the exposure rate in each cell to < 1 mR/h; and 3) reducing the removable contamination to none detectable. Since the contamination can be fixed with paint, the other two goals were given priority. The estimate of the 1995 emissions from K-3 was 20% of the 1991 emissions estimate. However, the 1996 estimates are ~9% of the 1991 emissions estimate. Since in 1991 the K-3 emissions were only ½% of the emissions from M-1, even the 20% reduction has little effect on the project reduction. The total emissions have been reduce to ~2¼% of the 1991 emissions from the 5 hot cells that were decontaminated. The emissions and exposure rates are presented in Table i below. Cells A-1 and M-1 exceed the exposure rate criteria. For the other cells, the general exposure rate in the middle of the cell meets the criteria. However, near the prefilters, the exposure rates increase. Cell M-1 has extensive floor contamination that penetrated to a 6 inch depth. At 30 cm above the floor, the exposure rate through the lead blanket is 50 mR/h. A more detailed list of acceptance criteria were specified before the final verification survey. Table ii compares the maximum survey results on the wall or floor surface of each cell to these criteria. Cells M-1 and A-1 frequently fail to meet these criteria.

Table i. General Hot Cell Exposure Rates and Emissions

Cell	mR/h		mR/h @ 30 cm		% 1991 Emissions	
	Criteria	General @ 1¼ m	High Flow Filter	Low Flow Filter	Criteria	Current
A-1	≤ 1.0	2.5	2.0	2.0	< 10	NA
K-1	≤ 1.0	0.5	0.5	2.0	< 10	0.8
K-3	≤ 1.0	0.2	0.2	0.1	< 10	~9
M-3	≤ 1.0	0.2	0.1	2.0	< 10	6
M-1	≤ 1.0	5.0	10	5.0	< 10	3
M-1 cell center		10				

^a The highlighted bolded values are above the cleanup criteria.

Table ii. Maximum Survey Results							
Survey Type (units)	West Wall	North Wall	East Wall	South Wall	Floor	*Overhead	Criteria
Cell A-1							
^b Direct γ (mR/h)	30	20	1.0	20	8	^d NA	^e 5 or 50
^f Direct α (dpm/61 cm ²)	1M	500k	100k	1M	1M	NA	3k
^g Smear α/β (dpm/1 m ²)	12k/510k	3.9k/120k	630/35k	14k/180k	15k/440k	NA	20k/1M
^h Smear α/β (dpm/100 cm ²)	520/12k	6.4k/160k	180/9k	520/15k	1.1k/32k	NA	800/50k
Cell K-1							
Direct γ (mR/h)	0.5	10	25	10	4	0.1	5 or 50
Direct α (dpm/61 cm ²)	60k	600k	200k	180k	> 1M	30k	3k
Smears α/β (dpm/1 m ²)	3.4k/190k	2.3k/82k	730/78k	3.5k/180k	4.7k/600k	9.3k/320k	20k/1M
Smears α/β (dpm/100 cm ²)	55/2k	430/13k	320/3.6k	300/7k	1.7k/1M	NA	800/50k
Cell K-3							
Direct γ (mR/h)	0.5	0.5	0.7	0.4	0.1	0.1	5 or 50
Direct α (dpm/61 cm ²)	50k	50k	90k	9k	20k	50k	3k
Smears α/β (dpm/1 m ²)	110/4.6k	430/5.2k	200/5.9k	480/7.1k	440/16k	NA	20k/1M
Smears α/β (dpm/100 cm ²)	50/1.4k	70/560	90/540	260/1.2k	90/2.5k	NA	800/50k

Table ii. Maximum Survey Results							
Survey Type (units)	West Wall	North Wall	East Wall	South Wall	Floor	*Overhead	Criteria
Cell M-3							
Direct γ (mR/h)	3.0	10	0.5	3.0	2.0	0.1	5 or 50
Direct α (dpm/61 cm ²)	6k	30k	20k	50k	10k	4k	3k
Smears α/β (dpm/1 m ²)	220/33k	120/19k	86/5.7k	490/32k	210/19k	3.2k/460k	20k/1M
Smears α/β (dpm/100 cm ²)	55/1.4k	290/1.4k	71/4.5k	48/2.8k	300/32k	NA	800/50k
Cell M-1							
Direct γ (mR/h)	5	45	10	20	1,000	50	5 or 50
Direct α (dpm/61 cm ²)	500k	>1M	1M	700k	>1M	600k	3k
Smears α/β (dpm/1 m ²)	900/81k	6k/4.3M	20k/680k	1k/71k	57k/1.5M	NA	20k/1M

^a Overhead usually refers to the crane, not the ceiling

^b Direct γ (mR/h) = Direct γ Survey with an RO-20 Ion Chamber with the β shield closed; Bkgd = 0.1

^c **The highlighted bolded values are above the acceptance goals.**

^d NA = Not Available; survey was not performed

^e Direct γ Criteria 5 mR/h general; 50 mR/h Exhaust Ducts and HEPA filter housing (see Table 1)

^f Direct α (dpm/61 cm²) = Direct α Survey with the PAC 4G-3 in the alpha mode using a 61 cm² probe; Bkgd = 100

^g Smears α/β (dpm/1 m²) = Large Area Smears (1 m²) given as α/β ; Bkgd = 0/0

^h Smears α/β (dpm/100 cm²) = Small Area Smears (100 cm²) given as α/β ; Bkgd = 0/0

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The remote work and initial cell entries were performed by CMT and RE personnel with the support of HP and EWM personnel. The final decontamination of cells A-1, K-1 and K-3 were performed by CMT and RE personnel. The final decontamination of cells M-3 and M-1 were performed by EWM personnel. The verification surveys were performed by HP personnel. Individual contributions are indicated by their names.

CHEMICAL TECHNOLOGY (CMT) STAFF

J. C. Hoh - Technical Support Manager	L. D. Hafenrichter (repair manipulators)
T. DiSanto	R. Benson
M. Goss	M. Surchik
	J. W. Emery
	H. Wegerich

REACTOR ENGINEERING (RE) STAFF

R. H. Gebner - Assistant Technical Support Manager
J. K. Dunlap
A. Kras

HEALTH PHYSICS (HP) STAFF

D. C. Geraghty - Chief Technician	C. M. Sholeen - Health Physicist
N. L. Contos (generate cell maps)	A. L. Keebler (generate cell maps)
D. W. Reilly (generate cell maps)	F. P. Marchetti (calibrate stack monitors)
T. Branch	J. Erick
M. R. O'Connor	M. A. Sreniawski
R. Walker	C. Sullivan (word processing)
	M. E. Hayes
	V. K. Steed

ENVIRONMENT AND WASTE MANAGEMENT (EWM) STAFF

T. J. Lahey - Foreman	W. D. Ray - Foreman
E. E. Armond	K. Borman
J. J. Gleason	G. A. Harris
G. L. Redman	J. J. Smeets
	M. L. Davis
	D. E. Kuzma
	C. E. Wood

ELECTRONICS AND COMPUTING TECHNOLOGIES (ECT) STAFF

Designed, built, and maintained the stack monitoring system.

R. W. Fergus	J. E. Miranda, Jr
--------------	-------------------

ENVIRONMENT SAFETY AND HEALTH (ESH) STAFF

D. M. Nelson (Cell K-3 alpha spectrum interpretation)	
E. H. Dolecek (dosimetry)	R. R. Gustafson
	D. R. Pepalis

TECHNOLOGY DEVELOPMENT (TD) STAFF

C. L. Cheever - First Project Manager	R. W. Rose - Second Project Manager
W. E. Stacy - Project Engineer	

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ABBREVIATIONS AND ACRONYMS

ACL	Analytical Chemistry Laboratory
AGHCF	Alpha Gamma Hot Cell Facility
ALARA	As Low As Reasonably Achievable
Alpha-6	Eberline Alpha-6 Continuous Air Monitor (CAM)
ANL	Argonne National Laboratory
anti-C	anti contamination clothing (coveralls, gloves, shoe covers)
CAM	Continuous Air Monitor
CHM	Chemistry Division
CMT	Chemical Technology Division
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
dpm	disintegrations per minute
ESH	Environment Safety and Health Division
HEPA	High Efficiency Particulate Air Filter
HP	Health Physics Section of ESH
NE	NE Technology Limited Electra/DP6 Alpha/Beta Scintillation Detector
POB	Proof of Breeding
PAC 4G-3	Eberline Gas Proportional Detector
Radon	Radon-222 (^{222}Rn)
RGM-2	Eberline Radon Gas Monitor
RO-20	Eberline RO-20 Ion Chamber
ROI	Region of Interest
Thoron	Radon-220 (^{220}Rn)
TLD	Thermoluminescent Dosimeter
TRU	Trans-uranic
WIPP	Waste Isolation Pilot Plant

VERIFICATION SURVEY OF BUILDING 200 HOT CELLS

I. HISTORY

A. Description of the Shielded Cave Complex

The Chemistry (CHM) Division shielded "Cave Complex" is a monolithic concrete structure two stories in height. The lower floor includes four megacurie cells (cells M-1, M-2, M-3 and M-4, see Figure 1). On the main floor, there exist two large (K-1 and K-2) and one small (K-3) kilocurie cells, one double (A-5) and four single-sized (A-1, A-2, A-3, and A-4) analytical cells. There is also a sample storage area (M-6) and an area where shipping casks can be loaded or unloaded (M-5).

A common shielded transport corridor on both levels of the complex allows for entrance and exit of highly radioactive materials from any cell without disrupting ongoing work in other cells. There are 40 viewing windows which allow handling of materials inside the cells remotely from outside the windows. The manipulators are fitted with air restriction devices to limit airflow through the manipulator port in the event of failure of the sealed manipulator boot.

Heavier moving is handled by remotely operated bridge cranes. Each of the megacurie cells and the two large kilocurie cells have a one-ton capacity bridge crane, and two-ton capacity cranes exist in the pot unloading and lower floor transfer corridor areas. A five-ton monorail hoist is available on the main floor at the entrance. A ten-ton bridge crane operates over the loading dock at the west end of the building and the paved area beyond the dock. All cranes and self-propelled manipulators are operated remotely by control stations located outside the shielding walls at suitable window positions.

A narrow-gage (36-inch) railway track system runs into all areas of the cell complex and connects the individual cells with the central corridor and the pot unloading area. Battery driven, radio-controlled flat carts, "mules", traverse these tracks. These carts are remotely operated from outside the shielded areas by a small radio transmitter. The transmitter plugs into the cave antenna system at various shielding windows. Remotely operated turntables on the

main and lower floors at suitable positions permit right-angle changes in direction, while the hydraulic elevator, into which the track runs, permits remotely controlled movement of the mules between floors.

The ventilation system of the complex is controlled such that, with the external doors closed, the airflow is from the cold (clean) operating areas to the suspect transfer areas through the shielding walls to the interior transfer corridors and from there to the cells and out through the fan loft. Ventilation barriers isolate the pot loading area and the corresponding entrance area on the main floor from the rest of the complex.

Air from the lighter-duty analytical cells is filtered through one prefilter in the cell and one HEPA filter in the fan loft before being exhausted to the atmosphere. In the other cells, the air is filtered as it leaves the cell and again through two HEPA filters in the fan loft. The mounting for the in-cell filter is such that it can be changed remotely with the use of manipulators if necessary.

B. Pre-Proof of Breeding

The CHM Shielded Cave Complex was constructed in the early sixties with an original mission of conducting actinide research and isotope separation chemistry. During the seventies and eighties the facility became a user facility for projects outside the Chemistry Division. After a project was completed, the cell was decontaminated and/or painted to fix the residual contamination.

C. Proof of Breeding

The Proof of Breeding (POB) Project began in 1975. The POB project at Argonne National Laboratory (ANL) was part of a national effort sponsored by the Department of Energy (DOE) to develop technology for breeding uranium-233 (^{233}U) from thorium-232 (^{232}Th) in light-water reactors (see Figure 2). In the process of breeding ^{233}U , the reactor also generated ^{232}U (72 year half-life) which decays to Radon-220 (^{220}Rn) which is historically referred to as thoron. ^{220}Rn is also the decay product of naturally occurring ^{232}Th with a 10^{10} year half-life. Small components of concrete are naturally occurring uranium and thorium in equilibrium with their

decay products; ^{238}U (4.5×10^9 year half-life) and ^{234}U (2.4×10^5 year half-life) decay to Radon-222 (^{222}Rn) which is historically referred to as radon; and ^{235}U (7.0×10^8 year half-life) decays to Radon-219 (^{219}Rn) which is historically referred to as actinon. The decay schemes of radon, thoron and actinon are shown in Figure 3. Since radon is a noble gas, it readily becomes airborne when it is on surfaces that are exposed to the air.

Air was sampled in the clean operating area in the Building 200 service area with an Alpha-6 (Eberline Alpha-6 continuous air monitor). The alpha spectrum is presented in Figure 4 and the radon activities are presented in Figure 5. The Alpha-6 monitor detects alpha particles, measures the energy, and accumulates the data to produce an alpha spectrum. Therefore, it can distinguish between radon (Rn), thoron (Tn) and actinon (An) decay products. Three peaks are seen in this spectrum; one, ^{212}Po (8.78 MeV), from thoron; one, ^{214}Po (7.69 MeV), from radon; and one from a combination of ^{218}Po (6.00 MeV) from radon and ^{212}Bi (6.05 MeV) from thoron. Here the ^{214}Po peak from ^{222}Rn dominates the spectrum and the radon daughter activity is greater than the thoron daughter activity. The Alpha-6 calculates ^{222}Rn concentrations in pCi/l and radon and thoron daughter concentrations in milli Working Levels (mWL). For ^{220}Rn a Working Level is defined as any combination of short-lived radon daughters (^{212}Pb , ^{212}Bi , and ^{212}Po) in one liter of air that will result in the "ultimate emission" of 1.3×10^5 MeV of alpha particle energy. The alpha emission of ^{216}Po is ignored since its half live is 150 milliseconds. For ^{222}Rn a Working Level is defined as any combination of short-lived radon daughters (^{218}Po , ^{214}Pb , ^{214}Bi , and ^{214}Po) in one liter of air that will result in the "ultimate emission" of 1.3×10^5 MeV of alpha particle energy. The alpha emission of ^{210}Po , delayed by a 21 year half live, is excluded from the "ultimate emission" definition.

Before equipment was installed in the hot cells, each cell was decontaminated to levels such that there was no need for personnel protective equipment (PPE), anti contamination (anti-C) clothing and respiratory protection, during the installation and testing phase of the project. During the POB project's main campaign at ANL, there was destructive analysis of seventeen fuel rods from the Shippingport Light Water Breeder Reactor, which had operated from September 1977 to October 1982. Operation on the actual fuel rods began in August 1984 and was completed in November 1985. ANL performed a destructive evaluation to determine (1)

the isotopic composition of the uranium, (2) the total uranium content, and (3) the amount of selected fission products contained in the irradiated fuel. The results of the POB project were used to verify and validate a nondestructive examination technique developed by the Bettis Atomic Power Laboratory to determine the fissile ^{233}U content of the fuel rods.

The irradiated fuel rods were received at ANL in segments of about 6" to 30" (15 cm to 75 cm) lengths. They were sheared in cell M-3 into pieces about half the rod diameter in height. The sheared pieces were taken to cell M-1 and dissolved in acid solutions. The solutions were sampled and the samples were taken to cell K-3 for examination and preparation for further gamma and chemical analysis outside the cell. The solutions were converted to a cemented waste and were shipped to Hanford for storage and potential final placement in the Waste Isolation Pilot Plant (WIPP). Non-transuranic waste was cemented and stored in cell K-1. Graczyk et al (1987) provides a detailed description of the facilities and equipment used, the operations, and the results of the POB project.

It was initially planned to restore the cells upon completion of the research work. However, at the close of the project funding for the final clean-up of the cells was not available due to budget restraints. Because the stack emissions from cells M-1 and K-1 were high some cleaning was performed in 1987. Some of the waste from the project was packaged in four 55 gallon drums and stored in cell M-4. The contaminated equipment, cells and waste were abandoned until funding became available for the clean-up. From 1987 through Spring 1992, the cells used by the POB project were idle and discharged large quantities of ^{220}Rn gas from the stacks of the Cave Complex, mainly from cells M-1 and K-1. The emissions from cells K-3 and M-3 were $\leq 1\%$ of either the cell K-1 or the cell M-1 emissions.

The Building 200 M-Wing Hot Cell D&D project was primarily concerned with decontamination to "restricted use" of cells M-1, M-3, K-1, K-3 and A-1. Work on the project was initiated in the spring of 1992 with the goal of reducing emissions to less than 10% of the 1991 emissions and reducing the external exposure rate in the cell to ≤ 1 mR/h with no loose contamination (April 1993).

D. ^{231}Pa work in Cell K-3

In 1991 a 1.5 gram ^{231}Pa source was subdivided and repackaged into smaller containers because of concern for the integrity of the original container. This source had been placed in storage on May 1, 1973. Since K-3 was relatively clean, it was used for the work on the source. After the source was repackaged into several smaller sources, they were removed from the cell. One of the sources was shipped to Berkeley, California. A gamma spectrometric analysis, performed to obtain the data required on the shipping documents, was consistent with an assumption that the sample was originally purified during 1971. Therefore, the ^{227}Ac activity is presently $\sim 54\%$ of the ^{231}Pa activity. As seen in Figure 3, ^{231}Pa and ^{227}Ac decay to ^{219}Rn .

E. Zion

The A-1 cell was used for examination of irradiated fuel (^{235}U and ^{239}Pu) from the Zion reactor in early 1985. 500 grams of irradiated fuel from the Zion reactor were received in ten 2-inch long rod segments. The rods were sheared into smaller pieces, cladding was removed and the fuel was pulverized in enclosed small stainless capsules. Samples of pulverized fuel each weighing 0.2 grams were dissolved in acid solutions. The solutions were analyzed to determine the composition of the fuel. The project was intended to experimentally test computational methods which were being developed for determining the fuel isotopic dynamics in reactor operations. The project and the results obtained are described in Heinrich et al 1985.

Before equipment was installed in hot cell A-1, it had been decontaminated to levels such that there was no need for anti-C clothing or respiratory protection during the installation of the equipment. At the beginning of the D&D project the cell was not in use. After the Zion fuel examination project ended, the equipment and the structures were not cleaned and the fuel was not removed from the cell.

The inventory of radioactive material in cell A-1 at the start of the D&D project was essentially the entire inventory in the 500 grams of fuel received from Zion minus the amount lost due to radioactive decay. Most of the fuel was in powder form in stainless steel pipe nipples. There was also about 200-300 ml of mixed waste containing about 2 grams of fuel dissolved in hydrochloric acid, nitric acid and a small quantity of hydrofluoric acid. There was

also a jar containing Zircaloy cladding. Some fuel dust was expected to reside on the surfaces in the cell from escaped wisps of air during opening of pulverization equipment.

The fuel in cell A-1 contained ~ 4 grams of ^{239}Pu (24,131 year half-life) and ~ 4 grams of ^{235}U (7.0×10^8 year half-life) and ^{238}U (4.5×10^9 year half-life). The air in the stacks from this cell was never sampled because the fuel did not decay to a radon isotope. There are two decay products between $^{238}\text{U}/^{234}\text{U}$ and ^{222}Rn with long half-lives (^{230}Th ; 7.7×10^4 years and ^{226}Ra ; 1600 years) preventing the generation of ^{222}Rn ; and there is one decay product between $^{239}\text{Pu}/^{235}\text{U}$ and ^{219}Rn with a long half life (^{231}Pa ; 3.3×10^4 years) preventing the generation of ^{219}Rn . There is also another decay product, ^{227}Ac , with a 21.7 year half-life. Therefore, any ^{222}Rn or ^{219}Rn generated by the fuel in A-1 was much less than that generated from the naturally occurring ^{238}U and ^{235}U inherent in all concrete.

The air in the stacks from the POB cells was sampled because the ^{232}U decays to a radon isotope. The longest half-life of the decay products between ^{232}U and ^{220}Rn is only 1.9 years (^{228}Th). Therefore there were large quantities of ^{220}Rn emitted from the stacks of the cells used in the POB project.

II. FINAL SURVEY PROCEDURES

Final verification surveys were performed by ESH-HP personnel. Each Health Physics Technician who performed the survey in the cell wore anti-C clothing and an air purifying respirator. Most of the time there were two Health Physics Technicians inside the large cells. One or both of these workers had radio communication with the data recorder(s) outside the cell. For the small cells such as A-1, there was room for only one person to survey the cell.

A. Grid

After the cell was decontaminated, the cell was divided into one meter square grids on each of the six walls and the floor. Construction chalk was used to snap the grids lines on the walls and floor. The intersections of the grid lines were marked in pen on the floor only. The origin of the floor grid was at the south west corner. The origin of the wall grids were at the floor and the south or west edge of the wall (see for example Figure A-1).

B. Acceptance Goals

Because of the time required to decontaminate below detectable levels, acceptance goals prior to painting were established. Since decontamination of the ventilation ductwork was not part of the scope of work, higher exposure rates were established for the filters and housings. The procedures for the final radiological cell survey, SOP 4.9, define the acceptance goals as presented in Table 1.

C. Direct α Survey

Each grid was surveyed direct with an Eberline PAC 4G-3 gas proportional monitor in the alpha mode. This instrument was chosen because there is no cross over from the residual beta or gamma contamination in the cell into the alpha detector. During the grid survey, the hot spot(s) and the general background measurements were logged directly on a cell map. The meter readings were communicated by radio to the recorder outside the cell. The recorder could visually determine the location of the meter reading through a viewing window. The activities

were calculated and compared to the total α activity maximum and average goals.

Table 1. Acceptance Goals Before Painting

Allowable Residual Contamination		
	<u>Average</u>	<u>Maximum</u>
Removable ^{1/} α Activity	200 dpm/100 cm ² 20,000 dpm/1 m ²	800 dpm/100 cm ²
Total ^{2/} α Activity	1,000 dpm/100 cm ²	3,000 dpm/100 cm ²
Removable ^{1/} $\beta\gamma$ Activity	10,000 dpm/100 cm ² 1,000,000 dpm/1 m ²	50,000 dpm/100 cm ²
Total ^{2/} γ Exposure rate ^{3/} on contact	1 mR/h	5 mR/h
Total ^{2/} γ Exposure rate ^{3/} at opening Exhaust Ducts; HEPA filter housing	10 mR/h	50 mR/h

^{1/} Removable Activity is for flat accessible surfaces

^{2/} Total Activity is the fixed and removable as measured by a survey instrument

^{3/} Measured with an ion chamber

D. Direct γ Survey

Each grid was surveyed direct with an Eberline RO-20 with the beta shield closed in order to measure only gamma (deep) dose and to eliminate the beta (shallow) dose. This instrument was chosen because it is an ion chamber and it can distinguish beta activity from gamma activity. During the grid survey, the hot spot(s) and the general background measurements were logged directly on a cell map. The meter readings were communicated by radio to the recorder outside the cell. The recorder could visually determined the location of the meter reading through a viewing window. The exposure rates were compared to the maximum and average location specific goals.

E. Large Area Smears and Small Area Smears

Each square meter grid was smeared with a single paper over the entire area. Grids that contained less than a 1 m² area were not combined with other small grids. Each smear was

counted with an NE Technology Limited Model Electra/DP6 Alpha Beta ZnS(Ag) scintillation detector in the integrate mode for one minute for both alpha and beta-gamma activity. The smears results were tabulated and the activity was calculated and logged on a cell map. The activities are compared to the average removable activities. For ease of comparison, the average removable values are presented as dpm/1 m² below the dpm/100 cm² values in Table 1.

During a separate entry, a 100 cm² smear was taken near the center of each grid. Each smear was counted for one minute for both alpha and beta-gamma activity with an NE in the integrate mode. The smears results were tabulated and the activities were calculated and logged on a cell map. The activities are compared to the maximum removable values.

III. CELL A-1

A. INITIAL CELL CONDITION

1. Spills and Contamination

In cell A-1 there were no known spills. There were large amounts of loose contamination and airborne contamination inside the cell. Work on the Zion fuel was performed inside a containment box on a work table.

2. Stack Emissions

Monitoring of the cell A-1 stack emissions was never initiated because neither ^{219}Rn nor ^{222}Rn was generated from the fuel as explained in section I.E.

B. DECONTAMINATION

Figure 6 indicates the period of time that work was being performed in the five cells that had the potential for accumulating external exposures. The deep doses that were actually accumulated are shown in figure 7. They were consistently less than the shallow doses shown in figure 8 or the ring doses shown in figure 9.

1. Waste Removed

Cell A-1 was remotely cleaned and waste was remotely packaged in the cell starting during October 1993. The fuel was transferred to the Building 212 Alpha Gamma Hot Cell Facility (AGHCF) in May 1994. The remote handled waste was also transferred to cell M-3 during the same month. Once the remote waste was removed, the dose rate in the cell was low. The entry tent was constructed and the anteroom was entered during May. The cell was originally considered completely decontaminated during September 1994. However in March 1995 the cell was rechecked prior to the final survey and found to have high levels of contamination. Further decontamination was performed prior to the final survey during June 1995.

2. Accumulated Dose

Personnel doses were tracked with SAIC dosimeters which responds well to deep dose. These dosimeter have two alarm points, one for dose rate and the second for accumulated dose. If the alarm points were properly set, the people actually performing the work in the cells had the ability to keep their doses as low as reasonably achievable (ALARA) during the performance of the work. They were able to minimize their time in fields above the dose rate alarm level. When the accumulated dose reached the alarm point, the entry was terminated. A running total of the monthly doses for cell entries were kept for each worker. Attempts were made to keep the monthly total for each worker below 100 mrem, the Argonne administrative exposure control guide. This was done successfully for all cells except cell M-1, where a conscious decision was made to exceed this dose for one month.

The doses of record were those measured by the thermoluminescent dosimeter (TLD) badge. Both deep and shallow doses were measured by this badge. In addition ring dosimeters were worn. Both the TLD badges and the ring dosimeters were changed monthly. It was found that there were times when there was a large shallow dose and a smaller deep dose. At those times, the SAIC dosimeter appeared to be responding to the shallow dose. It was also noticed that the SAIC dosimeter responded to a hand held radio, increasing the reading when there was only a background radiation field.

The total whole body (deep) dose that was accumulated during the decontamination of cell A-1 was ~330 person-mrem (see Figure 7). The total skin (shallow) dose was ~840 person-mrem (see Figure 8) and the total extremity (ring) dose was ~650 person-mrem (see Figure 9). The A-1 doses were estimated as $\frac{1}{3}$ of those accumulated from May 1994 through August 1994 and $\frac{1}{6}$ of those accumulated in September 1994. Although initial entries were made at the end of May, decontamination of cell K-1 was also being performed during the same time period.

3. Decontamination Limit

The cell was decontaminated to the paint layer. Numerous attempts were made to remove loose contamination that was on the paint. However, no attempt was made to remove

the paint or the contamination under the paint. The prefilter in the cell was replaced and the accessible exhaust duct was decontaminated after the loose contamination increased between September 1994 and March 1995.

C. FINAL SURVEY RESULTS

The values that were measured during the survey are compared to the acceptance goals. For each graph containing the direct survey data, the average grid measurements are presented in large numbers in the center of the grid; the elevated readings are presented in smaller numbers at the location of the hot spots. In the legend, the instrument and the corresponding units of the measurements are designated for direct surveys. The smear data is presented as a ratio with the alpha activity printed in the numerator to the beta-gamma activity printed in the denominator. The legend indicates whether the smear covered the large 1 m² or the small 100 cm² area near the center of the grid. The layout of cell A-1 is shown in Figure A-1.

1. A-1 West Wall

The filter housing on the west wall exhibits high direct radiation levels (8 mR/h) seen in Figure A-2. At 30 cm from the filter, the exposure rate decreased to 2 mR/h. In general the gamma readings ranged from 2 mR/h to 10 mR/h. The hot spots ranged from 2.5 mR/h to 30 mR/h. Neither the averages nor the hot spots meet the average and the maximum exposure rate goals on contact.

The average alpha readings in each grid ranged from 400 dis/min to 10,000 (10k) dis/min using a 61 cm² probe. The values near the ceiling are above the average alpha activity acceptance goal for 100 cm². The direct alpha readings of the hot spots ranged between 4k dis/min and 1,000,000 (1M) dis/min using a 61 cm² probe (see Figure A-3). All were above the maximum total α activity acceptance goal for 100 cm².

The removable contamination goal is stated in terms of a 100 cm² area. Therefore, the 1 m² smear data are compared to values 100 times the averages. The maximum loose activity was 12k dpm/1 m² α and 510k dpm/1 m² $\beta\gamma$, below the Table 1 values (see Figure A-4). The

highest removable activity was in the grids at the top of the wall. The 100 cm² smears were taken near the center of each grid. The highest alpha activity was 520 dpm/100 cm²; the highest $\beta\gamma$ activity was 12k dpm/100 cm² (see Figure A-5). Both are below the maximum removable activity goals.

2. A-1 North Wall

The grid average ranged from 1.0 mR/h to 10 mR/h (see Figure A-6). The hot spots ranged from 2 mR/h to 20 mR/h. Most of the measurements were at or above the average contact exposure rate goal.

The average alpha readings in each grid range from 400 dis/min to 100k dis/min using a 61 cm² probe (see Figure A-7). The hot spots range from 1k dis/min to 500k dis/min. The top east grid average is above the acceptance goal. Many of the hot spots on this wall exceed the acceptance goals. The top grids have the highest readings.

The maximum large area loose activity was 3.9k dpm/1 m² α and 120k dpm/1 m² $\beta\gamma$ in the upper west grid, these values are well below the average acceptance goals (see Figure A-8). The highest small area loose alpha activity was 6.4k dpm/100 cm²; the highest $\beta\gamma$ activity was 160k dpm/100 cm² (see Figure A-9). Both are above the maximum removable acceptance goals.

3. A-1 East Wall and Door

The east wall includes the door and the section above the door. The average gamma readings were 1.0 mR/h on the east wall and 0.5 mR/h on the door (see Figure A-10). No measurements were above the average exposure rates on contact.

The average alpha readings in each grid range from 100 dis/min to 20k dis/min using a 61 cm² probe (see Figure A-11). The upper north grid value was above the average total alpha activity acceptance goal. The direct alpha readings for the hot spots were between 5k dis/min and 100k dis/min using a 61 cm² probe. All of these values are above the maximum total α activity acceptance goal for a 100 cm² area.

The maximum large area loose activity was 630 dpm/1 m² α and 35k dpm/1 m² $\beta\gamma$, well below the average removable alpha activity acceptance goal (see Figure A-12). The highest

small area loose alpha activity was 180 dpm/100 cm²; the highest $\beta\gamma$ activity was 9.0k dpm/100 cm² (see Figure A-13). Both are below the maximum removable activity acceptance goals.

4. A-1 South Wall

The average gamma readings were between 1.0 mR/h and 2.0 mR/h (see Figure A-14). These measurements are at or above the average contact exposure rate goals. The hot spots ranged from 3 mR/h to 20 mR/h. Some of the hot spots were above the respective maximum contact exposure rate goals. These hot spots are associated with the exhaust duct and the transfer port. At 30 cm from the exhaust duct, the exposure rate decreased to 2 mR/h.

The average alpha readings in each grid range from 400 dis/min to 10k dis/min using a 61 cm² probe (see Figure A-15). The values at the top of the wall were above the average total alpha activity acceptance goal for 100 cm². The direct alpha readings for the hot spots were between 600 dis/min and 1M dis/min using a 61 cm² probe. Many of these values are above the maximum total α activity acceptance goal for 100 cm².

The maximum large area loose activity was 14k dpm/1 m² α and 380k dpm/1 m² $\beta\gamma$, well below the average removable acceptance goals (see Figure A-16). The highest small area loose alpha activity was 520 dpm/100 cm²; the highest $\beta\gamma$ activity was 15k dpm/100 cm² (see Figure A-17). Both are below the maximum removable activity acceptance goals. The smears with the highest loose activities were all in the upper west grid.

5. A-1 Floor

The average gamma readings on the cell floor were 1.0 mR/h (see Figure A-18). These measurements are equal to the average contact exposure rate acceptance goals. The hot spots ranged from 3 mR/h to 8 mR/h, most were below the maximum contact exposure rate acceptance goal. The general exposure rate at 1 ¾ meter above the floor was 2.5 mR/h. This is above the 1 mR/h goal.

The average alpha readings in each grid were between 4k dis/min and 50k dis/min using a 61 cm² probe (see Figure A-19). These are above the acceptance goal. The direct alpha

readings for the hot spots were between 8k dis/min and 1M dis/min using a 61 cm² probe. All of these values are above the maximum total α activity acceptance goal for 100 cm².

The maximum large area loose activity was 15k dpm/1 m² α and 440k dpm/1 m² $\beta\gamma$, well below the average removable activity acceptance goals (see Figure A-20). The highest small area loose alpha activity was 1.1k dpm/100 cm²; the highest $\beta\gamma$ activity was 32k dpm/100 cm² (see Figure A-21). The highest alpha smear is above and the highest beta smear is below the maximum removable acceptance goal.

D. CONCLUSIONS

Since the paint that was used to fix the contamination from the earlier projects was not removed, contamination remains under this paint. The present survey gives the level of activity in the cells at the end of the decontamination effort.

1. Measurements of Residual Radon Gas

The amount of thoron, radon and actinon in cell A-1 were measured by two monitors, a Radon Gas Monitor (RGM-2) and an Alpha-6. The RGM-2 monitor was calibrated with ²²⁰Rn generated from a ²²⁸Th standard source. The RGM-2 measures the total radon concentration (²¹⁹Rn + ²²⁰Rn + ²²²Rn). It filters out the radon daughters before the gas enters the counting chamber but it can not distinguish between the radon isotopes. The Alpha-6 monitor detects alpha particles from the radon decay products, measures the energy, and accumulates the data to produce an alpha spectrum (see Figure A-22). Therefore, it can distinguish between radon (Rn), thoron (Tn) and actinon (An). Three prominent peaks are seen in this spectrum; one, ²¹²Po (8.78 MeV), from thoron; one, ²¹⁴Po (7.69 MeV), from radon; and one from a combination of ²¹⁸Po (6.00 MeV) from radon and ²¹²Bi (6.05 MeV) from thoron.

The Alpha-6 calculates ²²²Rn concentrations in pCi/l and radon and thoron daughter concentrations in milli Working Levels (mWL). The concentrations of Rn daughters (²²²Rn decay products) varies in the same manner as the ²²²Rn gas concentrations. These change much more rapidly than the concentration of Tn daughters (²²⁰Rn decay products) which are controlled by the 10.6 hour half-life of ²¹²Pb (see Figure A-23). Although ²²⁸Th was not used in this cell,

it is presently used in cell A-3 and has been used in cell A-4 (see Figure 1). The Tn daughters that were measured by the Alpha-6 are the result of the ^{220}Rn concentrations in the A cell cave area.

During the final decontamination of cell A-1, an air sampling tube was inserted into the cell to sample the air for both radon (^{222}Rn) and thoron (^{220}Rn). The radon and thoron in the cell was ~ 1 pCi/l from April 5, 1995 through May 22, 1995 (see Figure A-24). The radon concentrations vary with humidity as measured by the weather station on the main floor of the Shielded Cave Complex. The symbols mark the 6:00 AM measurements for both the humidity and the radon concentrations. The Alpha-6 monitor was used to measure radon air samples on June 22 and 23, 1995.

2. Cell Decontamination Summary

This cell is intended to be left without further decontamination. Future users will have the option of either fixing the residual contamination before use, or attempting further decontamination with more aggressive methods. The identity and quantities of the radionuclides that remain in the cell were estimated from the direct alpha activities and the removable beta-gamma activities. As a conservative estimate, the direct/removable $\beta\gamma$ activity ratio was assumed to be the same as the direct/removable α activity ratio. These estimates are presented in Table 2. The beta-gamma contamination is assumed to be $\frac{1}{2}$ ^{90}Sr and $\frac{1}{2}$ ^{90}Y . The activity

Table 2. Surface Contamination in Cell A-1

Location	Area (m ²)	Alpha Contamination		Beta-Gamma Contamination	
		dis/min/m ²	mCi	dis/min/m ²	mCi
South	7	12,400,000	0.039	434,000,000	1.37
North	7	5,100,000	0.016	1,448,000,000	4.57
East	7	1,500,000	0.005	40,300,000	0.13
West	7	13,600,000	0.043	721,000,000	2.27
Floor	4	<u>10,300,000</u>	<u>0.019</u>	<u>1,234,000,000</u>	<u>2.22</u>
Total	32	42,900,000	0.122	3,877,300,000	10.56

is compared to the Nuclear Facility Category III quantities in Table 3. The estimated total alpha

activity is assigned to each of the three radionuclides that were in the Zion Fuel. The ratio of the activity to the Category III quantity indicates that ^{239}Pu is the most restrictive radionuclide. The total activity is $< 0.06\%$ of the Category III level.

Table 3. Contamination in Cell A-1 by Isotope

Radionuclide		Category III mCi	Cell Activity mCi Ratio	
^{90}Sr	β	16,000	5.3	3.3×10^{-4}
^{90}Y	β	1,420,000	5.3	3.7×10^{-6}
^{235}U	α	4,200	0.12	2.9×10^{-5}
^{239}Pu	α	520	0.12	2.3×10^{-4}
^{214}Pu	α	32,000	0.12	3.8×10^{-6}
Total β			10.6	3.3×10^{-4}
Maximum α			0.12	2.3×10^{-4}
$\alpha + \beta$			10.7	5.6×10^{-4}

A summary of the hot spots found by the direct surveys are presented in Table 4. Many exposure rates and direct α contamination measurements were above the acceptance goals that are presented in Table 1. Only the north wall had smear results above the acceptance goals. The direct survey results above the acceptance goals are highlighted and bolded.

Table 4. Direct Survey Hot Spot Summary; Cell A-1

Area	RO-20 mR/h γ	α dis/min-61 cm ²
West Wall	2.5 to 30	4k to 1M
North Wall	2 to 20	1k to 500k
East Wall	none	5k to 100k
South Wall	3 to 20	600 to 1M
Floor	3 to 8	8k to 1M

At the present time the general exposure rate in the cell is 2.5 mR/h at 1¼ meter from the walls and floors. At 30 centimeters from each filter the exposure rate is 2 mR/h. Workers who enter the cell need to be aware that they will accumulate low levels of external exposure. PPE and respiratory protection have been used for all work including the final survey.

IV. CELL K-1

A. INITIAL CELL CONDITION

1. Spills and Contamination

In cell K-1 there were several spills that were not completely cleaned up during the POB project. This produced loose contamination and increased the ease with which ^{220}Rn became airborne increasing the total amount of airborne contamination. One spill on the floor had a reading of 1 R/h one foot from the surface at the beginning of the decontamination effort.

2. Stack Emissions

Monitoring of the cell K-1 stack emissions was initiated for ^{129}I , ^{85}Kr and ^{220}Rn in October 1984, two months after operation on the fuel rods began. Hot work in cell K-1 began on October 5, 1984. The stack monitoring has continued through the decontamination of the cells. The emissions from cell K-1 peaked at 2,573 Ci in 1987 after the completion of the work on the fuel rods but during the solidification of the liquid waste and the initial decontamination. The ^{220}Rn emissions decreased to 657 Ci in 1988 but increased to 1,023 Ci in 1990 (see Table 5 and Figure 10) before the start of the decontamination of this cell began in 1992. Figure 11 shows the emissions from 1988 through 1995. At the completion of the decontamination, the monthly emissions for 1995 have been <1% of the 1990 emissions for the same month (see Table 5).

From the start of the project through 1987, the monthly emissions as seen in Figure 12 were related to the effort inside the cell. However from 1988 through 1995, the emissions peaked in the summer months and were lower in the winter months. The emissions during the summer months (e.g. 140 curies in August 1990) are more than twice the emissions during the winter months (e.g. 30 curies in January 1990 or January 1991).

Table 5. ^{220}Rn Emissions from Cell K-1

Month	Quantity (Ci) ^{220}Rn Released by month												
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
January		26.0	46.5	110	22.6	37.4	29.0	33.4	44.4	38.8	10.00	0.78	0.26
February		46.5	29.9	55	18.5	19.9	36.9	32.7	41.4	27.9	9.17	0.57	0.20
March		55.5	94.0	136	36.1	42.0	54.4	40.0	52.5	33.2	12.32	0.52	
April		100.4	53.3	262	40.4	62.6	66.3	66.6	40.4	55.7	14.56	0.49	
May		160.0	74.4	600	65.3	75.6	96.7	100.3	55.0	78.3	23.31	0.66	
June		307.7	236	278	70.6	86.4	118.0	101.8	82.4	66.2	34.24	0.78	
July		310.5	273	430	86.2	107.0	136.9	104.0	104.0	74.4	41.06	0.80	
August		191.9	316	461	90.9	99.5	139.2	111.0	76.6	80.0	28.42	0.74	
September		77.1	504	111	77.1	87.7	128.0	81.0	78.2	64.7	13.48	0.45	
October	9.8	155.8	282	50	53.7	69.6	95.1	69.0	62.8	42.4	8.03	0.41	
November	1.9	71.1	307	50	63.7	40.3	72.6	42.0	52.4	19.6	3.25	0.28	
December	<u>15.4</u>	<u>42.4</u>	<u>261</u>	<u>30</u>	<u>31.7</u>	<u>19.1</u>	<u>50.1</u>	<u>31.0</u>	<u>42.5</u>	<u>14.6</u>	<u>1.42</u>	<u>0.26</u>	
Total (Ci)	27.1	1,544.9	2,477.1	2,573	656.8	747.1	1,023.2	812.8	732.6	595.8	199.26	6.74	0.46
% previous year		5,700.7	160.3	104	25.5	113.8	137.0	79.4	90.1	81.3	33.44	3.38	6.82
Month	Percentage (^{220}Rn released during month / ^{220}Rn released during same month in 1990)												
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
January		89.7	160.3	379	77.9	129.0	100.0	115.2	153.1	133.8	34.48	2.69	0.90
February		126.0	81.0	149	50.1	53.9	100.0	88.6	112.2	75.6	24.85	1.54	0.54
March		102.0	172.8	250	66.4	77.2	100.0	73.5	96.5	61.0	22.65	0.96	
April		151.4	80.4	395	60.9	94.4	100.0	100.5	60.9	84.0	21.96	0.74	
May		165.5	76.9	620	67.5	78.2	100.0	103.7	56.9	81.0	24.11	0.68	
June		260.8	200.0	236	59.8	73.2	100.0	86.3	69.8	56.1	29.02	0.66	
July		226.8	199.4	314	63.0	78.2	100.0	76.0	76.0	54.4	29.99	0.58	
August		137.9	227.0	331	65.3	71.5	100.0	79.7	55.0	57.5	20.42	0.53	
September		60.2	393.8	87	60.2	68.5	100.0	63.3	61.1	50.6	10.53	0.35	
October	10.3	163.8	296.5	53	56.5	73.2	100.0	72.6	66.0	44.6	8.44	0.43	
November	2.6	97.9	422.9	69	87.7	55.5	100.0	57.9	72.2	27.0	4.48	0.39	
December	<u>30.7</u>	<u>84.6</u>	<u>521.0</u>	<u>60</u>	<u>63.3</u>	<u>38.1</u>	<u>100.0</u>	<u>61.9</u>	<u>84.8</u>	<u>29.1</u>	<u>2.83</u>	<u>0.52</u>	
Average %	14.5	138.9	236.0	245	64.9	74.2	100.0	81.6	80.4	62.9	19.48	0.84	0.72

B. DECONTAMINATION

1. Waste Removed

Size reduction and clean up of hot spots was performed remotely and waste was packaged in the cell from May 1993 through July 1994. Remote handled waste was removed from this cell during May 1994. Cell entries began during May 1994 to measure the radiation levels. Starting in June 1994, the equipment was disassembled, size reduced, and bagged out. Removal of floor and wall coverings and decontamination of the interior of the cell started in December 1994. The final survey was initiated during March 1995 and it was completed in May 1995.

2. Accumulated Dose

The total whole body (deep) dose that was accumulated during the decontamination of cell K-1 was ~2,000 person-mrem. The total skin (shallow) dose was ~7,100 person-mrem and the total extremity (ring) dose was ~4,800 person-mrem. The doses were estimated as 2/3 of those accumulated from May 1994 through August 1994, and 100% of those accumulated from September 1994 through December 1994. In Figures 7, 8, and 9 it is seen that significant doses were accumulated during this time. Although the final decontamination continued through March 1995, the dose rates during the 1995 work effort in the cell were low and did not contribute to the doses presented above.

3. Decontamination Limit

The cells were decontaminated to the paint layer. If there was loose contamination on the paint it was removed. However, no attempt was made to remove contamination under the paint except for the area of the spill on the floor in grid 3 east, 6 north. The other area where additional effort was expended to reduce the contamination was on the north wall near the HEPA filter, grids 3 east, 1 high; 3 east, 2 high; and 4 east, 1 high.

C. FINAL SURVEY RESULTS

The values that were measured during the survey are compared to the acceptance goals. For each graph containing the direct survey data, the average grid measurements are presented

in large numbers in the center of the grid; the elevated readings are presented in smaller numbers at the location of the hot spots. In the legend, the instrument and the corresponding units of the measurements are designated for direct surveys. The smear data is presented as a ratio with the alpha activity printed in the numerator to the beta-gamma activity printed in the denominator. The legend indicates whether the smear covered the large 1 m² or the small 100 cm² area near the center of the grid. The layout of cell K-1 is shown in Figure B-1.

1. K-1 West Wall

The average grid dose rates ranged from 0.1 mR/h to 0.5 mR/h. The grids with the crane rails and brackets on the west wall exhibit higher direct radiation levels than the rest of the wall (see Figure B-2). The gamma readings for the rail and brackets were 0.5 mR/h. These readings are below both the average and the maximum exposure rate goals.

The average alpha reading in each grid ranged from 100 dis/min to 600 dis/min using a 61 cm² probe. The direct alpha readings for the crane rails and brackets ranged between 1k dis/min and 60k dis/min (see Figure B-3). These values are above the maximum total α activity goal for 100 cm². There were also other hot spots that ranged from 160 dis/min to 5k dis/min. Small smears were taken of the three brackets in grids 3 north, 4 high; 4 north, 4 high; and 5 north, 4 high and analyzed for gamma emitting radionuclides. The main radionuclides present were ¹³⁷Cs (65 $\pm$ 7 dpm to 542 $\pm$ 20 dpm) and ¹²⁵Sb (21 $\pm$ 11 dpm to 123 $\pm$ 25 dpm), nuclides that are found in contamination from the POB project.

The maximum loose activity on the large area smears was 3.4k dpm/1 m² α and 190k dpm/1 m² $\beta\gamma$, well below the above values (see Figure B-4). The highest removable activity was in a grid at the top of the wall that contained the crane rail and brackets. The highest alpha activity on a small area smear was 55 dpm/100 cm²; the highest $\beta\gamma$ activity was 2k dpm/100 cm² (see Figure B-5). Both are below the maximum removable activity goals.

2. K-1 North Wall

The grids around the HEPA filter to the high flow stack on the north wall had average exposure rates on contact between 1.5 and 2.5 mR/h; for all other grids, the average exposure

rates were between 0.1 mR/h and 1.0 mR/h (see Figure B-6). All are below their respective average contact exposure rate goals. The maximum exposure rates ranged from 0.5 mR/h to 3 mR/h on the lights and around the viewing window, to a maximum of 10 mR/h around the HEPA filter housing; below the respective maximum contact exposure rate goals. At 30 cm from the filter, the exposure rate decreased to 0.5 mR/h.

The average alpha readings in each grid range from 50 dis/min to 600 dis/min using a 61 cm² probe except in two of the grids that contain the HEPA filter that had average readings of 1k dis/min and 5k dis/min (see Figure B-7). The hot spots range from 900 dis/min to 600k dis/min. Although most the grid averages are below the acceptance goal, most of the hot spots on this wall exceed the acceptance goals. The HEPA filter housing has the highest reading. There is also high residual activity in grid 3 east, 2 high that is the result of a spill.

The maximum loose activity on a large area smear was 2.3k dpm/1 m² α and 82k dpm/1 m² $\beta\gamma$, well below the average acceptance goals (see Figure B-8). The largest removable activity was again in grid 3 east, 2 high that had the spill. The highest alpha activity on a small area smear was 430 dpm/100 cm²; the highest $\beta\gamma$ activity was 13k dpm/100 cm² (see Figure B-9). Both are above the maximum removable acceptance goals.

3. K-1 East Wall

The average gamma readings on the east wall were between 0.3 to 5.0 mR/h (see Figure B-10). The measurements that are above the average exposure rates on contact were in the bottom two rows. The exposure rates ranged from 1.5 mR/h to 25 mR/h. Several hot spots around the viewing ports do not meet the acceptance goals nor does the area opposite the filter bank on the south wall.

The average alpha readings in each grid range from 100 dis/min to 1k dis/min using a 61 cm² probe (see Figure B-11). All of these values except the 1k dis/min in grid 4 north, 1 high were below the average total alpha activity acceptance goal. The direct alpha readings for the hot spots were between 500 dis/min and 200k dis/min using a 61 cm² probe. Most of these values are above the maximum total α activity acceptance goal for a 100 cm² area. The hot spots were along the crane rail and brackets, around the viewing ports, on the light fixtures, on

the pipe, and in the manipulator ports.

The maximum loose activity on a large area smear was 730 dpm/1 m² α and 78k dpm/1 m² $\beta\gamma$, well below the average removable alpha activity acceptance goal (see Figure B-12). The largest removable alpha activity was in grid 4 north, 2 high that contained a viewing port. The largest removable beta activity was in grid 3 north, 3 high that contained the section of piping with a high direct alpha reading. The highest alpha activity on a small area smear was 320 dpm/100 cm²; the highest $\beta\gamma$ activity was 3.6k dpm/100 cm² (see Figure B-13). Both are below the maximum removable activity acceptance goals.

4. K-1 South Walls and Door

The south wall has many sections including the door. Although some of these sections are actually facing east and west, for this report they will be considered as part of the south wall. The average gamma readings were between 0.2 to 0.7 mR/h except behind the low flow filter ducts in grids (east 3, 4 and 5, and the bottom 2 rows) where the readings are up to 4 mR/h (see Figure B-14). These measurements are below the average contact exposure rate goals. The hot spots ranged from 0.5 mR/h to 4 mR/h except by the HEPA filters where the exposure rate was up to 10 mR/h. At 30 cm from the filters, the exposure rate decreased to 2 mR/h. The hot spots are below the respective maximum contact exposure rate goals.

The average alpha readings in each grid range from 100 dis/min to 1.2k dis/min using a 61 cm² probe (see Figure B-15). All of these values except the 1.2k dis/min reading behind the HEPA filters were below the average total alpha activity acceptance goal for 100 cm². The direct alpha readings for the hot spots were between 400 dis/min and 180k dis/min using a 61 cm² probe. Most of these values are above the maximum total α activity acceptance goal for 100 cm². The hot spots were on lights, a switch and along the bottom of the door.

The maximum loose activity on a large area smear was 3.5k dpm/1 m² α and 180k dpm/1 m² $\beta\gamma$, well below the average removable acceptance goals (see Figure B-16). The largest removable activity was in grid 4 east, 1 high behind the HEPA filters. The highest alpha activity on a small area smear was 300 dpm/100 cm²; the highest $\beta\gamma$ activity was 7k dpm/100 cm² (see Figure B-17). Both are below the maximum removable activity acceptance goals.

5. K-1 Floor

The average gamma readings on the cell floor were between 0.3 to 1.5 mR/h (see Figure B-18). The high measurements are below the HEPA filters on the north and south walls and in grid 3 east, 5 north that contained a spill. Except for the spill, these measurements are below the average contact exposure rate acceptance goals. The hot spots ranged from 0.5 mR/h to 1.5 mR/h in the rails for the mule and up to 4 mR/h below the south HEPA filter bank (duct space). The spill still had a direct reading of 3.5 mR/h. The hot spots are below the maximum contact exposure rate acceptance goals. The general exposure rate a $1\frac{3}{4}$ meter above the floor was 0.5 mR/h.

The average alpha readings in each grid range from 200 dis/min to 400k dis/min using a 61 cm² probe (see Figure B-19). The average total activities on the grids that had the spill (3 east, 5 north and 3 east, 6 north) and row of grids 4 east and 5 east are above the 1k dis/min acceptance goal. The direct alpha readings for the hot spots were between 500 dis/min and >1M dis/min using a 61 cm² probe. Most of these values are above the maximum total α activity acceptance goal for 100 cm². The hot spots were in the mule rails, and scattered over most of the floor including the areas of the spill.

The maximum loose activity on a large area smear was 4.7k dpm/1 m² α and 600k dpm/1 m² $\beta\gamma$, well below the average removable activity acceptance goals (see Figure B-20). The highest removable activity was in grid 3 east, 6 north the location of the spill. The smears in the mule rails are presented on the graph with the data for the 100 cm² data (see Figure B-21). The loose activity in the rails ranged from 280 dpm to 1.7k dpm α and from 12k dpm to 28k dpm $\beta\gamma$. Although the loose alpha activity in the rails is above the maximum removable acceptance goal for 100 cm², the beta-gamma activity is below the maximum removable acceptance goals. The highest alpha activity on the other small area smears was 550 dpm/100 cm²; the highest $\beta\gamma$ activity was 1M dpm/100 cm². The alpha activities are below the maximum removable acceptance goal however, one smear below the HEPA filters on the south wall had a $\beta\gamma$ activity that was above the maximum acceptance goal.

6. K-1 Overhead

The only overhead equipment that was surveyed was the one ton capacity bridge crane. All of the gamma readings were 0.1 mR/h (see Figure B-22). The direct alpha readings range from 3k dis/min to 30k dis/min using a 61 cm² probe. These values are above the maximum total alpha activity acceptance goal for 100 cm². In some sections the direct alpha readings were measured on each side of the I-beam that supports the crane.

The maximum loose activity on large area smears was 9.3k dpm/1 m² α and 320k dpm/1 m² $\beta\gamma$, well below the average removable acceptance goals. No 100 cm² smears were taken.

D. CONCLUSIONS

1. Measurements of Residual Radon Gas

As a result of the residual contamination from the POB project, thoron is present in the cell and it is emitted from the stacks. The amount of thoron and naturally occurring radon were measured by two monitors, an RGM-2 and an Alpha-6. The Alpha-6 measured the energy of the alpha particle and generated the spectrum seen in Figure B-23. Three prominent peaks are seen; one, ²¹²Po (8.78 MeV), from thoron; one, ²¹⁴Po (7.69 MeV), from radon; and one from a combination of ²¹⁸Po (6.00 MeV) from radon and ²¹²Bi (6.05 MeV) from thoron.

The Alpha-6 calculates ²²²Rn concentrations in pCi/l and radon and thoron daughter concentrations in milli Working Levels (mWL). The concentrations of decay products in the air from ²²²Rn is much less than the concentration of decay products from ²²⁰Rn (see Figure B-24). The Rn daughter concentration changes much more rapidly than the Tn daughter concentration which is controlled by the 10.6 hour half-life of ²¹²Pb. The Tn daughter activity is 1.3 to 3 times the Rn daughter activity.

During the final decontamination of cell K-1, an air sampling tube was inserted into the cell to sample the air for ²²⁰Rn. The air sample was measured on an RGM-2 monitor. The ²²⁰Rn activity in the cell was ~ 10 pCi/l except during spray painting and scrubbing when it rose to ~ 40 pCi/l (see Figure B-25). At the same time the stack emissions ranged from 200 pCi/l to 400 pCi/l from the high flow stack, and from 300 pCi/l to 800 pCi/l from the low flow stack. It is assumed that the difference between the stack measurements and the cell measurements is

due to residual contamination in the air ducts and on the HEPA filters in the fan loft. These were not intended to be changed as part of this decontamination project.

2. Cell Decontamination Summary

The cell is intended to be left without further decontamination. The identity and quantities of radionuclides that remain in the cell were estimated from the stack emissions. Since the stack emissions are so much greater than the cell concentrations, it was assumed that all the gas released from the stack was entirely ^{220}Rn and its daughters. The estimates as

Table 6. Isotopes in Cell K-1 from Stack Emissions

Radionuclide	Cat III mCi	Activity mCi	Ratio
^{137}Cs β	60,000	4.2	7.1×10^{-5}
^{90}Sr β	16,000	4.2	2.6×10^{-4}
^{90}Y β	1,420,000	4.2	3.0×10^{-6}
^{125}Sb β	1,200,000	0.34	2.8×10^{-7}
^{134}Cs β	42,000	0.16	3.8×10^{-6}
^{154}Eu β	200,000	0.052	2.6×10^{-7}
^{155}Eu β	940,000	0.010	1.1×10^{-8}
^{232}Th α	100	<0.00001	2.4×10^{-8}
^{233}U α	4,200	0.0071	1.7×10^{-6}
^{232}U α	820	0.021	2.6×10^{-5}
^{228}Th α	1,000	0.021	2.1×10^{-5}
^{224}Ra α	200,000	0.021	1.1×10^{-7}
^{220}Rn α	2,000	0.021	1.1×10^{-5}
^{216}Po α		0.021	
^{212}Pb β	3,200,000	0.021	6.6×10^{-9}
^{212}Bi α, β		0.021	
^{212}Po α		0.021	
^{208}Tl β		0.021	
Total α		0.14	5.9×10^{-5}
Total β		13.3	3.4×10^{-4}
Total $\alpha + \beta$		13.4	4.0×10^{-4}

presented in Table 6 are based on the emissions after the HEPA filters were changed in the fan loft on February 16, 1996. The discharge rate before the filters were changed was $\sim 6 \mu\text{Ci}/\text{min}$; and $\sim 3.5 \mu\text{Ci}/\text{min}$ after they were changed (see Figure 26). The radionuclides listed above ^{232}U are estimated from analyses of smear at the start of the D&D project. These activities are compared to the Nuclear Facility Category III quantities. As seen at the bottom of the table, the sum of the ratios is $\leq 0.04\%$ of the Category III level.

A summary of the hot spots found by the direct surveys are presented in Table 7. Direct α contamination measurements on each wall, floor or overhead were above the acceptance goals that are presented in Table 1. The east wall had direct γ readings above the acceptance goals. The floor had small area smears greater than the acceptance goal. The direct survey results above the acceptance goals are highlighted and bolded.

Table 7. Direct Survey Hot Spot Summary; Cell K-1

Area	RO-20 mR/h γ	α dis/min-61 cm ²
West Wall	0.5	160 to 60k
North Wall	0.5 to 10	900 to 600k
East Wall	1.5 to 25	500 to 200k
South Wall	0.5 to 10	400 to 180k
Floor	0.5 to 4	500 to > 1M
Crane	none	3k to 30k

At the present time the general exposure rate at 1 3/4 meter from the walls and floors is 0.5 mR/h. The exposure rate at 30 centimeters from the high flow filter on the north wall was also 0.5 mR/h. However, the exposure rate at 30 centimeters from the low flow filters on the south wall was 2 mR/h. Workers can enter the cell without concern for external exposure. Some level PPE would be required depending upon the intended work.

3. Stack Emissions

Before the decontamination project began, the discharge rate of the air from the K-1 stacks ranged from 300 $\mu\text{Ci}/\text{min}$ to 4,000 $\mu\text{Ci}/\text{min}$ as seen in Figure B-26, that presents the values from February 1992 through February 1993. During the final stages of the decontami-

nation project, the discharge of the air from the K-1 stacks ranged from 5 $\mu\text{Ci}/\text{min}$ to 30 $\mu\text{Ci}/\text{min}$ from February 1995 through January 1996. After the HEPA filters in the fan loft were changed, the discharge rate ranged from 2.5 $\mu\text{Ci}/\text{min}$ to 3.5 $\mu\text{Ci}/\text{min}$ in February and March 1996. From March through June 1995 when the humidity increased, the stack discharge rate remained below 30 $\mu\text{Ci}/\text{min}$. Since the flow rate through the filters does not change significantly during the year, the discharge rate reflects the radon concentration in the stack gas.

The peak year for emissions since 1987 was 1990 (1,023 Ci). In 1992 the yearly emissions were less than in 1990. In 1995 there were 6.7 Ci emitted 0.6% of the 1990 value or 0.8% of the 1991 value (see Table 5 and Figure 11). In 1995 the emissions decreased in April and May with respect to the previous months. In Figure 12 it can be seen that this is very unusual. The pre-filters in the cell were changed at the end of February 1995 and the final scrubbing of cell K-1 was performed during the beginning of March.

V. CELL K-3

A. INITIAL CELL CONDITION

1. Spills and Contamination

In cell K-3 there were no known spills. There was some loose contamination but little airborne contamination. In 1991 a ^{231}Pa source was repackaged in this cell. Smears from the cell at the start of the D&D project did not detect ^{231}Pa contamination.

2. Stack Emissions

Monitoring of the cell K-3 stack emissions was initiated in January 1984 for ^{129}I and ^{220}Rn . Because the emissions from this cell were low after the conclusion of the project, the pumps for the stack monitors were removed on March 3, 1986. Starting in 1991 the stack concentration and flow rate were measured semi-annually. This practice has continued through the decontamination of the cells. The emissions from cell K-3 were at their maximum during June and August 1985 (see Table 8 and Figure 12). The monthly emissions were less than 4 Ci during the operation on the fuel rods in 1984 and 1985. Before the cell was decontaminated, the estimated monthly emissions were less than 2 Ci from 1991 through 1993. Since the cell decontamination has been completed, the estimated monthly emissions have been less than 0.2 Ci.

The estimated quarterly and yearly emissions are presented in Figure 13. During 1985 the emissions were much greater than in 1984. The decontamination effort has reduced the 1995 emissions to ~9% of the 1993 emissions or 20% of the 1991 emissions. The current 1996 emission estimates are ~9% of the 1991 emission estimate.

B. DECONTAMINATION

1. Waste Removed

Cell K-3 was remotely cleaned and waste was remotely packaged in the cell starting during October 1993. The entry tent was constructed during December 1993. Cell entries

Table 8. ^{220}Rn Emissions from Cell K-3

Month	Quantity (Ci) ²²⁰ Rn Released by month												
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
January	0.108	0.2	0.17					0.70	1.19	1.19	1.17	0.17	0.06
February	0.027	0.2						0.70	1.19	1.19	0.09	0.15	0.06
March	0.027	0.6						0.70	1.19	1.19	0.10	0.17	
April	0.015	0.5						0.70	1.19	1.77	0.10	0.16	
May	0.023	0.5						0.70	1.19	1.83	0.09	0.13	
June	0.034	3.3						0.70	1.19	1.77	0.09	0.13	
July	0.024	1.1						0.70	1.19	1.83	0.09	0.13	
August	0.185	3.8						0.70	1.19	1.83	0.09	0.13	
September	0.60	1.6						0.70	1.19	1.77	0.09	0.13	
October	0.40	.8						0.70	1.19	1.83	0.17	0.13	
November	0.05	.6						0.70	1.19	1.14	0.16	0.13	
December	<u>0.75</u>	<u>.3</u>						<u>0.70</u>	<u>1.19</u>	<u>1.17</u>	<u>0.17</u>	<u>0.13</u>	
Total (Ci)	2.243	13.50	0.17	0.00	0.00	0.00	0.00	8.40	14.28	18.51	2.41	1.69	0.12
% previous year		601.87							170.00	129.62	13.02	70.12	7.10
Percentage (²²⁰ Rn released during month / ²²⁰ Rn released during same month in 1992)													
Month	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
January	9.080	16.81	14.29					58.82	100.00	100.00	98.32	14.29	5.04
February	2.270	16.81						58.82	100.00	100.00	7.56	12.61	5.04
March	2.270	50.42						58.82	100.00	100.00	8.40	14.29	
April	1.260	42.02						58.82	100.00	148.74	8.40	13.45	
May	1.930	42.02						58.82	100.00	153.78	7.56	10.92	
June	2.860	277.31						58.82	100.00	148.74	7.56	10.92	
July	2.020	92.44						58.82	100.00	153.78	7.56	10.92	
August	15.550	319.33						58.82	100.00	153.78	7.56	10.92	
September	50.420	134.45						58.82	100.00	148.74	7.56	10.92	
October	33.610	67.23						58.82	100.00	153.78	14.29	10.92	
November	4.200	50.42						58.82	100.00	95.80	13.45	10.92	
December	<u>63.030</u>	<u>25.21</u>						<u>58.82</u>	<u>100.00</u>	<u>98.32</u>	<u>14.29</u>	<u>10.92</u>	
Average %	15.708	94.54	14.29	0.00	0.00	0.00	0.00	58.82	100.00	129.62	16.88	11.83	5.04

began during January 1994 and were completed during March 1994. The final release survey was performed during June 1995.

2. Accumulated Dose

The total whole body (deep) dose that was accumulated during the decontamination of cell K-3 was ~ 40 person-mrem (see Figure 7). The total skin (shallow) dose was ~ 300 person-mrem (see Figure 20) and the total extremity (ring) dose was ~ 370 person-mrem (see Figure 21). The doses were estimated as $\frac{1}{4}$ of those accumulated in December 1993 and 100% of those accumulated from January through March 1994. Although initial entries were made at the end of November, the November and December doses were mainly due to the movement of drums from cell M-4 to cell M-3 and repackaging these drums.

3. Decontamination Limit

The cells were decontaminated to the paint layer. Numerous attempts were made to remove loose contamination that was on the paint. However, no attempt was made to remove the paint or the contamination under the paint.

C. FINAL SURVEY RESULTS

The values that were measured during the survey are compared to the acceptance goals. For each graph containing the direct survey data, the average grid measurements are presented in large numbers in the center of the grid; the elevated readings are presented in smaller numbers at the location of the hot spots. In the legend, the instrument and the corresponding units of the measurements are designated for direct surveys. The smear data is presented as a ratio with the alpha activity printed in the numerator to the beta-gamma activity printed in the denominator. The legend indicates whether the smear covered the large 1 m^2 or the small 100 cm^2 area near the center of the grid. The layout of cell K-3 is shown in Figure C-1.

1. K-3 West Wall

The filter housing on the west wall exhibits higher direct radiation levels (0.5 mR/h) than the rest of the wall (see Figure C-2). In general the gamma readings were 0.1 mR/h. The highest reading was below both the average and the maximum exposure rate goals on contact.

The average alpha readings in each grid ranged from 100 dis/min to 500 dis/min using a 61 cm² probe. All of these values are below the average alpha activity acceptance goal for 100 cm². The direct alpha readings of the hot spots ranged between 1.5k dis/min and 50k dis/min using a 61 cm² probe (see figure C-3). All except the 1.5k value were above the maximum total α activity acceptance goal for 100 cm².

The maximum loose activity on large area smears was 110 dpm/1 m² α and 4.6k dpm/1 m² $\beta\gamma$, well below the Table 1 values (see Figure C-4). The highest removable activity was in the grid between the windows containing part of the south window. The highest alpha activity on a small area smear was 50 dpm/100 cm²; the highest $\beta\gamma$ activity was 1.4k dpm/100 cm² (see Figure C-5). Both are below the maximum removable activity goals.

2. K-3 North Wall

The HEPA filter to the high flow stack had an exposure rate of 0.5 mR/h; for all grids, the average exposure rate was 0.1 mR/h (see Figure C-6). At 30 cm from the filter, the exposure rate decreased to 0.2 mR/h. All measurements were below the average contact exposure rate goal.

The average alpha readings in each grid range from 100 dis/min to 400 dis/min using a 61 cm² probe (see Figure C-7). The hot spots range from 1.2k dis/min to 50k dis/min. All of the grid averages are below the acceptance goal. Most of the hot spots on this wall exceed the acceptance goals. The transfer lock has the highest reading.

The maximum loose activity on large area smears was 430 dpm/1 m² α and 5.2k dpm/1 m² $\beta\gamma$ in the upper left grid (see Figure C-8). These values are well below the average acceptance goals. The highest alpha activity on a small area smear was 70 dpm/100 cm²; the highest $\beta\gamma$ activity was 560 dpm/100 cm² (see Figure C-9). Both are well below the maximum removable acceptance goals.

3. K-3 East Walls and Door

The east wall has many sections including the recess for the low flow HEPA filter and the door. Although some of these sections is actually facing south and north, for this report they will be considered as part of the east wall. The average gamma readings on the east wall were 0.1 mR/h (see Figure C-10). The measurements that are above the average exposure rates on contact were either on the low flow HEPA filter housing, 0.5 mR/h, or on pipes, 0.4 mR/h and 0.7 mR/h. These hot spots meet the maximum contact exposure rate acceptance goal. At 30 cm from the HEPA filters, the exposure rate decreased to 0.1 mR/h.

The average alpha readings in each grid range from 100 dis/min to 500 dis/min using a 61 cm² probe (see Figure C-11). All of these values were below the average total alpha activity acceptance goal. The direct alpha readings for the hot spots were between 6k dis/min and 90k dis/min using a 61 cm² probe. All of these values are above the maximum total α activity acceptance goal for a 100 cm² area. The hot spots were around the filter housing, on pipes, on a grate, on the extinguisher nozzle and on the north facing door frame.

The maximum loose activity on large area smears was 200 dpm/1 m² α and 5.9k dpm/1 m² $\beta\gamma$ (see Figure C-12), well below the average removable alpha activity acceptance goal. The highest alpha activity on small area smears was 90 dpm/100 cm²; the highest $\beta\gamma$ activity was 540 dpm/100 cm² (see Figure C-13). Both are below the maximum removable activity acceptance goals.

4. K-3 South Wall

The average gamma readings were between 0.1 and 0.4 mR/h (see Figure C-14). These measurements are below the average contact exposure rate goals. The hot spots were 0.4 mR/h. The hot spots are below the respective maximum contact exposure rate goals.

The average alpha readings in each grid range from 400 dis/min to 600 dis/min using a 61 cm² probe (see Figure C-15). All of these values were below the average total alpha activity acceptance goal for 100 cm². The direct alpha readings for the hot spots were between 1k dis/min and 9k dis/min using a 61 cm² probe. Many of these values are above the maximum total α activity acceptance goal for 100 cm².

The maximum loose activity on large area smears was 480 dpm/1 m² α and 7.1k dpm/1 m² $\beta\gamma$ (see Figure C-16), well below the average removable acceptance goals. The highest alpha activity on small area smears was 260 dpm/100 cm²; the highest $\beta\gamma$ activity was 1.2k dpm/100 cm² (see Figure C-17). Both are below the maximum removable activity acceptance goals. The smears with the highest loose activities were all in the same grid 2 east, 2 high.

5. K-3 Floor

The average gamma readings on the cell floor were 0.1 mR/h (see Figure C-18). These measurements are below the average contact exposure rate acceptance goals. There were no hot spots. The general exposure rate at 1 ¼ meter above the floor was 0.2 mR/h.

The average alpha readings in each grid were 100 dis/min using a 61 cm² probe (see Figure C-19). These are below the acceptance goal. The direct alpha readings for the hot spots were between 1k dis/min and 20k dis/min using a 61 cm² probe. Most of these values are above the maximum total α activity acceptance goal for 100 cm².

The maximum loose activity on large area smears was 440 dpm/1 m² α and 16k dpm/1 m² $\beta\gamma$ (see Figure C-20), well below the average removable activity acceptance goals. The highest alpha activity on a small area smear was 90 dpm/100 cm²; the highest $\beta\gamma$ activity was 2.5k dpm/100 cm² (see Figure C-21). Both are below the maximum removable acceptance goal.

6. K-3 Overhead

The only overhead equipment that was surveyed was the one ton capacity bridge crane motor, the trolley frame and rail. The exposure rates were all 0.1 mR/h. The direct alpha readings range from 300 dis/min to 50k dis/min using a 61 cm² probe (see Figure C-22). These values are above the maximum total alpha activity acceptance goal for 100 cm².

D. CONCLUSIONS

1. Measurements of Residual Radon Gas

After the verification survey was complete, the amount of airborne activity was measured by two monitors, an RGM-2 and an Alpha-6. The Alpha-6 measured the energy of the alpha

particles in the cell and generated the spectrum seen in Figure C-23. Four prominent peaks are seen. A normal alpha spectrum generated from the airborne activity in the POB cells such as K-1 has only 3 peaks (see Figure C-24). One peak, ^{212}Po (8.78 MeV), is from thoron; one, ^{214}Po (7.69 MeV), is from radon; and one from a combination of ^{218}Po (6.00 MeV) from radon and ^{212}Bi (6.05 MeV) from thoron. Cell K-3 is the only cell which has a distinct peak near 6.7 MeV. The ^{231}Pa from the source that was repackaged in this cell in 1991 decays through ^{219}Rn to a daughter, ^{211}Bi , that emits a 6.62 MeV alpha particle.

The Alpha-6 normally calculates ^{222}Rn gas concentrations in pCi/l; and radon and thoron daughter concentrations in milli Working Levels (mWL) from data in the regions of interest (ROI's) defined for the three normal peaks. This extra peak is normally included in the ROI defined for the ^{214}Po . To determine if the extra peak was actually from ^{231}Pa , several additional ROI's were defined; one containing 12 channels centered on the extra peak and another containing 15 channels centered on the ^{214}Po peak. An air sample was collected in the cell for 2 hours on a clean filter. The one minute decay data was collected and stored for three hours. Five minute sums that were generated for these two new ROI's are plotted in Figure C-26. The half-lives and 2σ uncertainties shown in the figure were calculated from a least squares fit of the data. The 42 ± 7 minute value calculated for the ^{214}Po curve is statistically equivalent to a theoretical value between 51 minutes and 34 minutes for the decay of the 26.8 minute ^{214}Pb and 19.8 minute ^{214}Bi parents for decays from 10 minutes to 50 minutes and 10 minutes to 200 minutes respectively. The 41 ± 8 minute value calculated for the ^{211}Bi curve is statistically equivalent to the 36.1 minute half-life of ^{211}Pb , the ^{211}Bi parent.

The ROI (R_3) centered on the 6.7 MeV peak was also used to calculate a radon daughter concentration (W_R) as a correction of the radon daughter value (W_B) calculated by the Alpha-6 monitor. An actinon daughter concentration (W_A) was also calculated. The contribution of the 6.7 MeV ROI was found to be 12% of the ^{214}Po ROI (R_2) for four spectra: Figure 4 from the clean area; Figure A-22 from cell A-1; Figure B-23 from cell K-1; and Figure D-24 from cell M-3. The radon daughter concentration was calculated as:

$$W_R = W_B - \frac{7.68 (1.135 R_3 - 0.135 R_2)}{V \epsilon 3.681 \times 10^6} \quad (1)$$

Where V is the volume of air collected for an hour (60 liters); ϵ is the efficiency of the detector (0.25); and 3.681×10^6 is $28.317 \text{ ft}^3/\text{l}$ times $1.3 \times 10^5 \text{ MeV/WL}$. The actinon daughter concentration was calculated by:

$$W_A = \frac{6.62 (1.135 R_3 - 0.135 R_2)}{V \epsilon 3.681 \times 10^6} \quad (2)$$

The concentrations of the Rn daughter product varies in the same manner as the ^{222}Rn gas concentrations (see Figure C-25). These change much more rapidly than the concentration of thoron (Tn) daughter products in the air from ^{220}Rn which is controlled by the 10.6 hour half-life of ^{212}Pb . The actinon (An) daughter concentration is very flat. The gaps in the data at 2/2/96 and 2/9/96 are due to the week ends when the data were not saved. On 2/5/96 the sampling pump was turned off and the activity on the filter was allowed to decay. The ^{214}Po peak decayed within 4 hours to 2.5 % of its value and the ^{211}Bi peak decayed to 1 % of its value within 5 hours. The residual decayed with a 10.6 hour half-life. Therefore, it was assumed to be the tail of the ^{212}Po peak.

An air sampling tube inserted into the cell sampled the air for all radon isotopes, ^{222}Rn , ^{220}Rn , and ^{219}Rn with an RGM-2 monitor. The radon in the cell ranged from 4 pCi/l to 8 pCi/l between May 22, 1995 and July 19, 1995 (see Figure C-27). The radon concentrations vary with humidity as measured by the weather station on the main floor of the Shielded Cave Complex. The symbols mark the 6:00 AM measurements for both the humidity and the radon concentrations. Both monitors simultaneously measured the air concentrations from June 23 through June 27, 1995. During this time when the humidity was relatively constant, the radon concentration as measured by the RGM-2 was $\sim 6 \text{ pCi/l}$. The ^{222}Rn concentration as measured by the Alpha-6 was $\sim 0.5 \text{ pCi/l}$ (see Figure C-28).

2. Cell Decontamination Summary

The cell is intended to be left without further decontamination by this project. The identity and quantities of radionuclides that remain in the cell were estimated from the stack emissions. As a conservative estimate, 100% of the stack emissions were assumed to be ^{220}Rn

Table 9. Isotopes in Cell K-3 from Stack Emissions

Radionuclide	Cat III mCi	Activity mCi	Ratio
¹³⁷ Cs β	60,000	1.7	2.8×10^{-5}
⁹⁰ Sr β	16,000	1.7	1.0×10^{-4}
⁹⁰ Y β	1,420,000	1.7	1.2×10^{-6}
¹²⁵ Sb β	1,200,000	0.13	1.1×10^{-7}
¹³⁴ Cs β	42,000	0.063	1.5×10^{-6}
¹⁵⁴ Eu β	200,000	0.020	1.0×10^{-7}
¹⁵⁵ Eu β	940,000	0.0041	4.4×10^{-9}
²³² Th α	100	<0.00001	9.2×10^{-9}
²³³ U α	4,200	0.0028	6.6×10^{-7}
²³² U α	820	0.0083	1.0×10^{-5}
²²⁸ Th α	1,000	0.0083	8.3×10^{-6}
²²⁴ Ra α	200,000	0.0083	4.1×10^{-8}
²²⁰ Rn α	2,000	0.0083	4.1×10^{-6}
²¹⁶ Po α		0.0083	
²¹² Pb β	3,200,000	0.0083	2.6×10^{-9}
²¹² Bi α, β		0.0083	
²¹² Po α		0.0083	
²⁰⁸ Tl β		0.0083	
²³¹ Pa α	210	0.00027	1.3×10^{-6}
²²⁷ Ac β	42	0.00015	3.5×10^{-6}
²²⁷ Th α		0.00015	
²²³ Ra α	62,000	0.00015	2.4×10^{-9}
²¹⁹ Rn α		0.00015	
²¹⁵ Po α		0.00015	
²¹¹ Pb β		0.00015	
²¹¹ Bi α		0.00015	
²⁰⁷ Tl β		0.00015	
Total α		0.056	2.4×10^{-5}
Total β		5.2	1.4×10^{-4}
Total $\alpha + \beta$		5.3	1.6×10^{-4}

and its daughters. These estimates are presented in Table 9. The radionuclides listed above ^{232}U are estimated from analyses of smear data at the start of the D&D project. In addition activity from ^{219}Rn is assumed to be 25% of the activity from ^{220}Rn . These activities are compared to the Nuclear Facility Category III quantities. As seen at the bottom of the table, the sum of the ratios is $<0.02\%$ of the Category III level.

A summary of the hot spots found by the direct surveys are presented in Table 10. Only direct α contamination measurements were above the acceptance goals that are presented in Table 1. The values above the acceptance goals are highlighted and bolded.

Table 10. Direct Survey Hot Spot Summary; Cell K-3

Area	RO-20 mR/h γ	α dis/min-61 cm ²
West Wall	0.5	1.5k to 50k
North Wall	0.5	1.2k to 50k
East Wall	0.4 to 0.7	6k to 90k
South Wall	0.4	1k to 9k
Floor	none	1k to 20k
Crane	none	300 to 50k

At the present time the general exposure rate at one meter from the walls and floors is 0.2 mR/h. The exposure rates are 0.1 mR/h at 30 centimeters from the low flow filters and 0.2 mR/h at 30 centimeters from the high flow filter. Therefore, workers can enter the cell without concern for external exposure. PPE and respiratory protection have been used for all work including the final survey.

3. Stack Emissions

The peak year for emissions since 1984 was 1993 with 18.5 Ci emitted. In 1995 there were 1.7 Ci emitted, 9% of the 1993 value or 20% of the 1991 value (see Table 8 and Figure 13). The 1996 values are $\sim 9\%$ of the 1991 values.

VI. CELL M-3

A. INITIAL CELL CONDITION

1. Spills and Contamination

In cell M-3 there were no known spills. There was some loose contamination but little airborne contamination.

2. Stack Emissions

Monitoring of the cell M-3 stack emissions was initiated in January 1984 for ^{129}I and ^{85}Kr . The monthly emissions were less than 1 Ci during the operation on the fuel rods in 1984 and 1985. Because the ^{85}Kr emissions from this cell were too low to measure at the conclusion of the project, the pumps for the stack monitors were removed on March 3, 1986. Starting in 1991 the ^{220}Rn concentration and flow rate were measured semi-annually. During 1992 it was decided to use M-3 as a staging area for the remote handled waste. A stack monitor was installed in December 1992 to measure the emissions from cell M-3. While the cell was used as a staging area the estimated monthly emissions increased from <1 Ci in 1991 to ~2 Ci during 1993 and 1994. Since the cell decontamination has been completed, the estimated monthly emissions have been less than 0.1 Ci (see Figure 12 and Table 11).

The quarterly and yearly emissions are presented in Figure 14. No measurements were made from 1986 through 1989. The reduction due to the decontamination effort can be seen by comparing the 1991 values and the values for the last quarter of 1995.

B. DECONTAMINATION

1. Waste Removed

By the summer of 1992 it was determined that remote handled waste had to be moved out of Cell K-1 into a staging area until it could be properly packaged and removed by Waste Management. Cell M-3 was selected as the staging area. Therefore it was remotely cleaned and waste was remotely packaged in the cell starting during September 1992. The tent was constructed and cell entries began during April 1993. Beginning in March 1993 the cell was

Table 11. ²²⁰Radon and ⁸⁵Krypton Emissions from Cell M-3

Month	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Quantity (Ci) ⁸⁵ Kr													
January	0.012						0.69	0.66	0.69	0.42	0.67	0.71	0.04
February	0.071	0.0013	0.092					0.66	0.64	0.41	0.64	0.63	0.04
March								0.66	0.69	0.40	0.77	0.76	
April								0.66	0.66	0.33	0.67	0.77	
May	0.036							0.66	0.69	0.22	0.73	0.91	
June	0.071							0.66	0.66	0.27	1.47	1.08	
July	0.100							0.66	0.69	0.27	1.95	0.62	
August	0.203		0.041					0.66	0.69	0.24	1.81	0.64	
September	0.365		0.080					0.66	0.66	0.16	1.57	0.21	
October	0.23							0.66	0.29	0.19	1.21	0.07	
November	0.19							0.66	0.28	2.19	1.00	0.04	
December	<u>0.55</u>							<u>0.66</u>	<u>0.43</u>	<u>1.72</u>	<u>0.79</u>	<u>0.04</u>	
Total (Ci)	1.54	0.503	0.00	0.00	0.00	0.00	0.69	7.92	7.07	6.82	13.28	6.48	0.08
% previous year		0.130	0.00	??	??	??	??	1,147.83	89.27	96.46	194.72	48.80	1.23
Month	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Quantity (Ci) ²²⁰ Rn Released by month													
January	1.79						102.99	98.51	102.99	62.69	100.00	105.97	5.97
February	11.09	0.20						103.13	100.00	64.06	100.00	98.44	6.25
March	11.95							85.71	89.61	51.95	100.00	98.70	
April								98.51	98.51	49.25	100.00	114.93	
May	4.93							90.41	94.52	30.14	100.00	124.66	
June	4.83							44.90	44.90	18.37	100.00	73.47	
July	5.13							33.85	35.38	13.85	100.00	31.79	
August	2.27	11.22						36.46	38.12	13.26	100.00	35.36	
September	5.10	23.25						42.04	42.04	10.19	100.00	13.38	
October		19.01						54.55	23.97	15.70	100.00	5.79	
November		19.00						66.00	28.00	219.00	100.00	4.00	
December	<u>69.62</u>							<u>83.54</u>	<u>54.43</u>	<u>217.72</u>	<u>100.00</u>	<u>5.06</u>	
Average %	23.72		5.886	0.00	0.00	0.00	0.00	69.80	62.71	63.85	100.00	59.30	6.11

used to repackage 55-gal drums that had been stored in cell M-4. Remote handled waste cans were transferred from cells K-1 and A-1 during May 1994. The remote handled waste was removed from the cell in June 1995. Once the remote handled waste was removed, the dose rates in the cell were low. The containment boxes were dismantled and the walls and floor were decontaminated through September 1995. The final survey was performed during October 1995.

2. Accumulated Dose

The doses were accumulated at 3 separate times; during early 1993, late 1993 and August to October 1995. Initial entries were made in March 1993 and continued through October 1993 to size reduce the shear and package it for removal by waste management. During October to December 1993, waste was moved to this cell and repackaged. During August to October 1994, drums were remotely repackaged and "hot" items were consolidated into fewer drums. During August to October 1995 the cell was completely stripped of experimental equipment. The walls were stripped of the wallpaper. Several applications of strip coat were applied to the walls and floor.

The total whole body (deep) dose that was accumulated during the decontamination of cell M-3 was ~500 person-mrem (see Figure 7). The total skin (shallow) dose was ~3,000 person-mrem (see Figure 8) and the total extremity (ring) dose was ~1,900 person-mrem (see Figure 9). The doses were estimated as 100% of those accumulated from April to October 1993; plus 1/2 of those accumulated during July 1995; plus 10% of those accumulated from August to October 1995. In addition, the doses for repackaging the drums were ~400 person-rem whole body, ~380 person-rem skin, and ~470 person-rem extremity. The drum doses were estimated as 100% of those accumulated during March 1993 and from October through December 1993.

3. Decontamination Limit

The cells were decontaminated to the paint layer. Numerous attempts were made to remove loose contamination that was on the paint. However, no attempt was made to remove the paint or the contamination under the paint.

C. FINAL SURVEY RESULTS

The values that were measured during the survey are compared to the acceptance goals. For each graph containing the direct survey data, the average grid measurements are presented in large numbers in the center of the grid; the elevated readings are presented in smaller numbers at the location of the hot spots. In the legend, the instrument and the corresponding units of the measurements are designated for direct surveys. The smear data is presented as a ratio with the alpha activity printed in the numerator to the beta-gamma activity printed in the denominator. The legend indicates whether the smear covered the large 1 m² or the small 100 cm² area near the center of the grid. The layout of cell M-3 is shown in Figure D-1.

1. M-3 West Wall

The average gamma readings ranged from 0.5 mR/h to 1.5 mR/h (see Figure D-2). Only the readings on the lower north grid exceeded the average exposure rate goal. The hot spot readings ranged from 1.0 mR/h to 3.0 mR/h on the lights and piping. All hot spots were below the maximum exposure rate goal.

The average alpha readings in each grid including the crane rails and brackets was 100 dis/min using a 61 cm² probe, below the average alpha activity acceptance goal for 100 cm². The direct alpha readings of the hot spots ranged from 1k dis/min to 6k dis/min using a 61 cm² probe (see Figure D-3). Most of the values were above the maximum total α activity acceptance goal for 100 cm².

The maximum loose activity on large area smears was 220 dpm/1 m² α and 33k dpm/1 m² $\beta\gamma$ (see Figure D-4), well below the Table 1 values. The highest removable activity was in the grid on the lower south side. The highest alpha activity on small area smears was 55 dpm/100 cm²; the highest $\beta\gamma$ activity was 1.4k dpm/100 cm² (see Figure D-5). Both are below the maximum removable activity goals.

2. M-3 North Walls and Door

The north wall has many sections including the recess for the low flow HEPA filter and the door. Although some of these sections are actually facing west and others are facing east,

for this report they will be considered as part of the north wall. The grids behind the HEPA filters to the low flow stack had average exposure rates of 2.0 mR/h and 3.0 mR/h; for the other grids, the average exposure rate ranged from 0.2 mR/h to 1.0 mR/h (see Figure D-6). All measurements were below the appropriate average contact exposure rate goals. The readings on the filters were 10 mR/h, below the maximum contact exposure rate goal for filters. At 30 cm from the filters, the exposure rate decreased to 2 mR/h.

The average alpha readings in the grids ranged from 100 dis/min to 200 dis/min using a 61 cm² probe (see Figure D-7). The hot spots range from 200 dis/min to 30k dis/min. All of the grid averages are below the acceptance goal. Most of the hot spots on this wall exceed the acceptance goals. The filters had the highest reading.

The maximum loose activity on large area smears was 120 dpm/1 m² α and 19k dpm/1 m² $\beta\gamma$ above the HEPA filters (see Figure D-8), these values are well below the average acceptance goals. The highest alpha activity on small area smears was 290 dpm/100 cm²; the highest $\beta\gamma$ activity was 1.4k dpm/100 cm² (see Figure D-9). Both are well below the maximum removable acceptance goals.

3. M-3 East Wall

The average gamma readings on the east wall were 0.1 mR/h including the interior of the transfer port (see Figure D-10). The measurement that is above the average exposure rate on contact was on the light, 0.5 mR/h. This hot spot meets the maximum contact exposure rate acceptance goal.

The average alpha readings in each grid including the crane rail and brackets was 100 dis/min using a 61 cm² probe (see Figure D-11). All of these values were below the average total alpha activity acceptance goal. The direct alpha readings for the hot spots were between 400 dis/min and 20k dis/min using a 61 cm² probe. Only the 20k dis/min value on the receptacle was above the maximum total α activity acceptance goal for a 100 cm² area. Other hot spots were on the light and in the transfer port.

The maximum loose activity on large area smears was 86 dpm/1 m² α and 5.7k dpm/1 m² $\beta\gamma$ (see Figure D-12), well below the average removable alpha activity acceptance goal.

The highest alpha activity on small area smears was 71 dpm/100 cm²; the highest $\beta\gamma$ activity was 4.5k dpm/100 cm² (see Figure D-13). Both are below the maximum removable activity acceptance goals.

4. M-3 South Wall

The average gamma readings were between 0.1 and 1.0 mR/h (see Figure D-14). These measurements are below the average contact exposure rate goals. The hot spot was 3.0 mR/h on the receptacle. The hot spot was below the respective maximum contact exposure rate goal.

The average alpha readings in each grid was 100 dis/min using a 61 cm² probe (see Figure D-15). These values were below the average total alpha activity acceptance goal for 100 cm². The direct alpha readings for the hot spots were between 400 dis/min and 50k dis/min using a 61 cm² probe. Four of these values are above the maximum total α activity acceptance goal for 100 cm².

The maximum loose activity on large area smears was 490 dpm/1 m² α and 32k dpm/1 m² $\beta\gamma$, well below the average removable acceptance goals (see Figure D-16). The highest alpha activity on small area smears was 48 dpm/100 cm²; the highest $\beta\gamma$ activity was 2.8k dpm/100 cm² (see Figure D-17). Both are below the maximum removable activity acceptance goals.

5. M-3 Floor

The average gamma readings on the cell floor ranged from 0.1 mR/h to 2.0 mR/h (see Figure D-18). Some of these measurements were above the average contact exposure rate acceptance goals. There was one hot spot, 0.5 mR/h on the grate for the high flow filter. At 30 cm from the filter the exposure rate decreased to 0.1 mR/h. The general exposure rate at 1¼ meter above the floor was 0.2 mR/h.

The average alpha readings in each grid ranged from 100 dis/min to 400 dis/min using a 61 cm² probe (see Figure D-19). These are below the acceptance goal. The direct alpha readings for the hot spots were between 1k dis/min and 10k dis/min using a 61 cm² probe. Most of these values are above the maximum total α activity acceptance goal for 100 cm².

The maximum loose activity on large area smears was 210 dpm/1 m² α and 19k dpm/1 m² $\beta\gamma$ (see Figure D-20), well below the average removable activity acceptance goals. The highest alpha activity on small area smears was 80 dpm/100 cm²; the highest $\beta\gamma$ activity was 8.1k dpm/100 cm² (see Figure D-21). Both are below the maximum removable acceptance goal.

For the sake of clarity the survey results for the mule rails, the pits and the plugs are presented separately in Figure D-22. The maximum loose activity in the rails was 220 dis/min α and 13k dis/min $\beta\gamma$. The pits had direct γ readings of 0.5 mR/h. The plugs and the filter grate were smear surveyed and the maximum loose activity was 300 dis/min α and 32k dis/min $\beta\gamma$. All these survey results were below their respective acceptance goals.

6. M-3 Overhead

The only overhead equipment that was surveyed were the one ton capacity bridge crane motor, ballast, the primary and secondary crane bridges and the drive shaft. The exposure rates were all 0.1 mR/h. The direct alpha readings ranged from 50 dis/min on the primary motor to 4k dis/min using a 61 cm² probe on the secondary motor and ballast (see Figure D-23). The maximum large area smear was 3.2k dis/min α and 460k dis/min $\beta\gamma$. The smears on the secondary crane bridge and motor are above the maximum acceptance goals for total and removable α activity and removable $\beta\gamma$ activity.

D. CONCLUSIONS

1. Measurements of Residual Radon Gas

As a result of the residual contamination from the POB project, thoron is present in the cell and it is emitted from the stacks. The amount of thoron and naturally occurring radon were measured by an Alpha-6 monitor. The Alpha-6 measured the energy of the alpha particle and generated the spectrum seen in Figure D-24. Three prominent peaks are seen; one, ²¹²Po (8.78 MeV), from thoron; one, ²¹⁴Po (7.69 MeV), from radon; and one from a combination of ²¹⁸Po (6.00 MeV) from radon and ²¹²Bi (6.05 MeV) from thoron.

The Alpha-6 calculates ²²²Rn concentrations in pCi/l and radon and thoron daughter concentrations in milli Working Levels (mWL). The concentrations of the Rn daughters in the

air from ^{222}Rn varies in the same manner as the ^{222}Rn gas concentrations (see Figure D-25). These change much more rapidly than the concentration of the Tn daughters in the air from ^{220}Rn which is controlled by the 10.6 hour half-life of ^{212}Pb .

2. Cell Decontamination Summary

The cell is intended to be left without further decontamination by this project. The identity and quantities of radionuclides that remain in the cell were estimated from the stack emissions. These estimates are presented in Table 12. The radionuclides listed above ^{232}U are

Table 12. Isotopes in Cell M-3 from Stack Emissions

Radionuclide		Cat III mCi	Activity mCi	Ratio
^{137}Cs	β	60,000	0.77	1.3×10^{-5}
^{90}Sr	β	16,000	0.77	4.8×10^{-5}
^{90}Y	β	1,420,000	0.77	4.5×10^{-7}
^{125}Sb	β	1,200,000	0.062	5.1×10^{-8}
^{134}Cs	β	42,000	0.029	7.0×10^{-7}
^{154}Eu	β	200,000	0.0096	4.8×10^{-8}
^{155}Eu	β	940,000	0.0019	2.0×10^{-9}
^{232}Th	α	100	<0.00001	4.3×10^{-9}
^{233}U	α	4,200	0.0013	3.1×10^{-7}
^{232}U	α	820	0.0039	4.7×10^{-6}
^{228}Th	α	1,000	0.0039	3.9×10^{-6}
^{224}Ra	α	200,000	0.0039	1.9×10^{-8}
^{220}Rn	α	2,000	0.0039	1.9×10^{-6}
^{216}Po	α		0.0039	
^{212}Pb	β	3,200,000	0.0039	1.2×10^{-9}
^{212}Bi	α, β		0.0039	
^{212}Po	α		0.0039	
^{208}Tl	β		0.0039	
Total α			0.03	1.1×10^{-5}
Total β			2.4	6.2×10^{-5}
Total $\alpha + \beta$			2.5	7.3×10^{-5}

estimated from analyses of smear data at the start of the D&D project. These activities are compared to the Nuclear Facility Category III quantities. As seen at the bottom of the table, the sum of the ratios is <0.008% of the Category III level.

A summary of the hot spots found by the direct surveys are presented in Table 13. Only direct α contamination measurements were above the acceptance goals that are presented in Table 1. The values above the acceptance goals are highlighted and bolded.

Table 13. Direct Survey Hot Spot Summary; Cell M-3

Area	RO-20 mR/h γ	α dis/min-61 cm ²
West Wall	1.0 to 3.0	1k to 6k
North Wall	10	200 to 30k
East Wall	0.5	400 to 20k
South Wall	3.0	400 to 50k
Floor	0.5	1k to 10k
Crane	none	4k

At the present time the general exposure rate at 1 ¾ meter from the walls and floor is 0.2 mR/h. The exposure rates are 0.1 mR/h at 30 centimeters from the low flow filter and 2.0 mR/h at 30 centimeters from the high flow filter. Workers can enter the cell without concern for external exposure. However, PPE and respiratory protection has been used for all work including the final survey.

3. Stack Emissions

The peak year for emissions since 1984 was 1994 (13.3 Ci). The November and December 1993 emissions were > 1 Ci during the repackaging of the drums from cell M-4. The emissions were also > 1 Ci from June through November 1994 when the remote handled waste was moved from cells K-1 and A-1 and repackaged. During June the discharge rate increased to 50 μ Ci/min (see Figure D-26). In June 1995 some of the remaining containers were repackaged prior to the removal of all the remote material from the cell. After this time the

discharge rate decreased until it stabilized at $\sim 1 \mu\text{Ci}/\text{min}$. After the final decontamination the measured emissions are $\sim 5\%$ of their peak in 1994 or $\sim 6\%$ of the 1991 value. These values are so low that they are indistinguishable from the naturally occurring radon levels.

VII. Cell M-1

A. INITIAL CELL CONDITION

1. Spills and Contamination

In cell M-1 there were several spills that were not completely cleaned up during the POB project. This produced extensive loose contamination and airborne contamination. One acid spill on the floor of M-1 had a surface reading of 100 R/h one foot from the surface at the beginning of the decontamination effort. The air flow from the intake filter passed over this spill before it was channeled into the anteroom and then into the containment boxes. Therefore the anteroom became highly contaminated.

2. Stack Emissions

Monitoring of the cell M-1 stack emissions was initiated in December 1983 for ^{129}I , ^{85}Kr and ^{220}Rn . Hot work in cell M-1 began on December 6, 1983. The stack monitoring has continued through the decontamination of the cells. The ^{129}I and ^{85}Kr emissions from this cell were greater than ^{129}I or ^{85}Kr emissions from either M-3 or K-3. When work on the fuel rods ended, the ^{129}I and ^{85}Kr emissions also ended as seen in Table 14. During 1984 and the first quarter of 1985 there was more krypton emitted than radon.

The ^{220}Rn emissions from cell M-1 peaked at 3,293 Ci in 1986 after the completion of the work on the fuel rods but during the solidification of the liquid waste and the initial decontamination. The emissions decreased after this decontamination but then increased to a peak 1,898 Ci in 1992 (see Table 15 and Figure 15) before the start of the final decontamination of this cell began. Figure 16 is an expanded view of the quarterly emissions since 1987. The monitor was not operational from June 4, 1987 through December 3, 1987. Therefore, the emission estimates during this time appear to be low (see Figure 12). Before the completion of the decontamination, the December 1995 emissions were <3% of the December 1992 emissions; the 1996 emissions were $\sim 2\frac{1}{4}\%$ of the 1992 emissions as seen in Table 15.

Table 14. ^{85}Kr and ^{129}I Emissions from Cell M-1

Month	Quantity (Ci) ^{85}Kr		Quantity (μCi) ^{129}I	
	1984	1985	1984	1985
January		3.0		3.2
February		25.1	0.031	5.1
March		16.3	0.00585	9.7
April		18.5	0.0146	0.5
May		13.6	0.012	7.4
June		11.4	0.033	7.0
July		17.5	0.0098	8.1
August	14.3	8.6	0.400	7.2
September	13.7	9.7	0.460	7.7
October	7.8	2.9	0.345	4.0
November	10.7		2.450	0.2
December	<u>21.3</u>		<u>4.160</u>	<u>1.6</u>
Total (Ci)	67.8	126.6	7.92	61.7

From the start of the project through 1987, the monthly emissions as seen in Figure 12 were related to the effort inside the cell. The monthly emission peak was 441 Ci in December 1986. However from 1988 through 1994, the emissions peaked in the summer months and were low in the winter months. The emissions during the summer months (e.g. 262 curies in August 1991) are more than twice the emissions during the winter months (e.g. 54 curies in January 1991 or 90 Ci in January 1992).

B. DECONTAMINATION

1. Waste Removed

Size reduction and clean up of hot spots was started in the summer of 1992. Because of the high radiation levels, it soon became clear that to make progress, waste had to be removed from the cell. However, the extensive contamination had to be carefully controlled so that contamination of M-5 and M-6 corridors was minimized. Therefore, cell M-3 was prepared as a staging area and decontamination of the cell M-1 stopped during the summer of 1993. Remote work resumed in December 1994. All work was performed remotely and waste was packaged in the cell through February 1995. A bag out wall was installed during February 1995 and

Table 15. ²²⁰Rn Emissions from Cell M-1

Month	Quantity (Ci) ²²⁰ Rn Released by month												
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
January	0.218	4.6	212	374	45.5	66.7	48.5	54.1	90.4	77.87	52.83	56.56	1.80
February	0.391	6.2	138	65	36.6	35.5	58.7	57.9	80.7	53.43	48.39	45.8	1.62
March	0.117	12.1	315	81	70.6	78.8	84.2	105.6	106.4	58.65	62.98	70.89	
April	0.225	23.2	283	115	84.4	114	104.5	148.5	133.4	73.48	75.21	65.05	
May	0.386	39.3	331	36	127.4	109	129.5	218.6	191.9	103.9	74.2	58.82	
June	0.473	109.3	269	35	145.2	118	155	201.6	229	116	112.43	66.3	
July	0.357	154	301	35	180	154	191.2	221	252	142.45	169.69	51.13	
August	0.843	108	251	35	204	164	198.7	262	211	151.38	181.63	59.72	
September	7.40	91.9	382	35	163	121	185.7	179	214	124.9	135.61	27.39	
October	16.9	113.5	188	35	113	83	137.5	156	177.1	88.95	111.41	15.02	
November	12.8	423.7	182	35	134	57.8	91	115	125.8	66.62	95.94	5.62	
December	<u>17.5</u>	<u>114</u>	<u>441</u>	<u>55</u>	<u>56.2</u>	<u>30.7</u>	<u>71.9</u>	<u>103</u>	<u>86</u>	<u>67.49</u>	<u>69.76</u>	<u>2.37</u>	
Total (Ci)	57.61	1,200	3,293	936	1,360	1,132	1,456	1,822	1,898	1,125	1,190	524.67	3.42
% previous year		2,082.6	274	28	145.3	83.3	128.6	125.1	104.1	59.29	105.77	44.09	0.65
Percentage (²²⁰ Rn released during month / ²²⁰ Rn released during same month in 1992)													
Month	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
January	0.24	5.1	235	414	50.3	73.8	53.7	59.9	100.0	86.14	58.44	62.57	1.99
February	0.48	7.7	171	81	45.4	44.0	72.7	71.8	100.0	66.21	59.96	56.75	2.01
March	0.11	11.4	296	76	66.4	74.1	79.1	99.3	100.0	55.12	59.19	66.63	
April	0.17	17.4	212	86	63.3	85.5	78.3	111.3	100.0	55.08	56.38	48.76	
May	0.20	20.5	172	19	66.4	56.8	67.5	113.9	100.0	54.14	38.67	30.65	
June	0.21	47.7	117	15	63.4	51.5	67.7	88.0	100.0	50.66	49.10	28.95	
July	0.14	61.1	119	14	71.4	61.1	75.9	87.7	100.0	56.53	67.34	20.29	
August	0.40	51.2	119	17	96.7	77.7	94.2	124.2	100.0	71.74	86.08	28.30	
September	3.46	42.9	179	16	76.2	56.5	86.8	83.6	100.0	58.36	63.37	12.80	
October	9.54	64.1	106	20	63.8	46.9	77.6	88.1	100.0	50.23	62.91	8.48	
November	10.17	336.8	145	28	106.5	46.0	72.3	91.4	100.0	52.96	76.26	4.47	
December	<u>20.35</u>	<u>132.6</u>	<u>513</u>	<u>64</u>	<u>65.4</u>	<u>35.7</u>	<u>83.6</u>	<u>119.8</u>	<u>100.0</u>	<u>78.48</u>	<u>81.12</u>	<u>2.76</u>	
Average %	3.79	66.5	199	71	69.6	59.1	75.8	94.9	100.0	61.30	63.24	30.95	2.00

contact handled waste was removed. Remote handled waste was removed after the shielding wall was removed in July 1995. Cell entries also began during July 1995. Removal of floor and wall coverings and decontamination of the interior of the cell started in October 1995. The final survey was initiated during February 1996.

2. Accumulated Dose

The doses accumulated from January 1995 through November 1995 are due primarily to the effort to decontaminate this cell. As seen in Figure 7, the doses that were accumulated while waste was removed from the cell through the bag out port from February through July were low. When the wall was removed and cell entries began the doses increased significantly. From August 1995 through January 1996, the cell was stripped of the equipment and the containment boxes that could not be removed through the bag out port in the shielding wall. The wall paper was removed. However stripcoat was not used to decontaminate the walls after the wall paper was removed. The final survey was performed in February 1996.

The total whole body (deep) dose that was accumulated during the decontamination of cell M-1 was $\sim 4,300$ person-mrem. The total skin (shallow) dose was $\sim 18,800$ person-mrem and the total extremity (ring) dose was $\sim 11,300$ person-mrem (see Figures 7 through 9). The doses were estimated as 100% of those accumulated from January 1995 through June 1995; 50% of those accumulated in July 1995; 90% of those accumulated from August 1995 through October 1995; and 100% of those accumulated from November 1995 through February 1996.

3. Decontamination Limit

In the cell the wall paper was decontaminated and removed. No attempt was made to remove contamination on the paint because of the lack of time and funding. Scabbling of the floor in the area of the spill is needed to reduce the dose rate inside the cell. A core sample was taken but the floor was not scabbled.

There was contamination on the outside of the north wall and the adjacent floor of the service area. All of the loose contamination on this wall was removed. Scabbling of the wall and floor were terminated when there was no more loose contamination as determined by

smears. The floor area was patched with concrete. A metal plate was epoxied to the wall area and both were painted with two colors of paint and "Fixed Contamination" was stencilled over the paint.

C. FINAL SURVEY RESULTS

The values that were measured during the survey are compared to the acceptance goals. For each graph containing the direct survey data, the average grid measurements are presented in large numbers in the center of the grid; the elevated readings are presented in smaller numbers at the location of the hot spots. In the legend, the instrument and the corresponding units of the measurements are designated for direct surveys. The smear data is presented as a ratio with the alpha activity printed in the numerator to the beta-gamma activity printed in the denominator. The legend indicates that the smear covered the large 1 m². The layout of cell M-1 is shown in Figure E-1.

Because of the extent of the remaining loose activity in this cell, only large area smears were taken. Both alpha and beta activities on the smears from the north wall were measured with an NE portable survey instrument in the integrate mode. Because of probe contamination problems, the beta activities on the smears from the other surfaces were measured through a plastic bag. In order to estimate the alpha activities on the other smears, the Eberline PAC 4G-3 gas proportional detector was used to measure the alpha activity on one smear from each wall or floor. The alpha/beta ratio of this smear was used to estimate the alpha activities on the other smears from the same wall or floor.

1. M-1 West Wall

The average gamma readings ranged from 1.5 mR/h to 4.0 mR/h (see Figure E-2). All of the readings exceeded the average exposure rate goal. The hot spot readings ranged from 4.0 mR/h to 5.0 mR/h on the lights, pipes and in the transfer port. Most hot spots were less than or equal to the maximum exposure rate goal.

The average alpha readings in each grid including the crane rails and brackets ranged from 100 dis/min to 500 dis/min using a 61 cm² probe, below the average alpha activity

acceptance goal for 100 cm². The direct alpha readings of the hot spots ranged from 1k dis/min to 500k dis/min using a 61 cm² probe (see Figure E-3). Most of the values were above the maximum total α activity acceptance goal for 100 cm². There are numerous hot spots. The highest activities were on the manipulator hands.

The alpha/beta ratio from the grid 4 north, 1 high was used to estimate the removable alpha activities in the other grids. The maximum loose activity on large area smears was estimated as 900 dpm/1 m² α and measured as 81k dpm/1 m² $\beta\gamma$ (see Figure E-4), below the Table 1 values. The highest removable activity was in the grid in the second row on the south side.

2. M-1 North Wall

The average exposure rates ranged from 1.5 mR/h to 5.0 mR/h (see Figure E-5). All measurements were above the average contact exposure rate goals. The hot spots readings ranged from 1 mR/h to 45 mR/h on fixtures, around the window and on the wall. Many are above the maximum contact exposure rate goal.

The average alpha readings in the grids ranged from 600 dis/min to 8k dis/min using a 61 cm² probe (see Figure E-6). The hot spots range from 6k dis/min to > 1M dis/min. Many of the grid averages are above the acceptance goal. All of the hot spots on this wall exceed the acceptance goals. The activities ≥ 1 M dis/min were on the viewing window and the concrete surfaces to the east of the window.

The maximum loose activity on large area smears was 6k dpm/1 m² α and 4.3M dpm/1 m² $\beta\gamma$ in the center grid along the floor (see Figure E-7), these values are above the average acceptance goals. All of the alpha activities were measured with an NE detector.

3. M-1 East Wall

The average gamma readings on the east wall ranged from 2.0 mR/h to 7.0 mR/h (see Figure E-8). All are above the average contact exposure rate acceptance goal. The hot spots ranged from 4.0 mR/h to 10 mR/h on light fixtures and at the bottom of the viewing window. Many of the hot spots exceed the maximum contact exposure rate acceptance goal.

The average alpha readings in each grid ranged from 500 dis/min to 10k dis/min using a 61 cm² probe (see Figure E-9). The direct alpha readings for the hot spots were between 4k dis/min and 1M dis/min using a 61 cm² probe. All of the values were above the maximum total α activity acceptance goal for a 100 cm² area. The highest activity was on the viewing window.

The alpha/beta ratio from the grid 3 north, 1 high was used to estimate the removable alpha activities in the other grids. The maximum loose activity on large area smears was 20k dpm/1 m² α and 680k dpm/1 m² $\beta\gamma$ (see Figure E-10). This alpha activity equals the average removable activity acceptance goal, and the beta activity is below the average removable activity acceptance goal.

4. M-1 South Walls and Door

The south wall has many sections including recesses for the low flow prefilters and the door. Although some of the sections are actually facing west and others are facing east, for this report they will be considered as part of the south wall. The average gamma readings were between 1.5 and 5.0 mR/h (see Figure E-11). These measurements are above the average contact exposure rate goals. The only hot spots were on the filters at 20 mR/h. The filters were below their respective maximum contact exposure rate goal. At 30 cm from the filter, the dose rate was 5.0 mR/h.

The average alpha readings in each grid ranged from 200 dis/min to 4k dis/min using a 61 cm² probe (see Figure E-12). These values were at or below the average total alpha activity acceptance goal for 100 cm². The direct alpha readings for the hot spots were between 4k dis/min and 700k dis/min using a 61 cm² probe. All of these values are above the maximum total α activity acceptance goal for 100 cm². The highest activities were on the filter housing.

The alpha/beta ratio from the grid 4 east, 1 high was used to estimate the removable alpha activities in the other grids. The maximum loose activity on large area smears was estimated as 1k dpm/1 m² α and measured as 71k dpm/1 m² $\beta\gamma$, below the average removable acceptance goals (see Figure E-13).

5. M-1 Floor

A lead blanket was used on the floor to shield the workers from the high exposure rates produced by the floor contamination. A 2½ inch diameter core sample was cut six inches deep. The sample was removed from the floor area with a high direct reading, 800 mR/h on contact. The sample was cut into four disks. The top three were each an inch thick and the deepest one was three inches thick. The dose rates from the disks were measured at contact and at 30 cm with an RO-20 ion chamber. The disks were sent to the Analytical Chemistry Laboratory (ACL) for gamma spectrometric analysis and alpha spectrometric analysis of chips from the top and bottom disks. Since there was still 62 pCi ^{137}Cs in the bottom disk, chips were removed to determine the level of Uranium contamination at the six inch depth. The analytical results are presented in Table 16. Since the main purpose of the analysis was to assist in determining the depth of the contamination, this was determined to be adequate. Environmental ^{137}Cs activity is the result of fall-out from atomic bomb blasts. Therefore, the soil concentrations should be a good indicator of the maximum expected uncontaminated concrete activities. The activities of soil around Argonne National Laboratory during 1994 as recorded in Golchert 1995 are also presented in Table 16. The bottom disk has 126 times the environmental ^{137}Cs activity. Environmental ^{134}Cs activities are below the detection limit. The chips from the bottom disk indicated that acid solution carried the contamination at least six inches into the concrete.

The average gamma readings on contact with the cell floor ranged from 1.5 mR/h to 75 mR/h (see Figure E-14). All of these measurements were above the average contact exposure rate acceptance goals. The hot spots ranged from 3.5 mR/h to 1 R/h in the area of the spill under the lead blanket.

To keep the dose to the personnel performing the survey ALARA, the area under the lead blanket was not scanned for total alpha activity. It was spot checked and found to be greater than the maximum meter reading, >1M dis/min using a 61 cm² probe. The average alpha readings in the other grids ranged from 4k dis/min to 200k dis/min using a 61 cm² probe (see Figure E-15). These are above the acceptance goal. The direct alpha readings for the hot spots were between 40k dis/min and >1M dis/min using a 61 cm² probe. All of these values are

Table 16. M-1 Core Sample Results

Section	γ Spec (pCi/g)		RO20 (mR/h)		α Spec Chip (pCi/g)		
	^{134}Cs	^{137}Cs	Contact	@ 30 cm	^{232}U	$^{233/234}\text{U}$	^{238}U
Top Chip		72,000k			33,600	11,200	
Top	143k $\pm$ 14k	9,260k $\pm$ 930k	100	4			
Second	78 $\pm$ 8	4,870 $\pm$ 490	0.5	0.1			
Third	1.9 $\pm$ 0.2	124 $\pm$ 12	0.3	<0.1			
Bottom	1.1 $\pm$ 0.1	62 $\pm$ 6	0.5	0.1			
Bottom Chips					1.91 $\pm$ 0.06	1.35 $\pm$ 0.05	0.31 $\pm$ 0.03
Soil		0.49 $\pm$ 0.4					1.1 $\pm$ 0.4

above the maximum total α activity acceptance goal for 100 cm². There is extensive contamination with many areas that pegged the meter at > 1 M dis/min.

The alpha/beta ratio from the grid 1 north, 3 east was used to estimate the removable alpha activities in the other grids. The maximum loose activity on large area smears was estimated as 57k dpm/1 m² α and 1.5M dpm/1 m² $\beta\gamma$ (see Figure E-16). Both are above the average removable activity acceptance goals. This grid contains part of the area covered with the lead blanket and other hot spots with direct alpha activities > 1 M dis/min.

For the sake of clarity the survey results for the mule rails, the pits and the plugs are presented separately in Figure E-17. The maximum gamma reading was 1 R/h in the rails. Through the lead blanket, the dose rate was 150 mR/h at the blanket surface and 50 mR/h at 30 cm. At 1 3/4 meters from the floor the dose rate was 10 mR/h over the blanket. For other areas of the cell, the dose rate at 1 3/4 meters was 5.0 mR/h. The prefilter housing for the high flow stack was 50 mR/h on contact and 10 mR/h at 30 cm.

The maximum direct alpha reading was 200k dis/min for a 61 cm² probe in the rails. One of the lifting lugs had removable $\beta\gamma$ activity up to 4M dis/min. The direct survey results were above their respective acceptance goals.

6. M-1 Overhead

The only overhead equipment that was surveyed were the one ton capacity bridge crane motor, hook, bucket, crane bridges and the drive shaft. The exposure rates ranged from 5.0 mR/h on the trolley to 50 mR/h on the bucket. The direct alpha readings ranged from 10k dis/min on the crane top to 600k dis/min on a hook using a 61 cm² (see Figure E-18).

7. M-1 North Wall Outside the Cell

The gamma reading on the outside of the north wall was 12 mR/h on contact before it was covered with a metal plate and 0.1 mR/h through the plate (see Figure E-19).

The direct alpha readings for the hot spots were between 100 dis/min and 3k dis/min using a 100 cm² probe. None of the values were above the maximum total α activity acceptance

goal for a 100 cm² area. The direct $\beta\gamma$ readings ranged from 6.5k dis/min to 820k dis/min using a 100 cm² probe.

D. CONCLUSIONS

1. Measurements of Residual Radon Gas

As a result of the residual contamination from the POB project, thoron is present in the cell and it is emitted from the stacks. The amount of thoron and naturally occurring radon were measured by an Alpha-6. The Alpha-6 measured the energy of the alpha particle and generated the spectrum seen in Figure E-20. Two prominent peaks are seen; one, ²¹²Po (8.78 MeV), from thoron; and the other from ²¹²Bi (6.05 MeV) also from thoron. The ²¹⁴Po (7.69 MeV), from radon, present in the spectra from the other cells is missing. An M-1 concentration of ²²²Rn similar to concentrations found in the other cells would be indistinguishable from the low energy tail of the ²¹²Po peak.

The Alpha-6 calculates ²²²Rn concentrations in pCi/l and radon and thoron daughter concentrations in milli Working Levels (mWL). The calculated concentration of decay products in the air from ²²²Rn is much lower than the concentration of decay products from ²²⁰Rn (see Figure E-21). The calculated ²²²Rn gas concentration is approximately equal to zero. The fact that it is negative at times is caused by subtracting a fraction of the large 8.78 MeV peak from the smaller 6 MeV peak to obtain the ²²²Rn concentration which is less than 5% of the ²²⁰Rn concentrations.

2. Cell Decontamination Summary

The cell is intended to be left without further decontamination by this project. The identity and quantities of radionuclides that remain in the cell were estimated from the stack emissions. The estimates as based on the emissions after the HEPA filters in the fan loft were changed on February 16, 1996 are presented in Table 17. The radionuclides listed above ²³²U are estimated from analyses of smear data at the start of the D&D project and the core sample ratios. These activities are compared to the Nuclear Facility Category III quantities. As seen at the bottom of the table, the sum of the ratios is <2% of the Category III level.

Table 17. Isotopes in Cell M-1 from Stack Emissions

Radionuclide	Cat III mCi	Activity mCi	Ratio
¹³⁷ Cs β	60,000	210	3.5×10^{-3}
⁹⁰ Sr β	16,000	210	1.3×10^{-2}
⁹⁰ Y β	1,420,000	210	1.5×10^{-4}
¹²⁵ Sb β	1,200,000	17	1.4×10^{-5}
¹³⁴ Cs β	42,000	8.0	1.9×10^{-4}
¹⁵⁴ Eu β	200,000	2.6	1.3×10^{-5}
¹⁵⁵ Eu β	940,000	0.52	5.6×10^{-7}
²³² Th α	100	0.00012	1.2×10^{-6}
²³³ U α	4,200	0.086	2.1×10^{-5}
²³² U α	820	0.26	3.2×10^{-4}
²²⁸ Th α	1,000	0.26	2.6×10^{-4}
²²⁴ Ra α	200,000	0.26	1.3×10^{-6}
²²⁰ Rn α	2,000	0.26	1.3×10^{-4}
²¹⁶ Po α		0.26	
²¹² Pb β	3,200,000	0.26	8.1×10^{-8}
²¹² Bi α, β		0.26	
²¹² Po α		0.26	
²⁰⁸ Tl β		0.26	
Total α		1.7	7.3×10^{-4}
Total β		660	0.017
Total $\alpha + \beta$		662	0.018

A summary of the hot spots found by the direct surveys are presented in Table 18. The values above the acceptance goals are highlighted and bolded. Many of the direct measurements and some the large areas smears were above the acceptance goals that are presented in Table 1.

Table 18. Direct Survey Hot Spot Summary; Cell M-1

Area	RO-20 mR/h γ	α dis/min-61 cm ²
West Wall	4.0 to 5	1k to 500k
North Wall	1.0 to 45	6k to > 1M
East Wall	4.0 to 10	4k to 1M
South Wall	20	4k to 700k
Floor	3.5 to 1,000	40k to > 1M
Crane	5 to 50	10k to 600k
Outside N Wall	0.1	100 to 3k

At the present time the general exposure rate at 1 ¼ meters from the walls and floors is 5.0 mR/h. In the center of the cell, over the blanket, the exposure rate is 10 mR/h. The exposure rate at 30 cm from the high flow filter on the floor was 10 mR/h. The exposure rate at 30 cm from the low flow filters on the south wall was 5.0 mR/h. Workers who enter the cell need to be concerned about external exposure. Also, some level of PPE and respiratory protection would be required for work in the cell.

3. Stack Emissions

Before the decontamination project began, the discharge rate of the air from the M-1 stacks ranged from 900 μ Ci/min to 7,500 μ Ci/min as seen in Figure E-22, that presents the values from February 1992 through March 1993. During the final stages of the decontamination project, the discharge of the air from the M-1 stacks ranged from 30 μ Ci/min to 80 μ Ci/min for December 1995 and January 1996. After the HEPA filters in the fan loft were changed in February 1996, the discharge rate decreased to a minimum of $\sim$ 25 μ Ci/min. The large fluctuations in the discharge rate are due the large variations in the measured flow rate.

The peak year for emissions since 1986 was 1992 (1,898 Ci). In 1995 there were 525 Ci emitted 28% of the 1992 value (see Table 15 and Figure 16). In 1995 the emissions decreased in April with respect to the previous month. In Figure 12 it can be seen that this is

very unusual. The pre-filters in the cell were changed at the end of February 1995 and the final removal of equipment began in August 1995. The final decontamination was completed in January 1996. The January and February 1996 emissions are ~2% of the 1992 emissions and ~3% of the 1991 emissions.

The January and February 1996 emissions from the four POB cells; M-1, K-1, M-3 and K-3 are ~2¼ % of the 1991 emissions.

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Figure 1.
Shielded Cave Complex

Figure 2. Fissionable ^{233}U from ^{232}Th ;
 ^{238}U & $^{239}\text{Pu}/^{235}\text{U}$ Decay

Figure 3. Decay of Radon, Thoron & Actinon

Figure 4. Alpha Spectrum from Radon Gas in Clean Area

Figure 5. Alpha-6 Rn & Tn Activities in Clean Area

Figure 6. Contributions to the Dose

Figure 8. TLD Badge Shallow Doses

Figure 9. TLD Ring Doses

Figure 10. Quarterly Rn-220 Emissions from Cell K-1; 1984 to 1996

Figure 11. Quarterly Rn-220 Emissions from Cell K-1; 1988 to 1996

Figure 12. Emissions from Project Stacks

Figure 13. Quarterly Rn-220 Emissions from Cell K-3

Figure 14. Quarterly Kr-85 and Rn-220 Emissions from Cell M-3

Figure 15. Quarterly Rn-220 Emissions from Cell M-1; 1984 to 1996

Figure 16. Quarterly Rn-220 Emissions from Cell M-1; 1987 to 1996

APPENDIX A. Cell A-1 Figures

FILE: DD\200\CELLA1

KEY

ACTIVE AREA

PAC Alpha (dis/min)

R020 Gamma (mR/h)

SMEAR LOCATION

α/β dis/min 1m

GRID = 1 SQ METER

TITLE:

FIGURE A-1

BUILDING 200

WING M - CELL A-1

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D SITE CHARACTERIZATION

A3

3715 001\200\CELLA1WG

KEY

GRID = 1 SQ METER

R020 Gamma (mR/h)

R020 Gamma Hot Spots (mR/h)

TITLE:

FIGURE A-2
BUILDING 200

WING M - CELL A-1

WEST WALL.

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE 001000CELLA1WA

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

PAC Alpha Hot Spots (dis/min)
61cm² PROBE

TITLE:

FIGURE A-3
BUILDING 200

WING M - CELL A-1

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: 00V200VCELLA1W

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min $1m^2$

TITLE:

FIGURE A-4

BUILDING 200

WING M - CELL A-1

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE 001200\CELLA1WC

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE A-5

BUILDING 200

WING M - CELL A-1

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

1 2

1 2

1 2

1 2

FILE DD\200\CELLA10C

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE A-9
BUILDING 200

WING M - (FLL A-1

NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

DOOR

0.5	0.5	3
0.5	0.5	2
0.5	0.5	1

2

1

EAST WALL

1.0	1.0	4
1.0	1.0	3

2

1

FILE 00\200\CELLA10

KEY

GRID = 1 SQ METER

R020 Gamma (mR/h)

R020 Gamma Hot Spots (mR/h)

TITLE:

FIGURE A 10
BUILDING 200

WING M - CELL A-1
EAST WALL AND DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D SITE CHARACTERIZATION

DOOR

400	100	3
400	100	2
400	100	1

2

1

EAST WALL

100k	20k	5k
20k	400	400
100k	100k	100k
400	400	400
8k UNISTRUT		

2

1

FILE D05203/CELLA12A

KEY

GRID = 1 SQ METER

Alpha (dis/min)

Alpha Hot Spots (dis/min)

TITLE:

FIGURE A-11
BUILDING 200

WING M - CELL A-1

EAST WALL AND DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D SITE CHARACTERIZATION

DOOR

0 / 330	43 / 370	3
33 / 2.7k	5 / 780	2
43 / 1.2k	24 / 530	1

EAST WALL

630 / 55k	81 / 6.3k	4
0 / 330	43 / 370	3

2 1

2 1

FILE DOORCELLA13M

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min $1m^2$

TITLE: FIGURE A-12
BUILDING 200

WING M - CELL A-1
EAST WALL AND DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

DOOR

22 / 0	31 / 210	3
0 / 100	22 / 24	2
3 / 0	22 / 0	1

2

1

EAST WALL

180 / 9.0K	31 / 370	4
22 / 0	31 / 210	3

2

1

FILE DOX200\CELLATEC

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE A 13
BUILDING 200

WING M -- CELL A-1

EAST WALL AND DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE DD\200\CELLA15G

KEY

GRID = 1 SQ METER

R020 Gamma (mR/h)

R020 Gamma Hot Spots (mR/h)

TITLE:

FIGURE A-14
BUILDING 200

WING M - CELL A-1

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D SITE CHARACTERIZATION

FILE DD\200\CELLA15A

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

PAC Alpha Hot Spots (dis/min)

ALL READINGS-61cm² PROBE

TITLE:

FIGURE A-15

BUILDING 200

WING M - CELL A-1

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D SITE CHARACTERIZATION

2 1

2 1

FILE D:\200\CELLA18C
KEY
GRID = 1 SQ METER
(X) SMEAR
 $\alpha/\beta\gamma$ dis/min 100cm²

TITLE: FIGURE A-17
BUILDING 200
WING M - CELL A-1
SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST
D & D FINAL RADIOLOGICAL SURVEY

READINGS-1.75 METER OFF FLOOR (mR/h) 2.5

FILE: DD\200\CELLA1FC

KEY

GRID = 1 SQ METER

R020 Gamma (mR/h)

R020 Gamma Hot Spots (mR/h)

TITLE:

FIGURE A-18
BUILDING 200

WING M - CELL A-1
FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D SITE CHARACTERIZATION

Verification Survey of
Building 200 Hot Cells
March 1996

A20

FILE: 00A200A/C/LA/TA

KEY

GRID = 1 SQ METER

Alpha (dis/min)
Alpha Hot Spots (dis/min)
61cm² PROBE

TITLE:

FIGURE A 19
BUILDING 200

WING M - CELL A-1
FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D SITE CHARACTERIZATION

FILE CONCELLAEM

KEY

GRID = 1 SQ MEIER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min $1m^2$

TITLE: FIGURE A-20
BUILDING 200

WING M - CELL A-1
FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE DD\200\CELLA1FC

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE: FIGURE A 21
BUILDING 200

WING M - CELL A-1
FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Figure A-22. Alpha Spectrum from Radon Gas in Cell A-1

Figure A-23. Alpha-6 Rn & Tn Activities in Cell A-1

Figure A-24. RGM-2 Radon Concentrations in Cell A-1

APPENDIX B Cell K-1 Figures

FILE DD\200\CELLA1

KEY

ACTIVE AREA

PAC Alpha (dis/min)

RO20 Gamma (mR/h)

SMEAR

GRID = 1 SQ METER

TITLE:

FIGURE B-1

BUILDING 200

WING M - CELL K-1

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE DOX200\CELLK1.WG

KEY
GRID = 1 SO METER

RO20 Gamma (mR/h)
Gamma Hot Spots (mR/h)

TITLE: FIGURE B 2
BUILDING 200

WING M - CELL K-1
WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: DD\200\CELLK1WA

KEY
GRID = 1 METER SQUARE
PAC Alpha (dis/min)
Alpha Hot Spots (dis/min)
ALL READINGS-61cm² PROBE

TITLE:

FIGURE B-3
BUILDING 200
WING M - CELL K-1
WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

4	70/ _{2K}	0/ ₇₁₀	940/ _{61K}	3.4K/ _{190K}	2K/ _{90K}	330/ _{26K}
3	10/ ₇₁₀	80/ _{1K}	0/ _{1K}	50/ _{3.6K}	0/ _{4.5K}	30/ _{14K}
2	50/ _{4K}	20/ ₉₀₀	50/ _{2K}	0/ ₉₀₀	0/ _{1K}	40/ _{1K}
1	0/ ₀	0/ _{1K}	50/ ₉₀₀	30/ _{1K}	20/ ₉₀₀	40/ _{2K}

1 2 3 4 5 6

FILE: DD\200\CELL\1\W4

KEY

GRID = 1 m

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 1m²

TITLE:

FIGURE B-4
BUILDING 200

WING M - CELL K-1

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

4	0/470	0/0	30/80	20/0	0/130	30/480
3	10/0	10/0	10/0	5/0	40/450	15/290
2	5/460	0/0	5/140	5/14	25/1K	10/430
1	5/0	0/140	40/0	25/0	55/2K	20/610

6

5

4

3

2

1

ARGONNE
NATIONAL LABORATORY
ANL EAST
D & D FINAL RADIOLOGICAL SURVEY

TITLE: FIGURE B-5
BUILDING 200

WING M -- CELL K-1
WEST WALL

KEY
GRID = ONE SQ METER
(X) SMEAR
 α/β dis/min 100 cm²

Verification Survey of
Building 200 Hot Cells
March 1996

B8

FILE 00\200\CELLK1.M

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (dis/min)

ALL READINGS - 61cm² PROBE

TITLE:

FIGURE B-7

BUILDING 200

WING M - CELL K-1

NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE DD\200\CELLK1M

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min $1m^2$

TITLE:

FIGURE B-8

BUILDING 200

WING M - CELL K-1

NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: D:\200\CELLS\B10

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE B-9
BUILDING 200

WING M - CELL K-1

NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: 001200CELLK1A

LEGEND

GRID = 1 50 METER

PAC Alpha (dis/min)

Alpha Hot Spots (dis/min)

ALL READINGS-61cm² PROBE

TITLE:

FIGURE B-11
BUILDING 200

WING M - CELL K-1

EAST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

ARGONNE
NATIONAL LABORATORY
ANL EAST
D & D FINAL RADIOLOGICAL SURVEY

FIGURE B-12

BUILDING 200

WING M - CELL K-1

EAST WALL

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 1m

FILE 00A300A/CCELLA1E0

FILE DD200\CELL\TEC

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE: FIGURE B-13
BUILDING 200

WING M - CELL K-1
EAST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

FILE: 00\200\CELLK1SG

KEY

GRID = 1 SQ METER

RO20 Gamma (mR/h)

Gamma Hot Spots (mR/h)

TITLE:

FIGURE B-14

BUILDING 200

WING M - CELL K1

SOUTH WALLS & DOOR

ARGONNE

NATIONAL LABORATORY

ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

B16

FILE: 00A200ACELX15A

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Hot Spots Alpha (dis/min)

ALL READINGS-61cm² PROBE

TITLE:

FIGURE B-15

BUILDING 200

WING M -- CELL K1

SOUTH WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

B17

S2 Underside

FILE 00\200\CELLK15M

KEY

GRID = 1 SQ METER

(X) SMEAR LOCATION
 $\alpha/\beta\gamma$ dis/min $1m^2$

TITLE:

FIGURE B-16
BUILDING 200

WING M - CELL K1
SOUTH WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

FILE: DR\200\CELLK1SC

KEY

GRID = 1 SQ METER

SMEAR LOCATION

α/βγ dis/min 100cm²

TITLE:

FIGURE B-17
BUILDING 200

WING M - CELL K1

SOUTH WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

B19

5
4
3
2
1

ARGONNE
NATIONAL LABORATORY
ANL EAST
D & D FINAL RADIOLOGICAL SURVEY

FIGURE B-18
BUILDING 200

WING M - CELL K1
FLOOR

KEY

GRID = 1 SQ METER

RO20 Gamma (mR/h)

Gamma Hot Spots (mR/h)

FIGURE B-19
BUILDING 200

WING M - CELL M1
FLOOR

D & D FINAL RADIOLOGICAL SURVEY

FILE 001200/CELL M1A

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (dis/min)

ALL READINGS-61cm PROBE

FILE DD\200\CELLK1.MF

KEY

GRID = 1.50 METER

SMEAR

$\alpha/\beta\gamma$ dis/min 1m^2

TITLE: FIGURE B-20
BUILDING 200

WING M - CELL KI
FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE 00\200\CELL K1.FLC

KEY

GRID = 1 SQ METER

(X) SMEAR

α/β dis/min 100cm²

TITLE:

WING M - CELL K1

FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Gamma Reading: 0.1 mR/h

1 Meter Sq. Smears
1W 1.3k / 5.7K
2W 9.3k / 320K
3W 7.6k / 84k
4W 1.2k / 61K
Motor and Ballast
2k / 79k

Crane

FILE 00\200\CELL1FR

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

SMEAR

RO20 Gamma (mR/h)

$\alpha/\beta\gamma$ dis/min 1m²

WING M - CELL k1
OVERHEAD CRANE & TROLLEY

TITLE: FIGURE B-22
BUILDING 200

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Figure B-26. Cell K-1 Discharge

Verification Survey of
Building 200 Hot Cells
March 1996

C1

APPENDIX C Cell K-3 Figures

FILE 001200VCELLK3

KEY

ACTIVE AREA

PAC Alpha (dis/min)

R020 Gamma (mR/hr)

SMEAR LOCATION

GRID = 1 SQ METER

TITLE:

FIGURE C-1

BUILDING 200

WING M - CELL K-3

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE D:\200\CELLS\3WG

LEGEND

GRID = 1 SQ METER

R020 Gamma (mR/hr)

Gamma Hot Spots (mR/hr)

TITLE:

FIGURE C-2
BUILDING 200

WING M - CELL 4-3

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

1 2 3 4

ARGONNE
NATIONAL LABORATORY
ANL EAST
D & D FINAL RADIOLOGICAL SURVEY

FILE DD\200\CELL K-3
GRID = 1 SQ METER
PAC Alpha (dis/min)
Alpha Hot Spots (dis/min)
ALL READINGS - 61cm PROBE

FIGURE C-4
BUILDING 200
WING M - CELL K-3
WEST WALL

1 2 3 4

FILE DD\200\CELL K-3.M

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 1m²

TITLE:

FIGURE C-4
BUILDING 200

WING M - CELL K-3

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

1 2 3 4

FILE DD\200\CELL\3WC

LEGEND

GRID = 1 SO METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE: FIGURE C-5
BUILDING 200

WING M - CELL K-3

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE DD\200\CELLK3MG

KEY

GRID = 1 SQ METER

RO20 Gamma (mR/hr)

Gamma Hot Spots (mR/hr)

TITLE:

FIGURE C-6

BUILDING 200

WING M - CELL K-3

NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST-

D & D FINAL RADIOLOGICAL SURVEY

200	8K	200
1.2K	200	200
FILTER	TRANSFER	
1.2K	LOCK	
LIGHT	3K	200
10K	50K	
200	20K	
400	1.2K	100
6K		

1 2

FILE DD\200\CELL\31A

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (mR/hr)
ALL READINGS-61cm² PROBE

TITLE:

FIGURE C-7
BUILDING 200

WING M - CELL K-3
NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

1 2

FILE 00\200\CELLK3M

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min $1m^2$

TITLE:

FIGURE C-8
BUILDING 200

WING M - CELL K-3

NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

1 2

FILE 000200\CELLK3NC

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE C-10
BUILDING 200

WING M - CELL K-3

NORTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

E2

0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1

4 3 2

DOOR OVERHEAD

0.1	0.1	0.1
-----	-----	-----

D1

0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1

4 3 2

E1

0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1

2 1

1

FILE DDY200VCELK3KG

KEY

GRID = 1 SQ METR

R020 Gamma (mR/hr)

Gamma Hot Spots (mR/h)

TITLE:

FIGURE C-10
BUILDING 200

WING M - CELL K-3

EAST WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

E1

400	400	400	400	400	400
GRATE 6K					NOZZLE 30K
400	400	400	400	400	400
500	500	500	500	500	500
500	500	500	500	500	500

2 1

E2

EXTINGUISHER

NOZZLE 30K	PIPE 30K	PIPE 90K
200	300	400
200	300	400

4 3 2

DOOR OVERHEAD

100	100	100
-----	-----	-----

D1

100	100	100	100
100	100	100	100
100	100	100	100

UNISTRUT
10K

4 4 3 2 2

FILE DD\200\CELLK3EA

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (mR/h)
ALL READINGS-61cm PROBE

TITLE:

FIGURE C-11
BUILDING 200

WING M - CELL K-3

EAST WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

E2

0 / 1.9K	80 / 5.2K	140 / 5.9K	50 / 2.9K
0 / 1.2K	0 / 1.2K	40 / 1.8K	10 / 1.5K

4 3 2

DOOR OVERHEAD

20 / 1.0K	0 / 780	0 / 540
-----------	---------	---------

D1

20 / 1.0K	0 / 1.7K	10 / 1.4K
-----------	----------	-----------

20 / 100	0 / 780	0 / 540
0 / 1.7K	0 / 730	130 / 2.6K
10 / 1.4K	10 / 720	200 / 2.4K

4

4 3 2

E1

50 / 2.9K	100 / 3.1K	100 / 3.1K	100 / 3.1K
10 / 1.5K	100 / 4.1K	100 / 4.1K	100 / 4.1K
0 / 6.0K	60 / 3.5K	60 / 3.5K	60 / 3.5K
40 / 2.4K	0 / 1.0K	0 / 1.0K	0 / 1.0K

2 1

1

100 / 3.1K	100 / 4.1K	filter	60 / 3.5K	0 / 1.0K
------------	------------	--------	-----------	----------

100 / 3.1K	100 / 4.1K	60 / 3.5K	0 / 1.0K
------------	------------	-----------	----------

FILE DO\200\CELLK3M

KEY

GRID = 1 SQ METER

(X) SMEAR

α/β dis/min $1m^2$

TITLE:

FIGURE C-12
BUILDING 200

WING M - CELL K-3
EAST WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

E1

10 / 440	0 / 360	0 / 360	0 / 360
0 / 260	40 / 40	40 / 40	40 / 40
0 / 140	10 / 410	10 / 410	10 / 410
30 / 30	0 / 320	0 / 320	0 / 320

1

2

2

3

4

DOOR OVERHEAD

D1

0 / 330	0 / 15	0 / 310
---------	--------	---------

0 / 310	20 / 300	0 / 120
---------	----------	---------

0 / 330	0 / 15	0 / 310
0 / 380	90 / 0	20 / 0
20 / 140	20 / 540	0 / 120

2

2

3

4

FILE: DDV200/CELLK3XC

KEY

GRID = 1 SQ METER

(X) SMEAR

α/β dis/min 100cm²

TITLE: FIGURE C-13

BUILDING 200

WING M - CELL K-3

EAST WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

S1

0.1	0.1
0.1	0.1
0.4	0.1
0.4	0.1
0.1	0.1

2 1

FILE DD\200\CELLA35G

KEY

GRID = 1 SQ METER

R020 Gamma (mR/h)

Gamma Hot Spots (mR/h)

TITLE:

FIGURE C-14
BUILDING 200

WING M - CELL K-3

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

S1

3K - BEHIND DUCT WORK	
400	CONDUIT - 9K 600 1K
500	5K 500
6K 500	3K 500
400 1K	2K 400 3K

2 1

FILE 001200\CELLK3SA

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (mR/h)

ALL READINGS - 61cm² PROBE

TITLE:

FIGURE C-15
BUILDING 200

WING M - CELL K-3

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

S1

260 / 5.7k	140 / 4.2k
40 / 1.2k	10 / 1.2k
480 / 7.1k	0 / 2k
90 / 2.5k	20 / 850

2

1

FILE DD\200\CELLK3SM

KEY
GRID = 1 SQ METER

SMEAR

$\alpha/\beta\gamma$ dis/min $1m^2$

TITLE:

FIGURE C-16
BUILDING 200

WING M - CELL K-3

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

31

0 / 300	20 / 580
40 / 740	0 / 240
260 / 1.2	30 / 560
20 / 140	20 / 130

2 1

FILE DIVISION CELL 135C

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE: FIGURE C-17
BUILDING 200

WING M - CELL K-3

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Gamma Reading 1.75 Meters off Floor (mR/hr) 0.2

FILE: D:\200\CELLK3FG

KEY
GRID = 1 SQ METER

R020 Gamma (mR/hr)
Gamma Hot Spots (mR/hr)

TITLE:
FIGURE C-18
BUILDING 200

WING M - CELL K-3 FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

C20

FILE DD\200\CELLK3FA

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (mR/hr)

Alpha Hot Spots (mR/hr)

TITLE:

FIGURE C-19
BUILDING 200

WING M - CELL 1-3 FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

C21

FILE DD-200-CELL-K-3

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min $1m^2$

TITLE:

FIGURE 20
BUILDING 200

WING M - CELL K-3
FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Verification Survey of
Building 200 Hot Cells
March 1996

C22

FILE 001200\CELLK3FC

KEY

GRID = 1 SQ METER

(X) SMEAR

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE C-21

BUILDING 200

WING M - CELL K-3

FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

RO20 GAMMA READINGS OF CRANE: 0.1 mR/h

GRID = 1 SQ METER
PAC Alpha (dis/min)
RO20 Gamma (mR/hr)

TITLE: FIGURE C22
BUILDING 200
WING M -- CELL K-3
CRAIF

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Figure C-23. Alpha Spectrum from Radon Gas in Cell K-3

Figure C-24. Alpha Spectrum from Radon Gas in Cell K-1

Figure C-27. RGM-2 Radon Concentrations in Cell K-3

Figure C-28. Alpha-6 Rn Activities in Cell K-3

Verification Survey of
Building 200 Hot Cells
March 1996

D1

APPENDIX D Cell M-3 Figures

S1

1 2 3 4 5

FILE: DD\200\CELLJ390

KEY

GRID = 1 SQ METER

RO20 GAMMA (mR/h)

Gamma Hot Spots (mR/hr)

TITLE:

FIGURE D-2

BUILDING 200

WING M - CELL M3

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

1 2 3 4 5

FILE: DD\200\CELLM3WA

KEY

GRID = 1 SQ METER

PAC (dis/min)

Alpha Hot Spots (dis/min)
ALL READINGS-61cm PROBE

TITLE:

FIGURE D-3
BUILDING 200

WING M - CELL M3

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

4	25/1.1K ()	0/300 ()	30/1K	0/0 ()	0/1.5K ()
3	20/300	20/380	0/600	0/620	110/2.9K
2	55/2.1K	25/1.8K	25/340	90/3.8K	20/0
1	220/3.5K	20/380	25/1K	45/630	0/750

1 2 3 4 5

FILE 00V200VCELLM3WL

KEY

GRID = 1.50 METER

(X) SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 1 m²

TITLE:

FIGURE D-4
BUILDING 200

WING M - CELL M3
WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

4					
3					
2					
1					

0/0	0/0	0/0	0/0	0/0
20/0	30/330	0/240	25/450	0/0
0/0	0/580	0/0	0/0	0/0
55/1400	25/0	50/650	0/0	0/0

1 2 3 4 5

FILE DDV200\CELLM3WS

LEGEND

GRID = 1.50 METER

(X) SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE D-5

BUILDING 200

WING M - CELL M3

WEST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

D7

DOOR OVERHEAD

0.3	0.3
-----	-----

N1 NE1 NW1 N2 NE2

DOOR

1 2

2 3 4 5

2 3 4

FILE: D:\200\CELL\330

LEGEND

GRID = 1 SQ METER

RO20 GAMMA READINGS (mR/h)

Gamma Hot Spots (mR/h)

TITLE:

FIGURE D-6

BUILDING 200

WING M - CELL M3

NORTH WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

DOOR OVERHEAD

100	100
-----	-----

N1

NE1

NW1

N2

NE2

DOOR

1 2

2 3 4 5

2 3 4

FILE: DD\200\CELLM3NA

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (dis/min)

ALL READINGS-61cm² PROBE

TITLE:

FIGURE D-7

BUILDING 200

WING M - CELL M3

NORTH WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

DOOR OVERHEAD

0/1.9k	40/1.2k
--------	---------

NE2

N2

NW1

NE1

N1

DOOR

0/0	10/1.7k	40/1.8k
0/0	50/1.6k	90/2.5k
0/0	30/1.4k	0/2k

40/1.2k
0/1.1k
30/1.7k

65/9.8k	120/7.5k	20/1.4k
120/19k	0/1.9k	40/1.2k
70/8.8k	0/1.1k	30/1.7k
60/7.3k		

120/19k
70/8.8k
60/7.3k

65/9.8k	120/19k	70/8.8k	60/7.3k
0/1.4k	0/1.9k	0/1.1k	0/2k
30/1.7k	30/1.7k	30/1.7k	30/1.7k
30/1.7k	30/1.7k	30/1.7k	30/1.7k

2 3 4

2 3 4 5

1 2

FILE DOA200-ELMNL

KEY

GRID = 1 SO METER

(X) SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 1m²

TITLE: FIGURE D-9
BUILDING 200

WING M -- CELL M3

NORTH WALL'S & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

D10

0/1.2K	0/0
--------	-----

SWZ

2Z

1 MWI

WZ

ROO

290 14K	0/0	0/400
0/0	0/0	0/0
0/0	0/120	0/110

4
3
2

0/0	0/0	0/0
-----	-----	-----

0/340	0/0	0/0	0/0	0/0
0/0	0/1,2K	0/0	0/0	0/0
0/0				
20/310				

543

315	0/0	0/0
-----	-----	-----

9/340	9/0	9/0	20/310
-------	-----	-----	--------

[illegible]

FILE. 00\200\CELMJNS

KEY

GRID = 1 SQ METER

(X) SMEAR LOCATION

 $\alpha/\beta\gamma$ dis/min 100cm^2

TITLE:

FIGURE D-9

BUILDING 200

WING M - CILL M3

NORTH WALLS & DOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE 00200VCELLW3G

KEY

GRID = 1 SQ METER

RO20 (mR/h)

Gamma Hot Spots (mR/hr)

TITLE:

FIGURE D-10

BUILDING 200

WING M - CELL M3

EAST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

5 4 3 2 1

TITLE: FIGURE D-11
BUILDING 200
WING M - CELL M3
EAST WALL

KEY
GRID = 1 SO METER
PAC Alpha (dis/min)
Alpha Hot Spots (dis/min)
ALL READINGS - 61cm PR10BE

ARGONNE
NATIONAL LABORATORY
ANL EAST
D & D FINAL RADIOLOGICAL SURVEY

0/1.1k	0/2.6k	0/820	0/590	0/760	4
0/1.5k	0/1.2k	0/710	86/5.7k	29/3.9k	3
52/2.2k	0/1.3k	0/538	29/1.4k	67/5.3k	2
0/1.4k	0/1.2k	0/1k	29/2.2k	0/2k	1

5 4 3 2 1

FILE 00V300CELLMSEL

KEY

GRID = 1 SQ METER

(X) SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 1m²

TITLE:

FIGURE D-12

BUILDING 200

WING M -- CELL M3

EAST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

0/650	0/630	0/800	0/750	0/710
29/610	0/720	0/550	0/880	0/750
38/1.81	0/590	0/640	0/670	71/4.5k
0/780	0/740	0/540	0/400	0/940

5 4 3 2 1

FILE DD200/CELL/YES

LEGEND

GRID = 1 SQ METER

SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE:

FIGURE P-13

BUILDING 200

WING M - CELL M3

EAST WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

D15

FILE: D:\2001\CELLM350

KEY

GRID == 1 SQ METER

RO20 GAMMA (mR/h)

Gamma Hot Spots (mR/hr)

TITLE:

FIGURE D-14

BUILDING 200

WING M - CELL M3

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: 00\200\CELLM3A

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha hot spots (dis/min)
All Readings 61cm² Probe

TITLE:

FIGURE D-15
BUILDING 200

WING M - CELL M3 BUILDING 200

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

0/ 870	0 / 2K ()	29 / 4K ○	150 / 7.6K	45 / 5.3K
24 / 430	0 / 1.1K	0 / 2.7K	45 / 3.2K	90 / 5.3K
62 / 1.2K	14 / 8.3K	150 / 9.2K	50 / 3.6K □	29 / 1.8K □
0 / 460	490 / 32K	71 / 5K	24 / 1K	76 / 3.8K

4

3

2

1

5

4

3

2

1

FILE: 00V200VCELLD551

KEY

GRID = 1 SO METER

⊗ SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 1 m²

TITLE:

FIGURE D 16
BUILDING 200

WING M - CELL M3

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

0/ 790	0/610 ()	0/890 ○	0/910	0/1.4k
0/ 760	0/860	0/2.8k	0/1.1k	48/2k
0/ 2.1k	0/1.5k	0/1.2k	0/1.4k □	0/1.9k □
0/ 1.2k	0/1.9k	0/2k	0/460	38/2.5k

4

3

2

1

1

2

3

4

5

FILE: DD\200\CELL\355

KEY

GRID = 1 SQ METER

(X) SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 100cm²

TITLE: FIGURE D 17

BUILDING 200

WING M - CELL M3

SOUTH WALL

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE 00V200/CELLU37A

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

Alpha Hot Spots (dis/min)

ALL READINGS-61cm PROBE

TITLE:

FIGURE D-19
BUILDING 200

WING M - CELL M3
CELL FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE 00A200CELLM3FL

KEY

GRID = 1 SQ METER

(X) SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 1 m²

TITLE:

FIGURE D-20
BUILDING 200

WING M - CELL M3

CELL FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE 00\200\CELLM3.F5

KEY

GRID = 1 SQ METER

(X) SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 100.m²

TITLE:

FIGURE 1: 21
BUILDING 200

WING M - CELL M3

CELL FLOOR

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Gamma Reading 0.1 mP/h

FILE 002000CELLM304

LEGEND

GRID = 1 SO METER

PAC Alpha (dis/min)

(X) SMEAR LOCATION

α/βγ dis/min 100. m²

R020 (mP/h)

TITLE:

FIGURE D 23

BUILDING 200

WING M - CELL M3

OVERHEAD CRANE AND TROLLEY

ARGONNE
NATIONAL LABORATORY
ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

Figure D-24. Alpha Spectrum from Radon Gas in Cell M-3

Figure D-25. Alpha-6 Rn & Tn Activities in Cell M-3

Figure D-26. Cell M-3 Discharge

APPENDIX E Cell M-1 Figures

<p>FILE: DD\200\CELLM1</p> <p>GRID = 1 SQ METER</p> <p>KEY</p> <p> R020 (mR/h) PAC (dis/min) <small>61cm PROBE</small> </p> <p> SMEAR LOCATION 1 SQ METER </p>	<p>TITLE:</p> <p>FIGURE E-1</p> <p>BUILDING 200</p> <p>WING M - CELL M1</p>	<p> ARGONNE NATIONAL LABORATORY ANL EAST D & D FINAL RADIOLOGICAL SURVEY </p>
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FILE: DP\200\CELLM1WG KEY GRID = 1 SQ METER RO-20 GAMMA READINGS (mR/h) GAMMA HOT SPOTS (mR/h)	TITLE: FIGURE E-2 BUILDING 200 WING M - CELL M1 WEST WALL	ARGONNE NATIONAL LABORATORY ANL EAST D & D FINAL RADIOLOGICAL SURVEY
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FILE: DD\20D\CELLM1WA

KEY
GRID = 1 SQ METER

PAC Alpha (dis/min)
Alpha Hot Spots (dis/min)
ALL READINGS—61cm² PROBE

TITLE:

FIGURE E-3
BUILDING 200

WING M — CELL M1
WEST WALL

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370/ 33k	260/ 23k	470/ 42k	210/ 19k	280/ 25k	460/ 41k	4
330/ 30k	590/ 53k	390/ 35k	340/ 31k	490/ 44k	310/ 28k	3
220/ 20k	390/ 35k	230/ 21k	410/ 37k	900/ 81k	630/ 57k	2
300/ 27k	230/ 21k	770/ 69k	*400/ 36k	330/ 30k	510/ 46k	1

TRANSFER PORT
FLOOR 200/20k
TOP 28/2.5k
DOOR 55/5k
WALLS 33/3k

1 2 3 4 5 6

FILE: D01200/CELLM1WS

KEY

GRID = 1 SQ METER

(X) SMEAR LOCATION
 $\alpha/\beta\gamma$ dis/min 1 m²
* MEASURED--ALL OTHERS CALCULATED

TITLE:

FIGURE E-4
BUILDING 200

WING M - CELL M1
WEST WALL

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D & D FINAL RADIOLOGICAL SURVEY

1 2 3 4 5

FILE: DD\200\CELLM1

KEY

GRID = 1 SQ METER

R020 GAMMA READINGS (mR/h)

GAMMA HOT SPOTS (mR/h)

TITLE:

FIGURE E-5
BUILDING 200

WING M - CELL M1

NORTH WALL

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ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: DD\200\CELLM1NA

KEY
GRID = 1 SQ METER
PAC Alpha (dis/min)
ALPHA HOT SPOTS
ALL READINGS 61cm² PROBE

TITLE: FIGURE E-6
BUILDING 200
WING M - CELL M1
NORTH WALL

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D & D FINAL RADIOLOGICAL SURVEY

130/50k	130/73k	110/52k	130/44k	190/100k	4
340/66k	130/56k	220/90k	130/57k	310/51k	3
270/120k	340/180k	740/810k	310/220k	290/110k	2
130/54k	920/400k	6k/4.3M	670/500k	740/240k	1

1 2 3 4 5

FILE: DD\200\CELLM1NS

LEGEND

GRID = 1 SQ METER

○ SMEAR LOCATION
 $\alpha/\beta\gamma$ dis/min 1m²

TITLE:

FIGURE E-7

BUILDING 200

WING M - CELL M1

NORTH WALL

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ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

5 4 3 2 1

FILE: DD\200\CELLUEG
key
GRID = 1 SQ METER

R020 GAMMA READINGS (mR/h)

GAMMA HOTSPOTS (mR/h)

TITLE:

FIGURE E-8

BUILDING 200

WING M - CELL M1

EAST WALL

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E10

ALL READINGS—61cm² PROBE

BUILDING 200
WING M - CELL M1
EAST WALL

ARGONNE
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ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: DD\200\CELLS

KEY

GRID = 1 SQ METER

○ SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 1m²

* MEASURED-ALL OTHERS CALCULATED

TITLE:

FIGURE E-10
BUILDING 200

WING M - CELL M1

EAST WALL

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DOOR OVERHEAD

2.5 2.5 2.5

SW1

S2

SE1

SW1

S1

DOOR

1.5 2.5 2.5

2.5 2.0 1.5 2.0

5 4

4 3 2 1

4 3 2

FILE: DOX200/CELLM156

KEY

GRID = 1 SQ METER

R020 GAMMA READINGS (mR/h)

GAMMA HOT SPOTS

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TITLE: FIGURE E-11

BUILDING 200

WING M - CELL M1
SOUTH WALLS
AND DOOR

LOW PASS FILTERS

INSIDE DUCT #1 150k

INSIDE DUCT #2 60k

INSIDE DUCT #3 100k

FILE: DD\200\CELLM1SA

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

ALPHA HOT SPOTS

ALL READINGS-61cm² PROBE

TITLE:

FIGURE E-12

BUILDING 200

WING M - CELL M1

SOUTH WALLS

AND DOOR

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ANL EAST

D & D FINAL RADIOLOGICAL SURVEY

FILE: DD\200\CELLM1SS

KEY
GRID = 1 SQ METER

○ SMEAR LOCATION
 $\alpha/\beta\gamma$ dis/min 1m²

• MEASURED—ALL OTHERS CALCULATED

TITLE: FIGURE E-13
BUILDING 200
WING M — CELL M1
SOUTH WALLS
AND DOOR

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READINGS 1.75 METER OFF FLOOR (mR/r) 5.0

FILE: 00\200\CELLM176	KEY GRID = 1 SQ METER	TITLE: FIGURE E-14 BUILDING 200 WING M - CELL M1 CELL FLOOR	ARGONNE NATIONAL LABORATORY ANL EAST D & D FINAL RADIOLOGICAL SURVEY
R020 GAMMA READINGS (mR/h) GAMMA HOT SPOTS			

Verification Survey of
Building 200 Hot Cells
March 1996

E16

UNDER LEAD
BLANKETS >1M

FILE: 00\200\CELLM1FA

KEY

GRID = 1 SQ METER

PAC ALPHA (dis/min)

ALPHA HOT SPOTS

TITLE:

FIGURE E-15
BUILDING 200

WING M -- CELL M1

CELL FLOOR

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D & D FINAL RADIOLOGICAL SURVEY

FILE: DD\200\CELLM1FS

KEY

GRID = 1 SQ METER

○ SMEAR LOCATION

$\alpha/\beta\gamma$ dis/min 1m²

• MEASURED—ALL OTHERS CALCULATED

TITLE:

FIGURE E-16
BUILDING 200

WING M — CELL M1
CELL FLOOR

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E18

FIGURE E-17
BUILDING 200

WING M - CELL M1
CELL FLOOR PITS,
PLUGS, & RAILS

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FILE: DDV200\CELLM1FP

LEGEND

GRID = 1 SQ METER

Δ PAC ALPHA (dis/min) $\otimes$ SMEAR LOCATION

β R020 (mR/h) $\beta\gamma$ dis/min Large Area

FILE: DD\200\CELLM10H

KEY

GRID = 1 SQ METER

PAC Alpha (dis/min)

RO20 (mR/h)

TITLE:

FIGURE E-18

BUILDING 200

WING M - CELL M1

OVERHEAD CRANE AND TROLLEY

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1 2 3 4 5

	①	②	③	④	⑤	⑥
	0.1 mR/h	0.1 mR/h	0.1 mR/h	0.1 mR/h	0.1 mR/h	0.1 mR/h

FLOOR

4

3

2

1

FLOOR DIRECTS TAKEN
WITH NE
ALL READINGS/dis min

- ① 170 α
6500 $\beta\gamma$
- ② 100 α
12k $\beta\gamma$
- ③ 270 α
110k $\beta\gamma$
- ④ 420 α
390k $\beta\gamma$
- ⑤ 170 α
68k $\beta\gamma$
- ⑥ 340 α
26k $\beta\gamma$

FILE: DD\200\CLM10T

KEY
GRID = 1 SQ METER

ELECTRA NE (dis/min)

R020 GAMMA READINGS (mR/h)

TITLE:

FIGURE-19
BUILDING 200
WING M - CELL M1
NORTH WALL-OUT SIDE

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Figure E-20. Alpha Spectrum from Radon Gas in Cell M-1

Figure E-21. Alpha-6 Rn & Tn Activities in Cell M-1

Figure E-22. Cell M-1 Discharge

Distribution for ANL/ESH-HP-96/02

T. DiSanto (CMT)
J. W. Emery (CMT)
L. D. Hafenrichter (CMT)
J. C. Hoh (CMT)
M. Surchik (CMT)

T. T. Anderson (RE)
R. H. Gebner (RE)
A. E. Wright (RE)

D. M. Nelson (ESH-DA)
T. Branch (HP)
N. L. Contos (HP)
J. Erick (HP)
D. C. Geraghty (HP)
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M. A. Sreniawski (HP)
R. Walker (HP)
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S. L. Santarelli (EWM)
M. A. Sodaro (EWM)

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F. A. Cafasso (CHM) - 3
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L. R. Morss (CHM)
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V. K. Steed (CHM)
A. C. Youngs (CHM)

H. I. Avci (EA)

C. L. Cheever (TD)
R. W. Rose (TD) - 6

R. W. Fergus (ECT)
J. E. Miranda, Jr (ECT)