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Grand Junction Projects Office
Remedial Action Project

Feasibility Test of Real-Time Radiation Monitoring During Removal of Surface Contamination From Concrete Floors

October 1995

U.S. Department of Energy
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DISCLAIMER

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Feasibility Test of Real-Time Radiation Monitoring During Removal of Surface Contamination From Concrete Floors

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Executive Summary

This feasibility test was conducted to determine if real-time radiation-monitoring instruments could be mounted on decontamination machines during remediation activities to provide useful and immediate feedback to equipment operators. The U.S. Department of Energy (DOE) sponsored this field test under the Grand Junction Projects Office Remedial Action Project (GJPORAP) to identify a more efficient method to remove radiological contamination from concrete floor surfaces. This test demonstrated that project durations and costs may be reduced by combining radiation-monitoring equipment with decontamination machines. The test also demonstrated that a microprocessor-based instrument such as a radiation monitor can withstand the type of vibration that is characteristic of floor scabblers with no apparent damage.

Combining radiation-monitoring equipment with a decontamination machine reduces the time and costs required to decontaminate concrete surfaces. These time and cost savings result from the reduction in the number of interim radiological surveys that must be conducted to complete remediation. Real-time radiation monitoring allows equipment operators to accurately monitor contamination during the decontamination process without support from radiological technicians, which also reduces the project duration and costs.

The DOE Grand Junction Projects Office recommends more extensive and rigorous testing of this real-time radiation monitoring to include a variety of surfaces and decontamination machines. As opportunities arise, additional testing will be conducted under GJPORAP.

1.0 Introduction

The U.S. Department of Energy (DOE) sponsored a feasibility test under the Grand Junction Projects Office Remedial Action Project (GJPORAP) to determine if real-time radiation detectors and monitors could be mounted on decontamination machines during remediation activities. The objective of this test was to demonstrate that real-time radiation monitoring could reduce the time and costs required to decontaminate radiologically contaminated concrete surfaces. The feasibility test was conducted from July 18 to July 28, 1995, in conjunction with the remediation of two small contaminated floor areas in Building 20 and Building 28 at the DOE Grand Junction Projects Office (GJPO).

2.0 Background

DOE–GJPO personnel developed the concept of combining readily available decontamination machines with off-the-shelf radiation-monitoring instruments to reduce project durations and costs. This concept was tested on two small floor areas in Building 20 and Building 28 that required remediation under GJPORAP.

Building 20 and Building 28 were both constructed in the 1950s to support government purchases of uranium ore and concentrate. Building 20 is currently being used as a chemistry laboratory supporting extensive radiochemistry. Although Building 28 currently houses offices, a maintenance shop, and a warehouse, this building was formerly used for washing and maintaining equipment that transported and processed the uranium ore. The concrete floor surfaces were contaminated by radioactive-material spills. The contaminated areas tested in Building 20 and Building 28 were approximately 3 square meters (m^2) and 1.5 m^2, respectively.

Remediation typically involves multiple surveys to identify and to verify the removal of contamination. A survey is initially performed to characterize and delineate contamination, radiological workers remove the identified material, technicians resurvey the area to delineate any remaining contamination, workers remove the additional material, and so on, until the contamination has been removed to specified levels. The process requires the extensive use of equipment and labor because workers visit the same areas repeatedly, and one group of workers frequently stands by while the other group works. In addition to being expensive, these multiple cycles increase the risk of worker exposure to contaminants and industrial hazards.

A feasibility test of the real-time radiation monitoring concept was planned to determine if survey cycles could be reduced by installing radiation-monitoring instruments directly on a decontamination machine. This combination was intended to allow the decontamination-equipment operator to accurately monitor remaining contamination while performing decontamination work, thus minimizing the time and costs required to decontaminate concrete surfaces by reducing the

- Interruptions of decontamination work for surveying purposes.
- Visits to previously decontaminated areas to remediate contamination that did not meet cleanup criteria.
- Overremediation of surfaces to avoid missing contamination.
- Use of personal protective equipment.
- Worker exposure to contaminants and industrial hazards.

A small-scale test was developed to address several important issues associated with the installation of radiation detectors and monitors on decontamination machines. The questions that were raised include:

- Can off-the-shelf radiation-monitoring instruments withstand the vibration, dust, and debris that are associated with equipment typically used for decontamination of concrete surfaces?

- Can a typical radiation worker read a radiation monitor while operating a decontamination machine and use this information effectively?
- Can radiation-monitoring instruments installed on decontamination machines provide accurate measurements to enable the efficient decontamination of concrete surfaces?

These questions were addressed by inspecting the radiation-monitoring instruments before and after decontamination of the concrete floor surfaces, by observing the equipment operators during decontamination activities, and by measuring the radioactivity of the floor areas before and after decontamination.

3.0 Scope of Work Summary

The scope of the feasibility test included the following activities:

- **Identifying cleanup criteria**—Cleanup criteria were derived from DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*
- **Procuring necessary equipment**—Personnel from the DOE–GJPO Environmental Instrumentation Laboratory (EIL) and GJPORAP selected and procured radiation-monitoring instruments and a decontamination machine.
- **Preparing equipment**—EIL personnel designed and fabricated fixtures for installing the radiation-monitoring instruments on the decontamination machine.
- **Baseline surveying**—EIL personnel performed baseline surveys to measure and map the radiation on the contaminated floor areas before decontamination.
- **Decontaminating floor areas**—The equipment operator used both the digital and analog displays on the radiation monitor to guide decontamination activities. The ease with which the operator read the instrument display and maneuvered the decontamination machine were observed.
- **Resurveying and measuring residual radioactivity**—Posttest measurements were taken and compared with baseline measurements to determine if real-time radiation monitoring was effective in guiding the decontamination work. Posttest measurements were also compared with cleanup criteria to ensure that decontaminated areas were remediated to applicable cleanup levels.

4.0 Pretest Activities

Several pretest activities were conducted before the feasibility test could begin. These activities included equipment selection and preparation, instrument calibration, performance of baseline surveys, and identification of applicable cleanup criteria.

4.1 Equipment Selection

4.1.1 Decontamination Machine

The decontamination machine that was selected had to be small enough for one person to operate and large enough for both a radiation detector and a radiation monitor to be mounted on it. A decontamination machine that can accommodate a continuous, high efficiency particulate air (HEPA) vacuum was preferable because of the potential for airborne hazards during remediation. GJPORAP program management also required that the machine be useful for performing general remediation work at DOE–GJPO that is not associated with testing of real-time radiation monitoring. A pneumatically operated Pentek Squirrel-III scabbler (Pentek 1995) (Figure 1) was selected for the feasibility test because this scabbler meets all applicable criteria and is compatible with Pentek equipment currently in use at DOE–GJPO. It removes (scabbles) contamination using three pistons that repeatedly strike the surface.

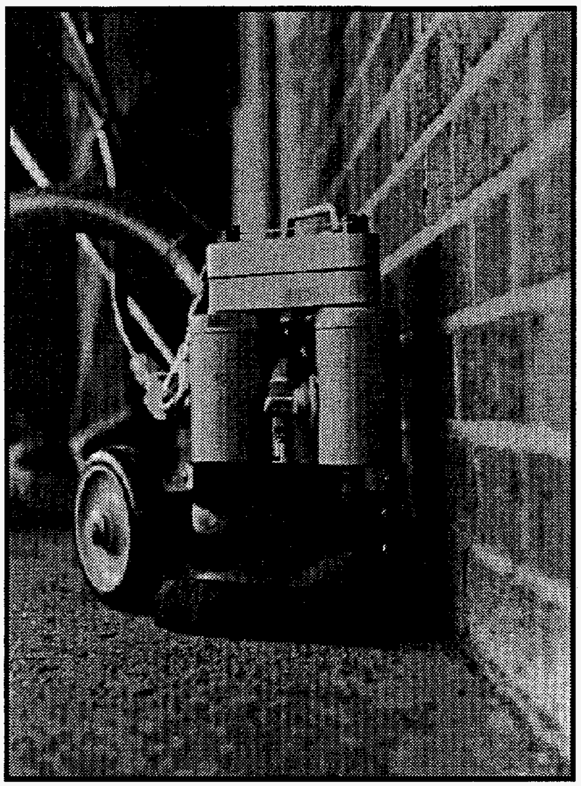

Figure 1. Pentek Squirrel-III Scabbler

4.1.2 Radiation Detector

An Eberline Model SHP–100 gas-proportional radiation detector (Eberline 1994) (Figure 2) was selected for installation on the scabbler because it detects alpha, beta, and gamma radiation; has a continuous gas flow that allows the detector to operate even if the detection window is punctured; has a 100-square-centimeter (cm^2) detection window that provides good counting statistics; and is currently available at DOE–GJPO. The dimensions of the detector are approximately 17 by 12 by 7 centimeters (cm). The detection window consists of 0.96-milligram (mg)-per-square centimeter aluminized Mylar, the counting gas is P–10 (10-percent methane and 90-percent argon), the 4π cesium-137 (Cs-137) efficiency is 19 percent for 100-cm^2 sources at approximately 1 cm, and the background gamma sensitivity for Cs-137 is 25,000 counts per minute (cpm) per milliroentgen per hour.

4.1.3 Radiation Monitor

An Eberline Model E–600 radiation monitor (Eberline 1994) (Figure 3) was selected for installation on the scabbler because this monitor performs the functions of a variety of other portable instruments; supports a wide range of radiation detectors, including the Eberline Model SHP–100; and displays radioactivity levels in many measurement units and formats. The Eberline Model E–600 can also be configured to store data and to match the skills of operators with varying levels of experience. Additional features that made this radiation monitor suitable for this test are its analog and digital displays; easy configuration; simultaneous counting of alpha, beta-gamma, and total activity; radiation-measurement displays with or without background; and automatic setup with Eberline smart probes.

4.1.4 Floor Monitor

A Ludlum Model 239–1F floor monitor was selected to perform pretest and posttest surveys of the contaminated floor areas. This floor monitor was selected because it is currently available at DOE–GJPO and because its 425-cm^2 window provides good counting statistics and complete and efficient surveys of the contaminated floor areas.

4.1.5 High Efficiency Particulate Air Vacuum

A Pentek Vak-Pac Model 9A HEPA vacuum (Pentek 1992) was selected because it is currently available at DOE–GJPO. In conjunction with the scabbler, the vacuum effectively captures dust from the scabbling operation and deposits it in a holding drum.

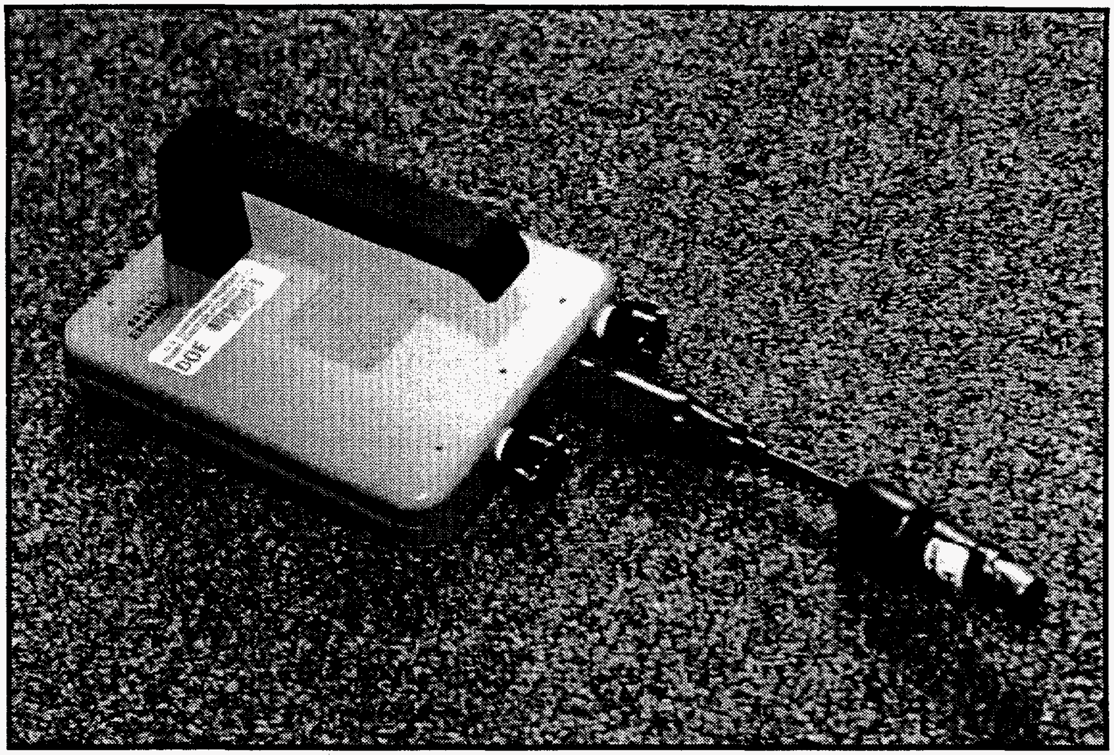

Figure 2. Eberline Model SHP–100 Gas-Proportional Radiation Detector

Figure 3. Eberline Model E–600 Radiation Monitor

4.2 Equipment Preparation and Assembly

Housings and attachment assemblies were designed and fabricated to attach the radiation detector and radiation monitor to the scabbler. The scabbler has three scabbling heads located within a plastic-broom skirt. There is no room for conventional detectors inside the skirt; therefore, the radiation detector had to be attached behind the scabbler with a housing assembly designed and fabricated (1) to keep the detector parallel to the floor and a fixed distance behind the scabbler, (2) to enable unrestricted movement of the scabbler, and (3) to minimize the vibrations transmitted from the scabbler to the detector. The housing was fabricated from a piece of plastic approximately 25 by 18 by 4 cm. Soft rubber cushions were installed within the milled cavity of the housing to dampen the vibrations generated by the scabbler. A brush assembly was mounted around the perimeter of the housing to keep the detector within 0.6 cm of the floor, further reducing vibrations and preventing debris from damaging the window of the detector (Figure 4). A similar housing was designed and fabricated to secure the radiation monitor to the handle of the scabbler and to protect it from vibration. The radiation detector and the radiation monitor were then installed on the scabbler (Figure 5 and Figure 6).

4.3 Instrument Calibration

EIL personnel calibrated the Ludlum floor monitor and Eberline radiation detector for alpha radiation using 100 cm^2 sources of thorium-230; both instruments were calibrated for beta radiation using 100 cm^2 sources of technetium-99. The Eberline radiation monitor was calibrated by the manufacturer. All calibrations were checked before collecting data.

4.4 Baseline Surveys

Pretest surveys were performed in the contaminated areas to establish baselines for comparison with posttest conditions. The floor monitor was used to measure and map the alpha and beta-gamma activity of both contaminated floor areas. The Building 20 and Building 28 floor areas were divided into 13- by 43-cm and 8- by 23-cm grid cells, respectively, and 1-minute counts were performed. Cell locations and cpm instrument readings were recorded for later use (Appendix A). Beta-gamma activity in

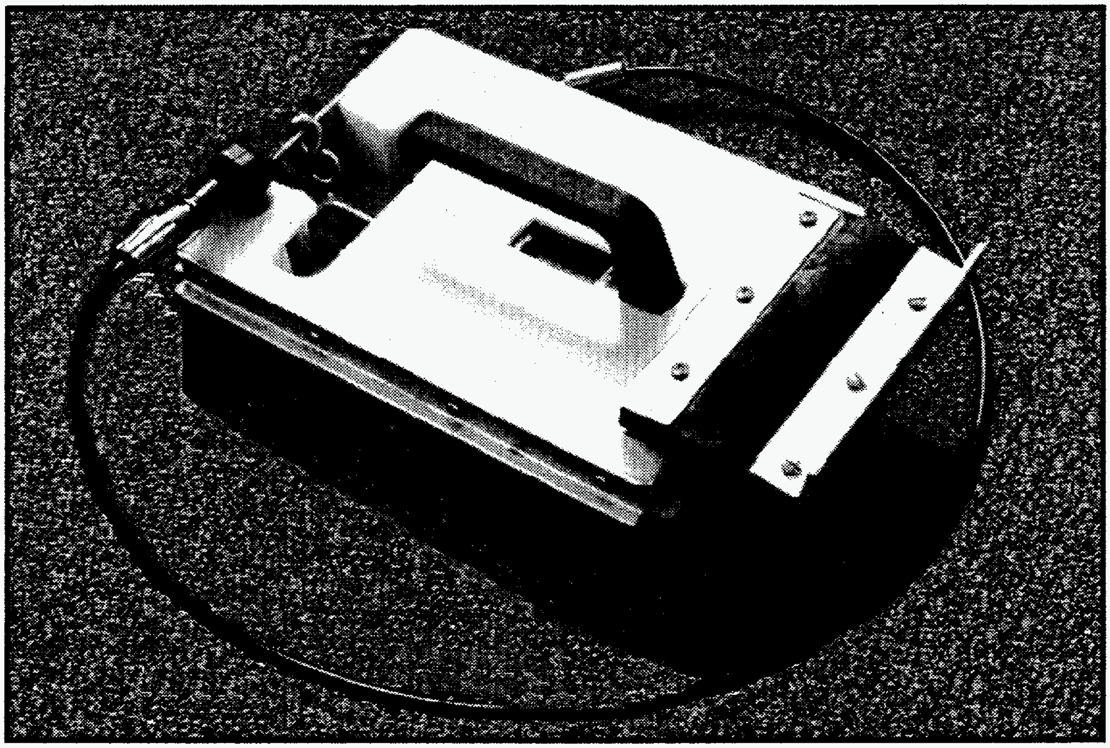

Figure 4. Eberline Model SHP–100 Radiation Detector Mounted in Plastic Housing

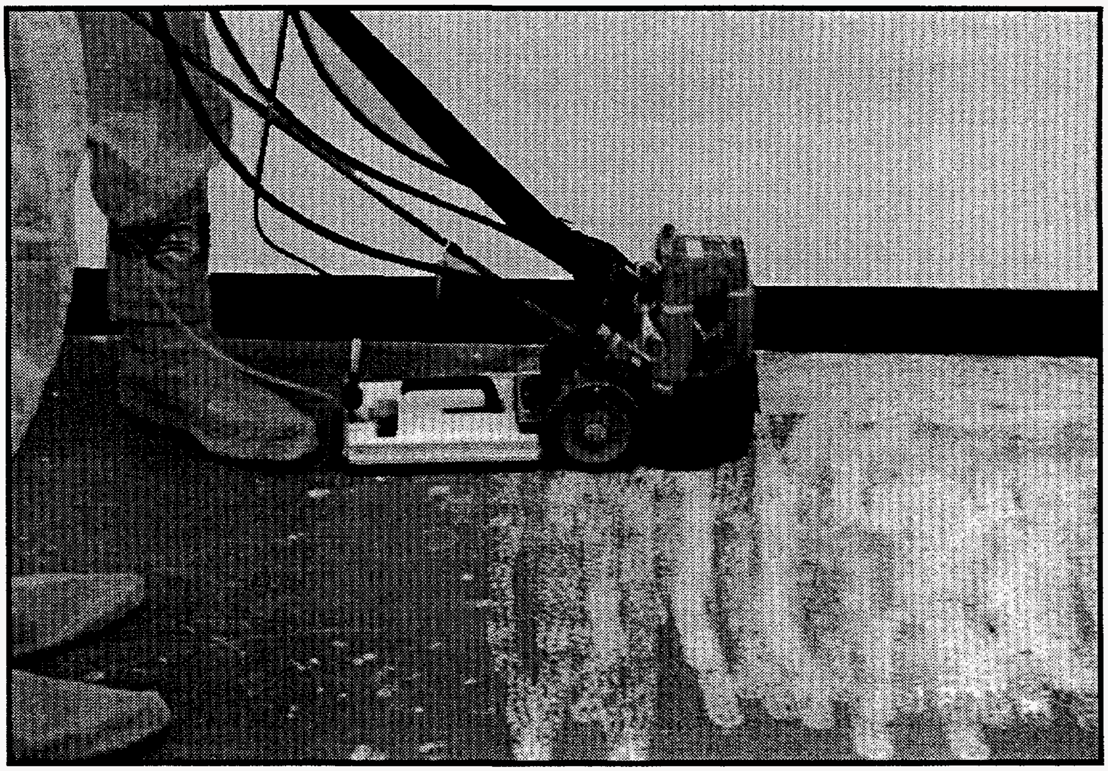

Figure 5. Eberline Model SHP–100 Radiation Detector Installed on Squirrel-III Scabbler

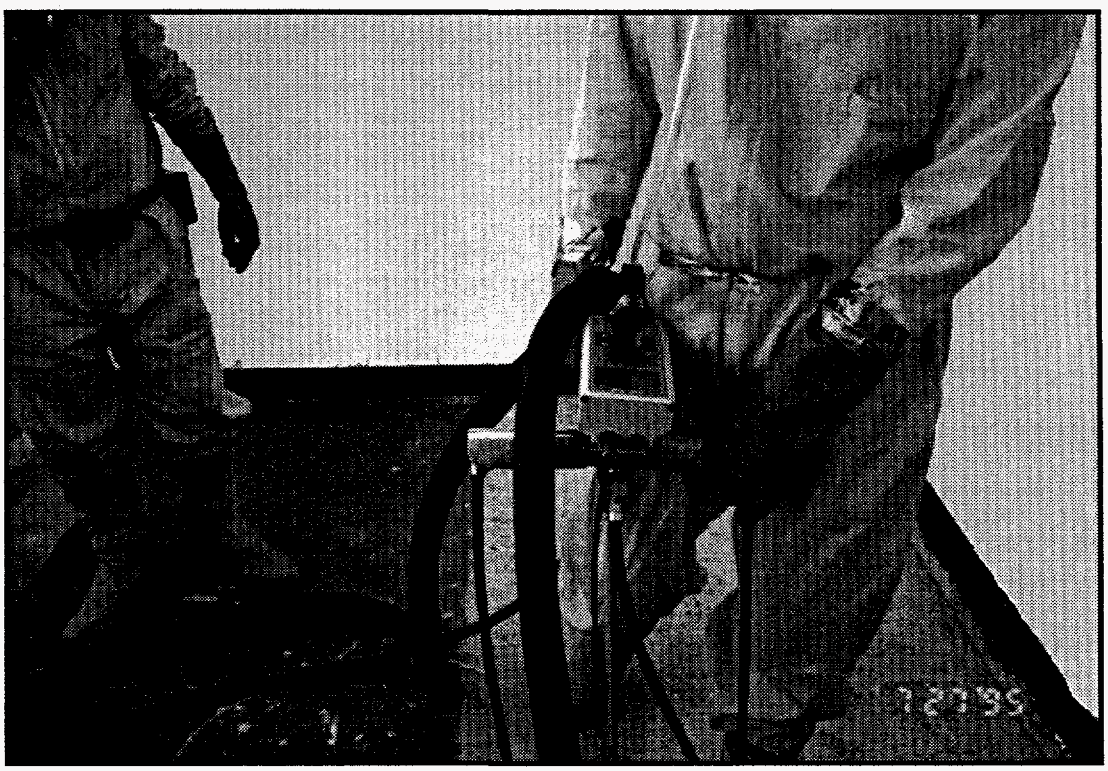

Figure 6. Eberline Model E–600 Radiation Monitor Installed on Squirrel-III Scabbler

disintegrations per minute (dpm) per 100 cm^2 was calculated using a conversion factor of 1 cpm per 0.84 dpm/100 cm^2.

4.5 Cleanup Guidelines

The goal for this project was to reduce all radioactivity in the contaminated floor areas to background. If this goal was not practical (e.g., excessive concrete removal), then cleanup guidelines for loose surface contamination (DOE Order 5400.5, Figure IV–1) would be applied to reduce the levels of radioactivity to as low as reasonably achievable. DOE guidelines were applied because decontaminated surface areas must meet these criteria before the areas can be released from marking, monitoring, and maintenance requirements. DOE guidelines specify that loose surface contamination cannot exceed background by more than 1,000 dpm/100 cm^2 of alpha or beta-gamma radiation, when averaged over 1 m^2 or less.

5.0 Test Procedure

The radiation-monitoring and decontamination equipment was transported to the work site and assembled. Inspections were performed to ensure that each piece of equipment was operational. The radiation detector was connected to a regulated P–10 gas supply using approximately 30 meters of Tygon tubing and was purged for more than an hour at a flow rate of 50 cubic centimeters of gas per minute.

Control areas were established, work barriers were erected, and radiation work permits and safe work permits were posted. Background levels of alpha and beta-gamma radiation were measured in areas adjacent to the contaminated floor areas.

The work plan was reviewed with all personnel involved in the project. Equipment operators were briefed on how to operate the equipment and on the hazards associated with the work to familiarize the operators with the proper use of combined radiation-monitoring and decontamination equipment. Equipment operators were required to wear modified Level D personal protective equipment because of the radiological hazards associated with decontaminating the concrete floor surfaces. Operators were also required to wear respirators because of potential dust hazards.

The concrete floor area in Building 20 was decontaminated inside a plastic enclosure to prevent contamination of the analytical laboratories housed in the building. The floor areas in both Building 20 and Building 28 were decontaminated by moving the scabbler back and forth over the contaminated areas until the display on the radiation monitor indicated residual radioactivity had been reduced to levels at or below 1,000 dpm/100 cm^2 above background. The back-and-forth motion was necessary to position the radiation detector over the scabbled areas and to prevent the scabbler from hammering grooves in the concrete floor.

During the decontamination activities, the radiation detector and monitor were inspected for loosening attachments, accumulations of dust, and overall operability. In addition, the scabbler operator was observed for any problems encountered while operating the machine or reading the radiation-monitor display.

The total time spent decontaminating both floors was approximately 5 hours. Following decontamination, the floor monitor was used to survey both surface areas for residual contamination.

6.0 Results

6.1 Instrument Survivability

The radiation monitor and radiation detector showed no evidence of physical damage or loosening of parts during the tests. Posttest calibration values were within 10 percent of the pretest values. The scabbler produced no visible dust or debris during operation.

6.2 Operator Efficiency

Because the scabbler operator had difficulty interpreting the analog and digital displays on the radiation monitor, a more experienced observer interpreted the displays. The displays were difficult for the operator to interpret because the instrument readings varied frequently with the natural statistical variation of the radioactivity being measured. The operator also reported that the radiation detector trailing behind the scabbler made the scabbler slightly awkward to maneuver. Despite these problems, it was never necessary to interrupt the work for radiological technicians to resurvey and mark contamination that was missed. With additional experience using the test equipment, the operator would have fewer or no problems.

6.3 Comparability of Measurements

Before performing decontamination activities, three background beta-gamma measurements were taken adjacent to the contaminated floor area in Building 28 with the instruments mounted on the scabbler. These measurements were taken to identify the extent to which radiation-detector and radiation-monitor readings would be affected by operating the scabbler. The two measurements taken when the scabbler was not in operation were 1,588 dpm/100 cm^2 and 1,532 dpm/100 cm^2. The measurement taken when the scabbler was operating was 1,659 dpm/100 cm^2, which was within 5 to 9 percent of the measurements taken when the machine was not in operation.

The background measurement taken in Building 28 with the radiation-monitoring equipment when the scabbler was operating was also in agreement with the measurement taken with the floor monitor; these measurements were 1,659 dpm/100 cm^2 and 1,650 dpm/100 cm^2, respectively, which reflect a 1-percent variation. Similarly, the background measurement taken in Building 20 when the scabbler was operating was within 2 percent of the background measurement taken with the floor monitor; these measurements were 1,507 dpm/100 cm^2 and 1,487 dpm/100 cm^2, respectively.

6.4 Effectiveness of Decontamination

The modified scabbler was successful in decontaminating both floor areas. Radiation levels were reduced to or below DOE guideline levels in all areas accessible to the machine (see Appendix A). Inaccessible areas consisted of a floor crack in Building 20 and a 2-inch-wide strip along the walls in both buildings.

The maximum beta-gamma activity that was measured with the Ludlum monitor before decontaminating the floor area in Building 20 was 61,421 dpm/100 cm^2, which included 1,487 dpm/100 cm^2 of background activity. Of the 72 grid cells that constitute this contaminated area, the maximum beta-gamma activity in 39 cells (54 percent) exceeded the DOE guideline for loose surface contamination; activity in 69 cells (96 percent) exceeded background activity. After decontamination, the activity in 71 cells (99 percent) was reduced to below the DOE guideline and activity in 18 cells (25 percent) was reduced to background levels (Figure 7 and Figure 8). Beta-gamma activity in one grid cell exceeded the DOE guideline after decontamination, measuring 2,500 dpm/100 cm^2 (1,013 dpm/100 cm^2 above background); this contamination was in a floor crack and had to be removed with hand tools.

The maximum beta-gamma activity that was measured with the Ludlum monitor before decontaminating the floor area in Building 28 was 2,919 dpm/100 cm^2, which included 1,650 dpm/100 cm^2 of background activity. Of the 91 grid cells that constitute this contaminated area, only 1 cell (1 percent) exceeded the DOE guideline for loose surface contamination; 76 cells (84 percent) exceeded background activity. After decontamination, no cells exceeded the DOE guideline, and the activity in 34 cells (37 percent) was reduced to background levels (Figure 9 and Figure 10).

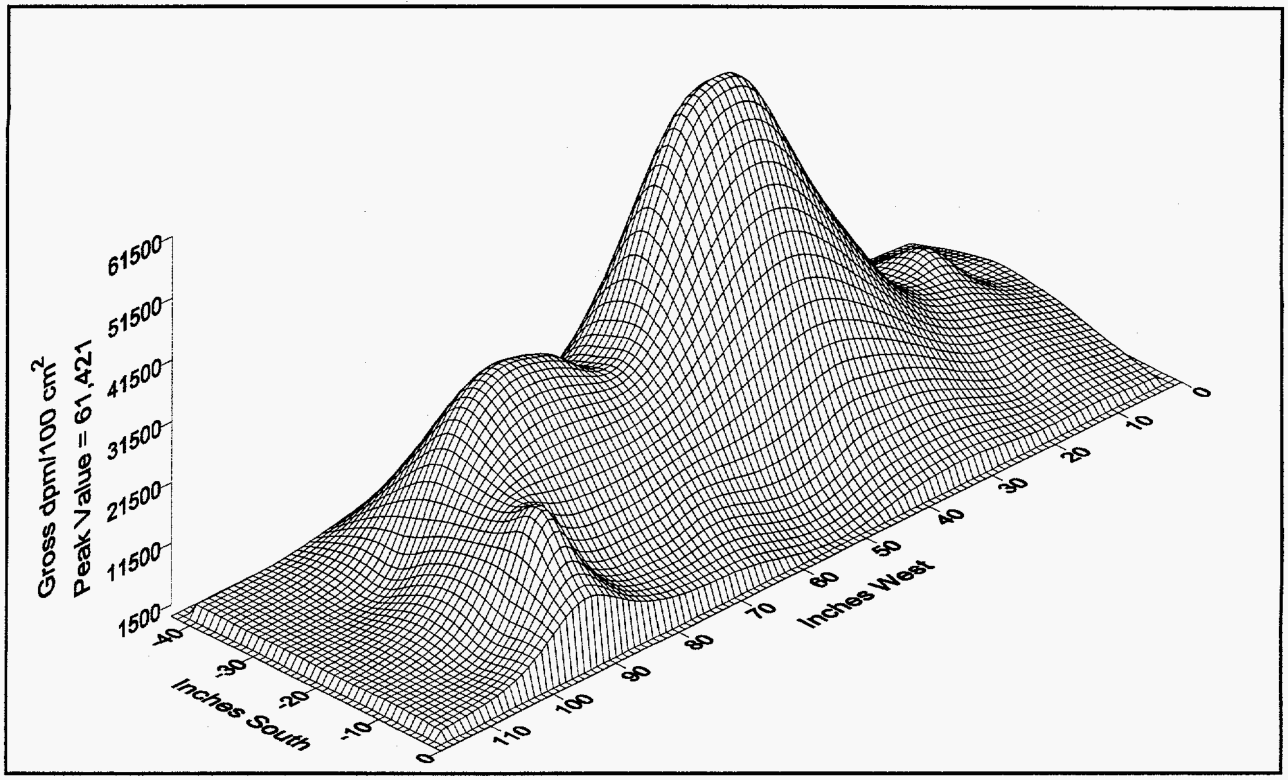

Figure 7. Building 20 Beta-Gamma Survey Before Decontamination

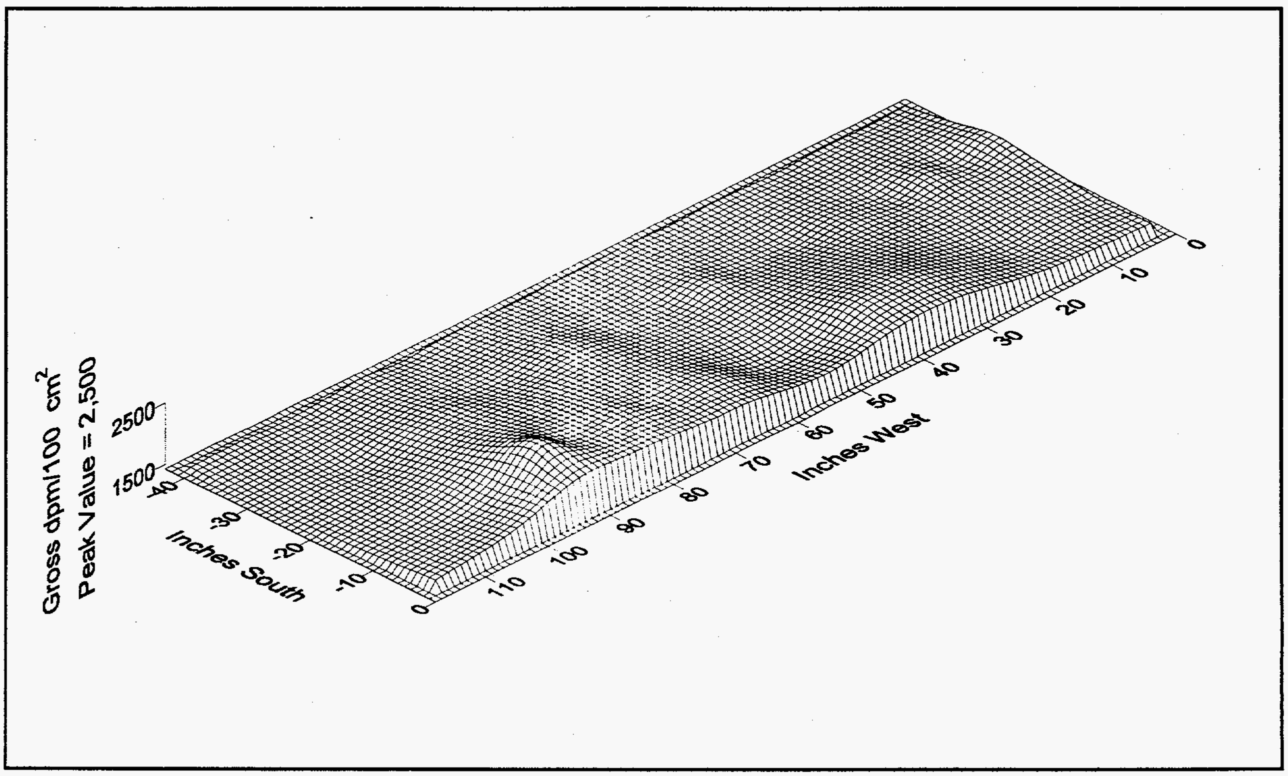

Figure 8. Building 20 Beta-Gamma Survey After Decontamination

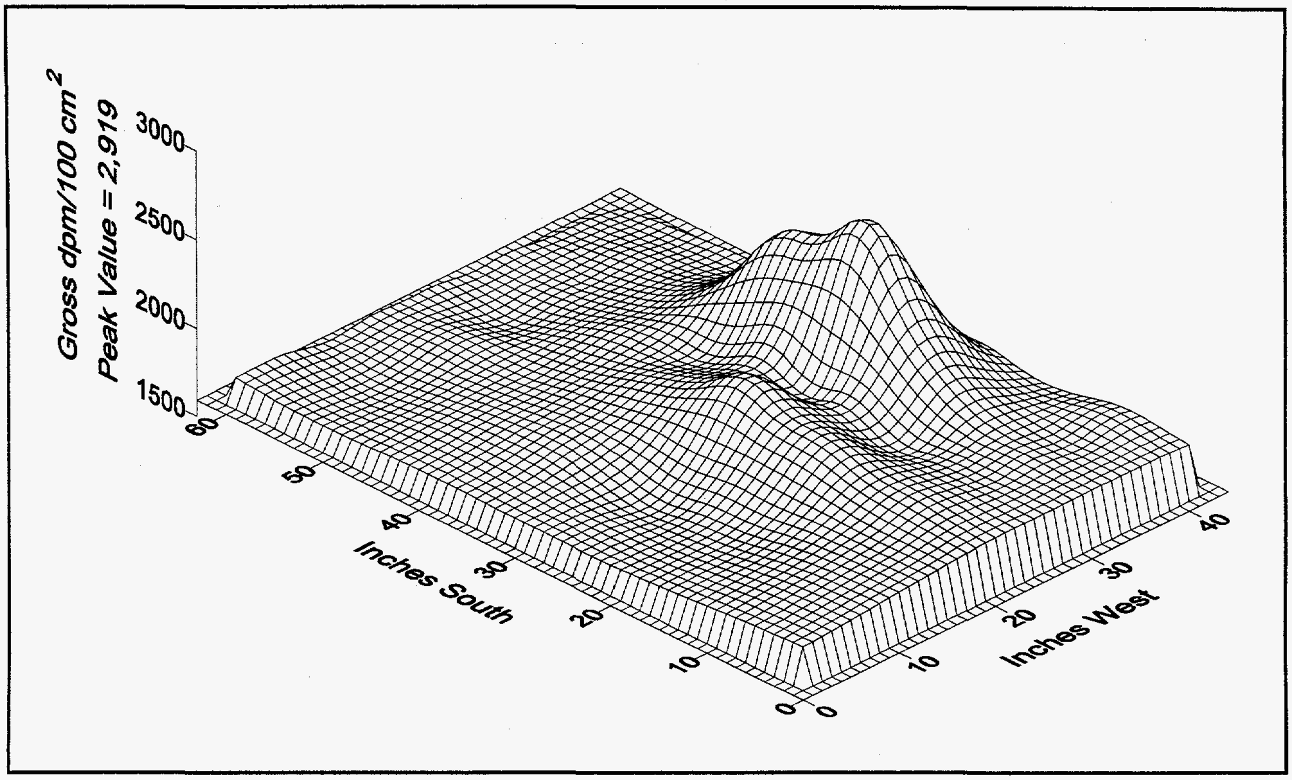

Figure 9. Building 28 Beta-Gamma Survey Before Decontamination

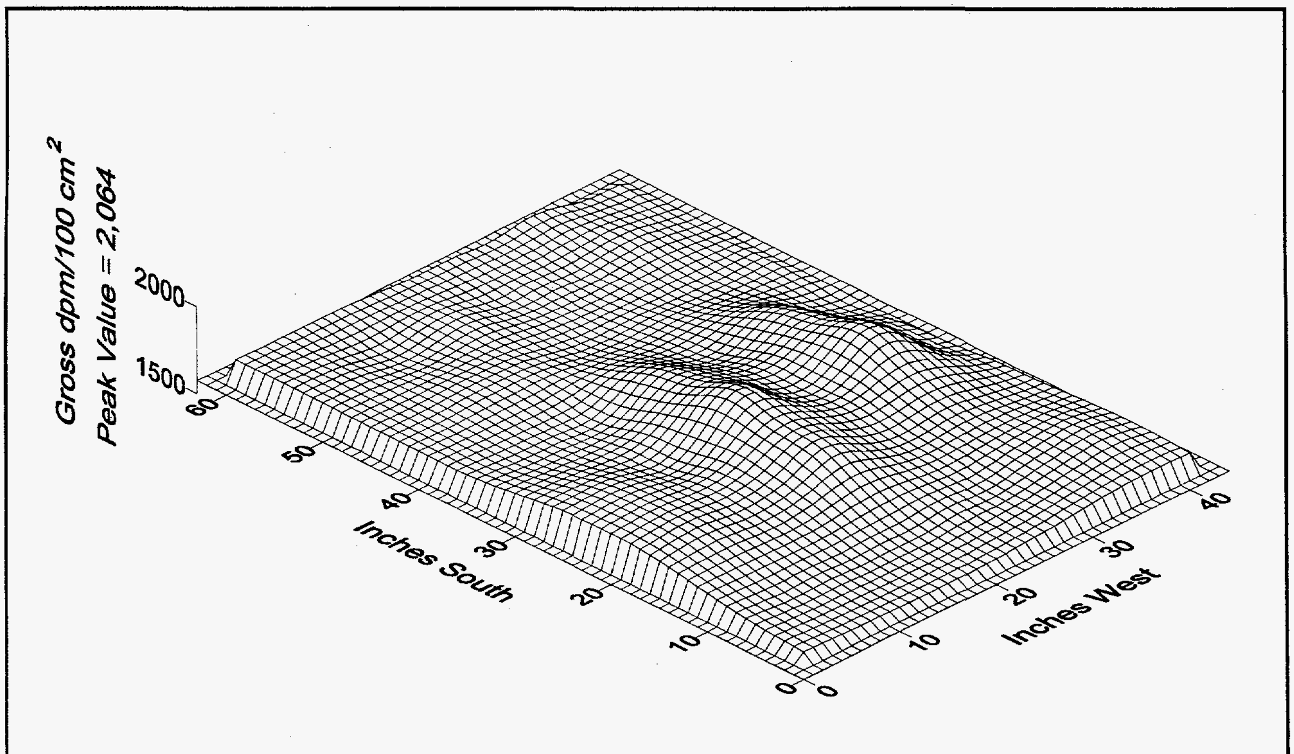

Figure 10. Building 28 Beta-Gamma Survey After Decontamination

7.0 Summary

Two contaminated concrete floor areas totaling approximately 5 m^2 were decontaminated using a scabbler equipped with a radiation detector and radiation monitor. This equipment was operated for approximately 5 hours without any equipment failures.

Two problems were observed during decontamination activities. The scabbler operator had trouble interpreting the analog and digital displays on the radiation monitor because these displays varied with the natural statistical variation of the radiation being measured. The operator found it difficult to decide which value to compare to the cleanup guidelines. Because there was not enough time to modify the monitor displays, a more experienced observer interpreted the displays for the operator. The operator also found the scabbler somewhat awkward to maneuver, which he attributed to the radiation detector that trailed approximately 20 cm behind the scabbler. Loss of maneuverability may also have resulted from less-than-optimum airflow and air pressure to the scabbler. Both of these problems could be corrected easily.

Total beta-gamma contamination was reduced in Building 20 from a maximum value of 61,421 dpm/100 cm^2 to 2,500 dpm/100 cm^2. Total beta-gamma contamination was reduced in Building 28 from a maximum value of 2,919 dpm/100 cm^2 to 2,064 dpm/100 cm^2. With the exception of the areas that were inaccessible to the scabbler, the contamination in both of the concrete floor areas was reduced to levels below the DOE cleanup guideline of 1,000 dpm/100 cm^2 above background and most areas were reduced to background levels. The radiation-monitoring instruments installed on the scabbler proved sufficient for detecting and removing the surface contamination in the test areas and no interruptions of the work were necessary for technicians to resurvey and delineate residual contamination. Therefore, this monitoring approach is considered feasible for large-scale, routine decontamination activities.

8.0 Recommendations

A follow-on test should be performed on two large, identically contaminated areas. One area should be designated as the control area and decontaminated using a machine without a radiation monitor, as is the current practice; the other area should be designated as the test area and decontaminated using a machine equipped with a radiation detector and radiation monitor. The control area would provide a baseline for making rigorous and objective comparisons of performance such as the number of interruptions required to decontaminate each area. Performing tests on large areas would also normalize testing conditions such as equipment start-ups, remediation along walls, and varying surface characteristics and levels of radioactivity.

Before conducting the follow-on test, the problems with interpreting the instrument displays and maneuvering the scabbler should be addressed. An audible tone might be used instead of visual displays to indicate when residual contamination is below the cleanup guidelines. The operator could then focus solely on operating the decontamination machine. To improve the scabbler's maneuverability, the radiation detector could be moved closer to the scabbler and the airflow and air pressure to the scabbler could be increased.

This real-time monitoring approach should also be tested on a variety of floor, wall, and ceiling surfaces with a variety of mechanical and other (e.g., laser-based) decontamination machines.

9.0 References

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__________, 1995. *Operating and Maintenance Manual for the Pentek Squirrel-III*, 1026 Fourth Avenue, Corapolis, Pennsylvania 15108-1659 ([412] 262–0725), April.

Appendix A
Survey Data

Table A–1. Building 20 Data From Radiological Survey Before Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
3	-9	65	2784	2352
8	-9	61	4287	3621
13	-9	110	5900	4984
18	-9	69	3854	3255
23	-9	114	6442	5442
28	-9	175	9609	8117
33	-9	206	11718	9898
38	-9	195	11714	9895
43	-9	202	12446	10513
48	-9	176	8603	7267
53	-9	117	6866	5800
58	-9	146	7776	6568
63	-9	191	10556	8917
68	-9	203	11794	9962
73	-9	161	8764	7403
78	-9	162	8948	7558
83	-9	169	8817	7448
88	-9	230	11743	9919
93	-9	541	32600	27537
98	-9	139	8486	7168
103	-9	51	2055	1736
108	-9	36	1833	1548
113	-9	29	1732	1463
118	-9	30	1771	1496
3	-26	140	8158	6891
8	-26	118	6631	5601
13	-26	348	19912	16820
18	-26	275	15086	12743
23	-26	268	15079	12737
28	-26	464	30748	25973
33	-26	751	39963	33757
38	-26	1013	55204	46631
43	-26	1287	71470	60371
48	-26	1246	72713	61421
53	-26	1327	70664	59690
58	-26	946	54250	45825
63	-26	558	31099	26270
68	-26	444	25944	21915
73	-26	585	34187	28878
78	-26	662	36439	30780
83	-26	704	38037	32130
88	-26	637	33442	28249

Table A–1 (continued). Building 20 Data From Radiological Survey Before Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
93	-26	366	21274	17970
98	-26	94	4025	3400
103	-26	38	1816	1534
108	-26	42	1798	1519
113	-26	29	1715	1449
118	-26	46	1765	1491
3	-43	31	1828	1544
8	-43	45	1906	1610
13	-43	39	1977	1670
18	-43	50	2032	1716
23	-43	45	1882	1590
28	-43	50	1974	1667
33	-43	50	1992	1683
38	-43	43	1962	1657
43	-43	57	2034	1718
48	-43	49	2090	1765
53	-43	45	1956	1652
58	-43	53	2033	1717
63	-43	45	1949	1646
68	-43	52	1978	1671
73	-43	57	1972	1666
78	-43	46	2012	1700
83	-43	40	1925	1626
88	-43	40	1946	1644
93	-43	36	1872	1581
98	-43	38	1887	1594
103	-43	43	1865	1575
108	-43	48	1753	1481
113	-43	54	1761	1488

Table A–2. Building 20 Data From Radiological Survey After Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
3	-9	49	1830	1546
8	-9	53	1944	1642
13	-9	59	1918	1620
18	-9	42	1865	1575
23	-9	58	2018	1705
28	-9	60	2218	1874
33	-9	63	2404	2031
38	-9	80	2399	2026
43	-9	57	2433	2055
48	-9	48	2015	1702
53	-9	43	1931	1631
58	-9	36	1955	1651
63	-9	56	2312	1953
68	-9	50	2337	1974
73	-9	44	2239	1891
78	-9	69	2450	2070
83	-9	79	2379	2010
88	-9	60	2363	1996
93	-9	63	2960	2500
98	-9	55	2143	1810
103	-9	50	1935	1635
108	-9	44	1875	1584
113	-9	42	1836	1551
118	-9	28	1766	1492
3	-26	48	2163	1827
8	-26	38	1801	1521
13	-26	57	2106	1779
18	-26	52	1788	1510
23	-26	32	1920	1622
28	-26	41	1967	1662
33	-26	46	1798	1519
38	-26	38	1860	1571
43	-26	50	1872	1581
48	-26	51	2111	1783
53	-26	42	1839	1553
58	-26	32	1913	1616
63	-26	41	1900	1605
68	-26	37	2136	1804
73	-26	52	2146	1813
78	-26	49	1975	1668
83	-26	45	1972	1666
88	-26	57	2066	1745

Table A–2 (continued). Building 20 Data From Radiological Survey After Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
93	-26	50	2068	1747
98	-26	51	1841	1555
103	-26	34	1678	1417
108	-26	42	1763	1489
113	-26	39	1685	1423
118	-26	45	1694	1431
-9	-43	47	1752	1480
8	-43	37	1736	1466
13	-43	41	1759	1486
18	-43	38	1763	1489
23	-43	50	1713	1447
28	-43	50	1761	1488
33	-43	40	1800	1520
38	-43	40	1741	1471
43	-43	47	1781	1504
48	-43	39	1814	1532
53	-43	43	1743	1472
58	-43	45	1806	1526
63	-43	34	1738	1468
68	-43	33	1783	1506
73	-43	46	1763	1489
78	-43	42	1760	1487
83	-43	36	1664	1406
88	-43	42	1835	1550
93	-43	51	1718	1451
98	-43	41	1715	1449
103	-43	33	1699	1435
108	-43	46	1751	1479
113	-43	37	1735	1466
118	-43	38	1724	1456

Table A–3. Building 28 Data From Radiological Survey Before Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
8	9	59	2127	1797
11	9	51	2139	1807
14	9	38	2179	1841
17	9	57	2157	1822
20	9	50	2297	1940
23	9	55	2256	1906
26	9	41	2221	1876
29	9	55	2179	1841
32	9	55	2291	1935
35	9	43	2167	1830
38	9	50	2221	1876
41	9	63	2306	1948
44	9	46	2175	1837
8	18	42	2045	1727
11	18	45	2018	1705
14	18	44	2085	1761
17	18	51	2228	1882
20	18	63	2454	2073
23	18	45	2362	1995
26	18	52	2113	1785
29	18	43	2104	1777
32	18	45	2397	2025
35	18	54	2373	2004
38	18	62	2196	1855
41	18	42	2159	1824
44	18	59	2068	1747
8	27	44	2029	1714
11	27	48	1909	1613
14	27	44	2052	1733
17	27	47	2178	1840
20	27	50	2612	2206
23	27	40	2565	2167
26	27	49	2116	1787
29	27	50	2146	1813
32	27	52	3091	2611
35	27	73	3456	2919
38	27	53	2520	2129
41	27	47	2137	1805
44	27	57	2172	1835
8	36	40	2053	1734
11	36	49	2126	1796
14	36	41	2111	1783

Table A–3 (continued). Building 28 Data From Radiological Survey Before Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
17	36	45	2144	1811
20	36	52	2251	1901
23	36	41	2223	1878
26	36	49	2110	1782
29	36	54	2160	1825
32	36	59	2856	2412
35	36	57	2929	2474
38	36	50	2273	1920
41	36	37	2042	1725
44	36	46	2076	1754
8	45	53	2044	1727
11	45	56	2050	1732
14	45	52	2051	1732
17	45	50	2027	1712
20	45	52	2064	1743
23	45	46	2078	1755
26	45	48	2174	1836
29	45	64	2066	1745
32	45	59	2149	1815
35	45	53	2114	1786
38	45	50	2072	1750
41	45	46	1940	1639
44	45	61	2039	1722
8	54	56	1952	1649
11	54	36	1947	1645
14	54	52	1993	1683
17	54	50	2054	1735
20	54	56	2026	1711
23	54	44	1885	1592
26	54	53	1959	1655
29	54	53	1977	1670
32	54	50	1948	1645
35	54	56	2001	1690
38	54	46	1980	1673
41	54	50	1909	1613
44	54	45	1974	1667
8	63	72	2073	1751
11	63	65	1920	1622
14	63	56	1987	1678
17	63	49	2029	1714
20	63	67	1937	1636
23	63	51	2060	1740

Table A–3 (continued). Building 28 Data From Radiological Survey Before Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
26	63	54	1897	1602
29	63	48	1986	1678
32	63	41	1966	1661
35	63	56	1869	1579
38	63	41	1931	1631
41	63	48	1882	1590
44	63	54	1835	1550

Table A–4. Building 28 Data From Radiological Survey After Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
8	9	50	1917	1619
11	9	54	1965	1660
14	9	52	1903	1607
17	9	54	1957	1653
20	9	56	1899	1604
23	9	55	1974	1667
26	9	64	1957	1653
29	9	66	1933	1633
32	9	79	2022	1708
35	9	72	2014	1701
38	9	79	2098	1772
41	9	85	2015	1702
44	9	82	1980	1673
8	18	69	2117	1788
11	18	60	2035	1719
14	18	62	2069	1748
17	18	79	2088	1764
20	18	69	2291	1935
23	18	72	2137	1805
26	18	83	2032	1716
29	18	74	2014	1701
32	18	71	2077	1754
35	18	70	2050	1732
38	18	75	2005	1694
41	18	64	1971	1665
44	18	78	1968	1662
8	27	63	2108	1781
11	27	56	2027	1712
14	27	82	1960	1656
17	27	64	2170	1833
20	27	85	2444	2064
23	27	92	2205	1863
26	27	65	2057	1738
29	27	71	2073	1751
32	27	63	2289	1934
35	27	63	2377	2008
38	27	71	2058	1738
41	27	58	1906	1610
44	27	68	1930	1630
8	36	49	1952	1649
11	36	55	1977	1670
14	36	44	1927	1628

Table A–4 (continued). Building 28 Data From Radiological Survey After Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
17	36	55	1955	1651
20	36	66	2225	1879
23	36	56	2093	1768
26	36	43	1992	1683
29	36	59	1982	1674
32	36	48	2141	1809
35	36	68	2190	1850
38	36	45	1899	1604
41	36	44	1880	1588
44	36	37	1828	1544
8	45	43	1995	1685
11	45	60	2025	1711
14	45	52	2002	1691
17	45	56	2020	1706
20	45	44	1937	1636
23	45	49	1925	1626
26	45	50	1902	1607
29	45	45	1946	1644
32	45	59	1908	1612
35	45	51	1900	1605
38	45	53	1870	1580
41	45	53	1911	1614
44	45	46	1884	1591
8	54	44	1995	1685
11	54	57	1907	1611
14	54	54	1939	1638
17	54	55	1997	1687
20	54	47	1991	1682
23	54	53	1874	1583
26	54	50	1949	1646
29	54	62	1889	1596
32	54	58	1905	1609
35	54	59	1954	1651
38	54	46	1935	1635
41	54	48	1876	1585
44	54	49	1842	1556
8	63	59	2000	1689
11	63	70	2011	1699
14	63	43	2021	1707
17	63	45	1982	1674
20	63	57	1948	1645
23	63	47	1971	1665

Table A–4 (continued). Building 28 Data From Radiological Survey After Decontamination

Inches West	Inches South	Gross Alpha Instrument Reading (cpm)	Gross Beta-Gamma Instrument Reading (cpm)	Gross Beta-Gamma Activity (dpm/100 cm^2)
26	63	63	1982	1674
29	63	55	1901	1606
32	63	55	2023	1709
35	63	64	1975	1668
38	63	63	1873	1582
41	63	47	1894	1600
44	63	55	1914	1617