AEBG-36-110

Summary Report

Decontamination of Laboratory Facilities

Building D
U.S. Air Force Plant No. 36
Evendale, Ohio

Submitted to

U.S. Nuclear Regulatory Commission

Region III

Glen Ellyn, Illinois

November 1986

GENERAL ELECTRIC

Aircraft Engine Business Group

Evendale, Ohio 45215

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Concluded)

LIST OF TABLES

1.0 INTRODUCTION

This report is submitted to the U.S. Nuclear Regulatory Commission (NRC), Region III, Glen Ellyn, Illinois, as partial fulfillment of the requirements for completing the decontamination activities within the facility known as Air Force Plant No. 36 located at Evendale, Ohio. A part of one building of this facility, known as Building D, is included in the NRC Industrial Byproduct License No. 34-00399-11. Part of another building, known as Building C West, was originally included in this same Byproduct License. It has since been decontaminated and was released from the license requirements for unrestricted usage by the NRC on January 17, 1985.

Air Force Plant No. 36 is contiguous with the facilities of the General Electric Company's Aircraft Engine Business Group where commercial and military jet engines are manufactured. This 1-1/2 mile long industrial complex is adjacent to the Interstate 75 highway and is located 12 miles north of downtown Cincinnati.

The contents of this report summarize the decontamination activities in Building D that are necessary for the release of the facility from regulatory requirements and for future unrestricted usage.

This report, called a Summary Report for Building D, is supported by 55 separate detailed reports from the prescribed licensed areas of Building D. Each of these individual area reports identifies the premises, the type of construction and surface finish, the effort required to eliminate residual surface and fixed contamination, and the postdecontamination monitoring data. The results are given in units specified by the U.S. Nuclear Regulatory Commission (10CFR30).

This Summary Report contains an overall synopsis of the decontamination effort, a history of the use of Building D, a description of the survey methods and the instrumentation used, a description of the decontamination procedures, and a summary of the results. The 55 detailed reports describe individual areas of the facility and contain the final radiation monitoring survey results.

2.0 SUMMARY

This general summary report documents the successful decontamination of Building D, Air Force Plant No. 36, to near-background levels of radiation. The entire Building D Laboratory area has been decontaminated to radiation levels substantially below the U.S. Nuclear Regulatory Commission acceptable guidelines for surface contamination.

This report also outlines the overall activities performed for the Building D decontamination effort. Fifty-five separate reports document the detailed activities for all the individual areas of the building. Table 2-1 tabulates the individual areas of Building D and the corresponding number of the detailed report where each are documented, thereby providing a cross-reference for the specific details. The final decontamination status is also summarized in this table.

Subsequent sections of this report describe Building D and provide a brief description of its history and past usage. The contamination that had to be removed is described and an overview of the work performed and the final decontamination results are provided. As indicated above, specific area-by-area results are documented in separate reports.

Table 2-1. Building D - Summary List of Decontamination Reports Postdecontamination Status.

Individual Area Report Number	Room or Area	Prior Usage	Postdecontamination Status (1)			
			Removable		Fixed	
			Alpha dmp/100cm2	Beta Gamma dpm/100cm2	Alpha dpm/100cm²	Beta-Gamma mR/hr @ 1.0 cm
AEBG-36-111	L1-1	Uranium Analysis Lab	< 20	< 200	< 200	< 0.05
-112	L1-3	Analytical Chemistry Lab	< 20	< 200	< 200	< 0.05
-113	L1-5	Sample Center Lab	< 20	< 200	< 200	< 0.05
-114	L1-7	Metal Research Lab	< 20	< 200	< 200	< 0.05
-115	L1-9	Research/Dev. Metals Lab	< 20	< 200	< 200	< 0.05
-116	L1-11	Research/Dev. General Lab	< 20	< 200	< 200	< 0.05
-117	L1-2	Spectrographic Lab	< 20	< 200	< 200	< 0.05
-118	L1-4	Moderator Research/Dev. Lab	< 20	< 200	< 200	< 0.05
-119	L1-6, -8	Radiochemistry Lab	< 20	< 200	< 200	< 0.05
-120	L1-10	Material Dev. Lab	< 20	< 200	< 200	< 0.05
-121	L1-12, -14	Office Area	< 20	< 200	< 200	< 0.05
-122	L2-2, -4	Lab and Offices Area	< 20	< 200	< 200	< 0.05
-123	L2-6, -8	Metallography Lab	< 20	< 200	< 200	< 0.05
-124	L2-10	Measurements Lab	< 20	< 200	< 200	< 0.05
-125	L3-1	General Purpose Lab	< 20	< 200	< 200	< 0.05
-126	L3-3	Mechanical Testing Lab	< 20	< 200	< 200	< 0.05
-127	L3-5	Fuel Element Processing	< 20	< 200	< 200	< 0.05
-128	L3-7, -9	Development Fuel Lab	< 20	< 200	< 200	< 0.05
-129	L3-2	Instrument Calibration Room	< 20	< 200	< 200	< 0.05
-130	L3-4	Fuel Element Development	< 20	< 200	< 200	< 0.05
-131	L3-6	Moderator Development	< 20	< 200	< 200	< 0.05
-132	L3-8	General Purpose	< 20	< 200	< 200	< 0.05
-133	L3-10	Moderator and Shielding Lab	< 20	< 200	< 200	< 0.05
-134	L3-12	High-Temp Fuels Research	< 20	< 200	< 200	< 0.05
-135	L3-14, -16	Health Physics Office	< 20	< 200	< 200	< 0.05
-136	L4-1	Metallurgical Dev. Lab	< 20	< 200	< 200	< 0.05
-137	L4-3	Mechanical Testing Lab	< 20	< 200	< 200	< 0.05
-138	L4-5	Special Metals Shop	< 20	< 200	< 200	< 0.05
-139	L4-7, -8	Warm Cell; Met. Lab	< 20	< 200	< 200	< 0.05
-140	L5-1	Powder Met. Lab	< 20	< 200	< 200	< 0.05
-141	L5-3	Powder Met. Lab	< 20	< 200	< 200	< 0.05
-142	L5-5	Powder Met. Lab	< 20	< 200	< 200	< 0.05
-143	L5-2	X-ray Inspection Lab	< 20	< 200	< 200	< 0.05
-144	L5-4	Welding, Joining Lab	< 20	< 200	< 200	< 0.05
-145	L5-6	Heat Treat Lab	< 20	< 200	< 200	< 0.05
-146	L5-8	Quality Control Lab	< 20	< 200	< 200	< 0.05
-147	L5-10	Cleaning, Plating Lab	< 20	< 200	< 200	< 0.05
-148	L6	Fuel Element Prod. Area	< 20	< 200	< 200	< 0.05
-149	L-6 Annex	General Purpose Area	< 20	< 200	< 200	< 0.05
-150	Laboratory Halls	Corridors and Elevator	< 20	< 200	< 200	< 0.05
-151	Laboratory Restrooms	Restrooms and Janitorial	< 20	< 200	< 200	< 0.05
-152	Laboratory Pipechases and Closets	Utility Service Area	< 20	< 200	< 200	< 0.05
-153	Laboratory Area Attic	Controlled Exhaust	< 20	< 200	< 200	< 0.05
-154	Laboratory Basement and Vaults	SS Materials, Regular Storage	< 20	< 200	< 200	< 0.05
-1[illegible]	Controlled Waste Drain System	Controlled Waste Drain	< 20	< 200	< 200	< 0.05
-156	Cobalt-60, Plasma, Van De Graaff Facilities	Irradiator, Particle Mass Electron Accel.	< 20	< 200	< 200	< 0.05
-157	Dynamic Air, Hydraulic Test, Burner Rig	Gas Dynamics Facil.	< 20	< 200	< 200	< 0.05
-158	Instrument Service Shop Nondestructive Test Lab.	Office, Computer Instr. Serv.	< 20	< 200	< 200	< 0.05
-159	North, Middle Mezzanine	Change Room, General Lab	< 20	< 200	< 200	< 0.05
-160	Water Test Area, Blockhouse Lab., Betatron	Misc. Nucl. Test Area High-Temp Furnace Electron Accel.	< 20	< 200	< 200	< 0.05
-161	Radioactive Mat. Lab.	Irradiated Mat. Lab.	< 20	< 200	< 200	< 0.05
-162	Nuclear Exper. Area	Nuclear Critical Exper.	< 20	< 200	< 200	< 0.05
-163	Radioactive Waste Storage Pad	Radioactive Waste Storage	< 20	< 200	< 200	< 0.05
-164	Special Source Vault	Special Source Storage	< 20	< 200	< 200	< 0.05
-165	717, 718, 738 High Bay Area	General Lab, Dispensary, Air Conditioner, High Bay	< 20	< 200	< 200	< 0.05

(1) See Table 4-3 for Full NRC Acceptable Guideline Values

3.0 HISTORY

This section describes the Building D facility and presents a short summary of its use and history.

3.1 FACILITY DESCRIPTION

Building D is one of the buildings in the government-owned facility known as Air Force Plant No. 36 located in Evendale, Ohio. Air Force Plant No. 36 is contiguous on its north side with the Evendale Plant of the Aircraft Engine Business Group of the General Electric Company (GE). Figure 3-1 shows an aerial photograph of this entire industrial complex. Figure 3-2 shows the layout outlining Air Force Plant No. 36 and identifies the location of Building D.

Building D was built during World War II (circa 1941) as an aluminum foundry by the Defense Mobilization Board as part of the Wright Aeronautical Engine Plant. After the war, Building D remained idle until 1951.

In 1951 the then Jet Engine Department of General Electric became a Prime Contractor to the U.S. Atomic Energy Commission (AEC) and formed the Aircraft Nuclear Propulsion (ANP) Project. This program was a joint venture contract between the U.S. Air Force, the AEC, and GE to develop a nuclear-powered aircraft. Building D was chosen as the operational building for the program. Before anyone moved into Building D the entire interior was gutted, and a special facility was designed and constructed to safely handle radioactive materials and to meet the needs of the ANP Project. The AEC established the Lockland Area Office and moved into a series of offices in Building D to administer the ANP contract.

In 1956 additional space was needed for the ANP Project. Forty-two percent of Building C on the west end was allocated and was thereafter called C-West. The C-West area was used as a large-scale pilot plant-type production line for ceramic nuclear fuel elements.

General Electric Evendale, Ohio Industrial Complex

Figure 3-1. Aerial View Delineating General Electric Complex and Air Force Plant No. 36.

General Electric Evendale, Ohio Industrial Complex

Figure 3-1. Aerial View Delineating General Electric Complex and Air Force Plant No. 36.

Air Force Plant 36

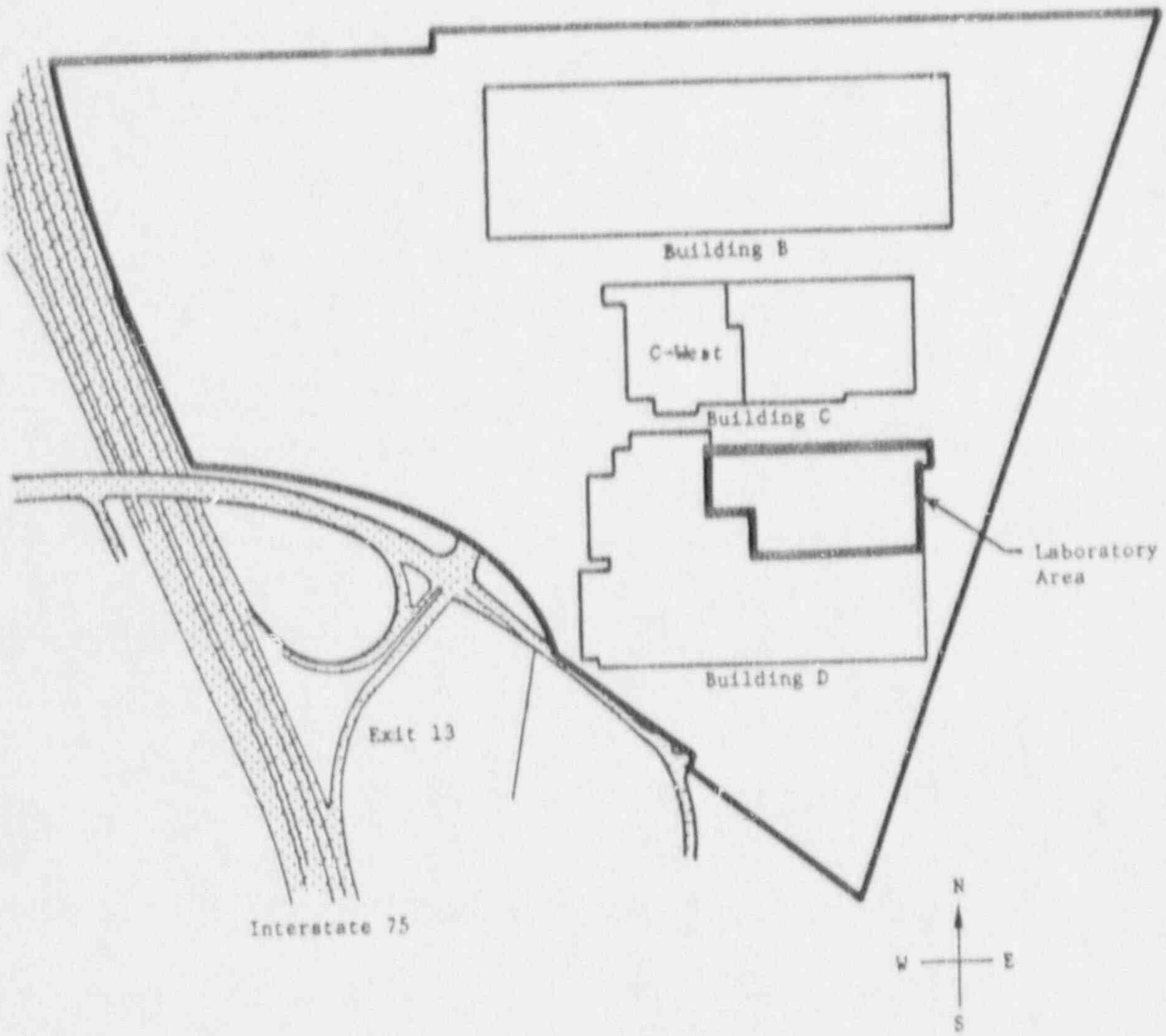


Figure 3-2. Layout Outlining Air Force Plant No. 36, Showing Location of Building D Laboratory Area.

Building D is the southernmost building of the facility comprising Air Force Plant No. 36. It is a single story, steel frame, brick outer wall, fire-resistant building approximately 680 feet long and 450 feet deep with a partial basement under the Laboratory area. Figure 3-3 shows the four main areas of Building D: Office, Engineering, Shop and Laboratory areas. A large mezzanine area was located over the western portion of the Laboratory area with its support facilities and office area. Figures 3-4 and 3-5 show the layout of the basement and mezzanine.

The Laboratory area of Building D is located in the northeast section of the building facility. It is 360 feet wide and 200 feet deep. Figure 3-6 shows the general arrangement of the Laboratory area. Basically, the Laboratory is divided into six blocks of alternate single and double rows of laboratories or rooms. Other support facilities were located west of the Laboratory area. A high bay area is located along the entire length of the north side of Building D. The east portion of the Laboratory area housed additional laboratories, the central air conditioning and exhaust facilities, and the Nuclear Experimental Area. The east portion of the high bay area is 40 feet wide and 530 feet long. The remainder of the high bay area is 40 feet wide and 150 feet long.

The Laboratory area of Building D was especially designed for the safe handling of radioactive materials. Many elaborate engineering and safety features were installed to attain that goal. It was virtually isolated from the remainder of the building with its own utility services and ventilation system.

The most prominent of the safety features was the central exhaust system where a negative differential air pressure system was maintained with respect to the outside of the building. Work areas where radioactive materials were handled were kept at a negative differential air pressure with respect to the interior of the building. Glove boxes were used for mixing and handling materials until the physical state was such that there would be no potential for the spread of contamination. Glove boxes were maintained at a negative differential pressure relative to the work area. The ventilation system in all laboratories, rooms, or areas where radioactive and toxic materials were

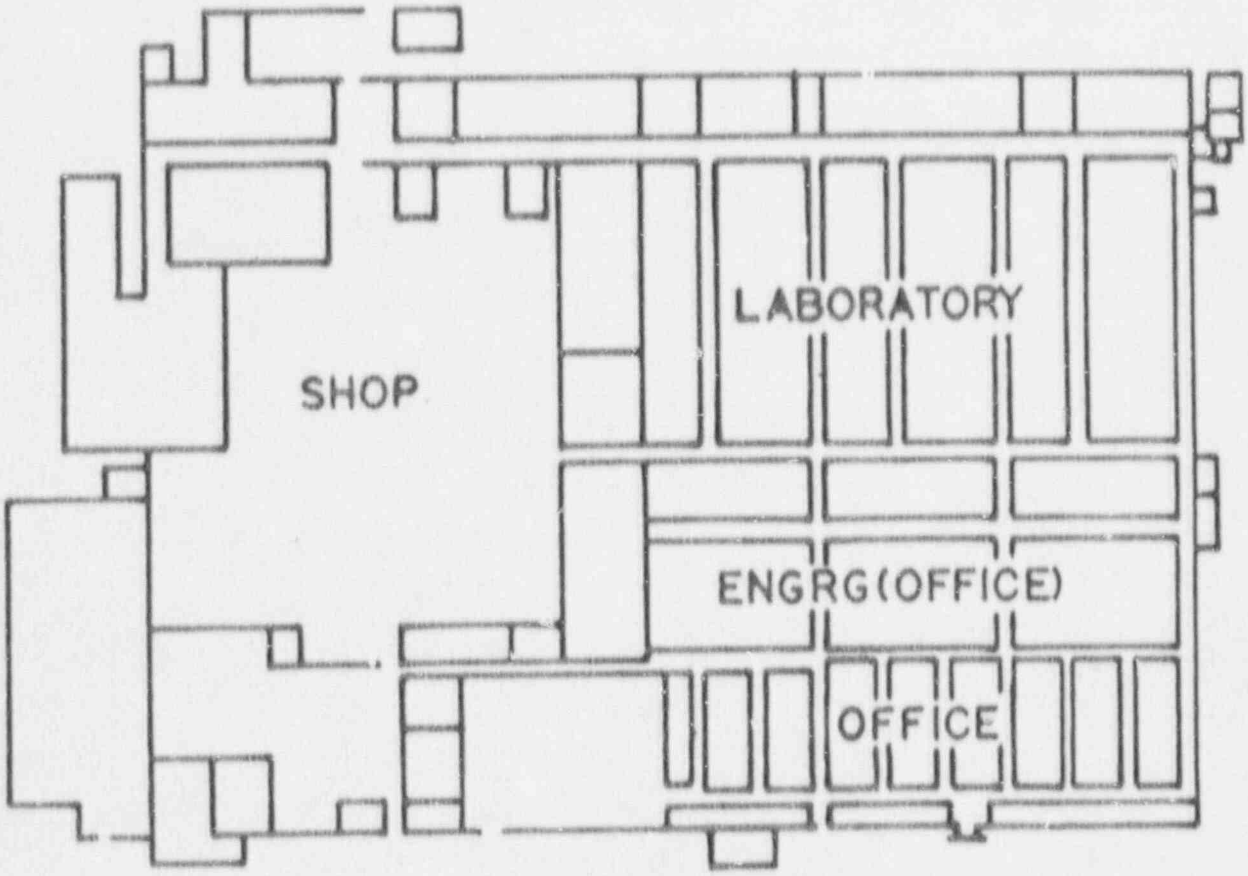


Figure 3-3. Layout Outlining General Arrangement of Main Floor, Building D.

Building D
Basement Plans

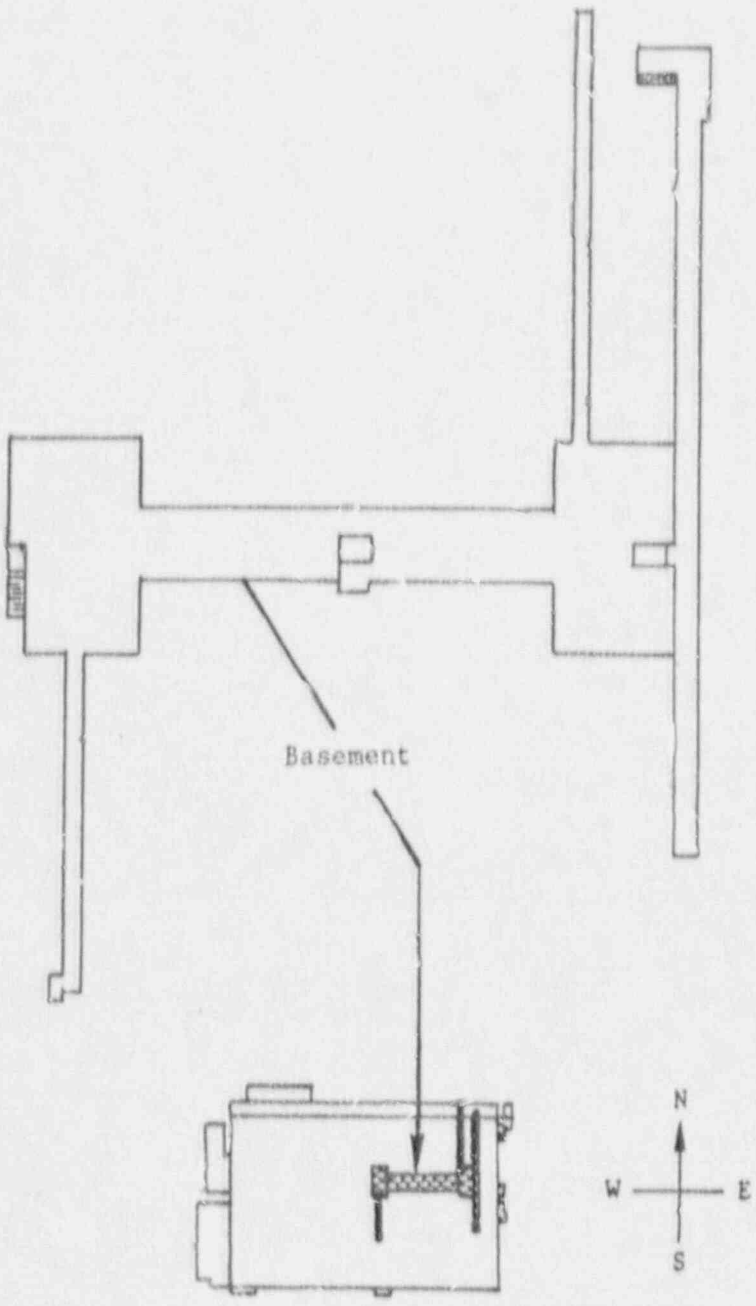


Figure 3-4. General Layout of Basement, Building D.

Building D
Mezzanine Plans

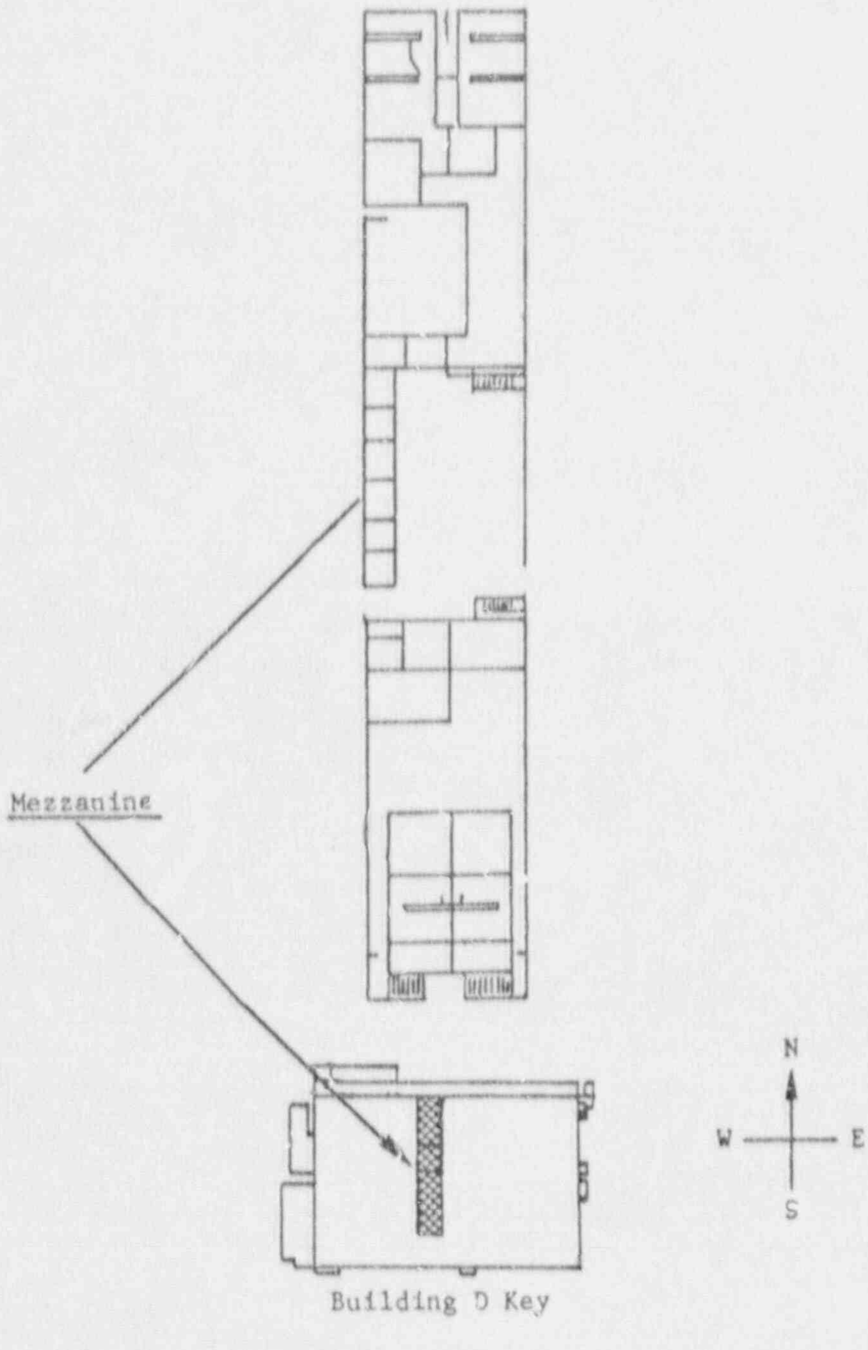


Figure 3-5. General Layout of Mezzanine, Building D.

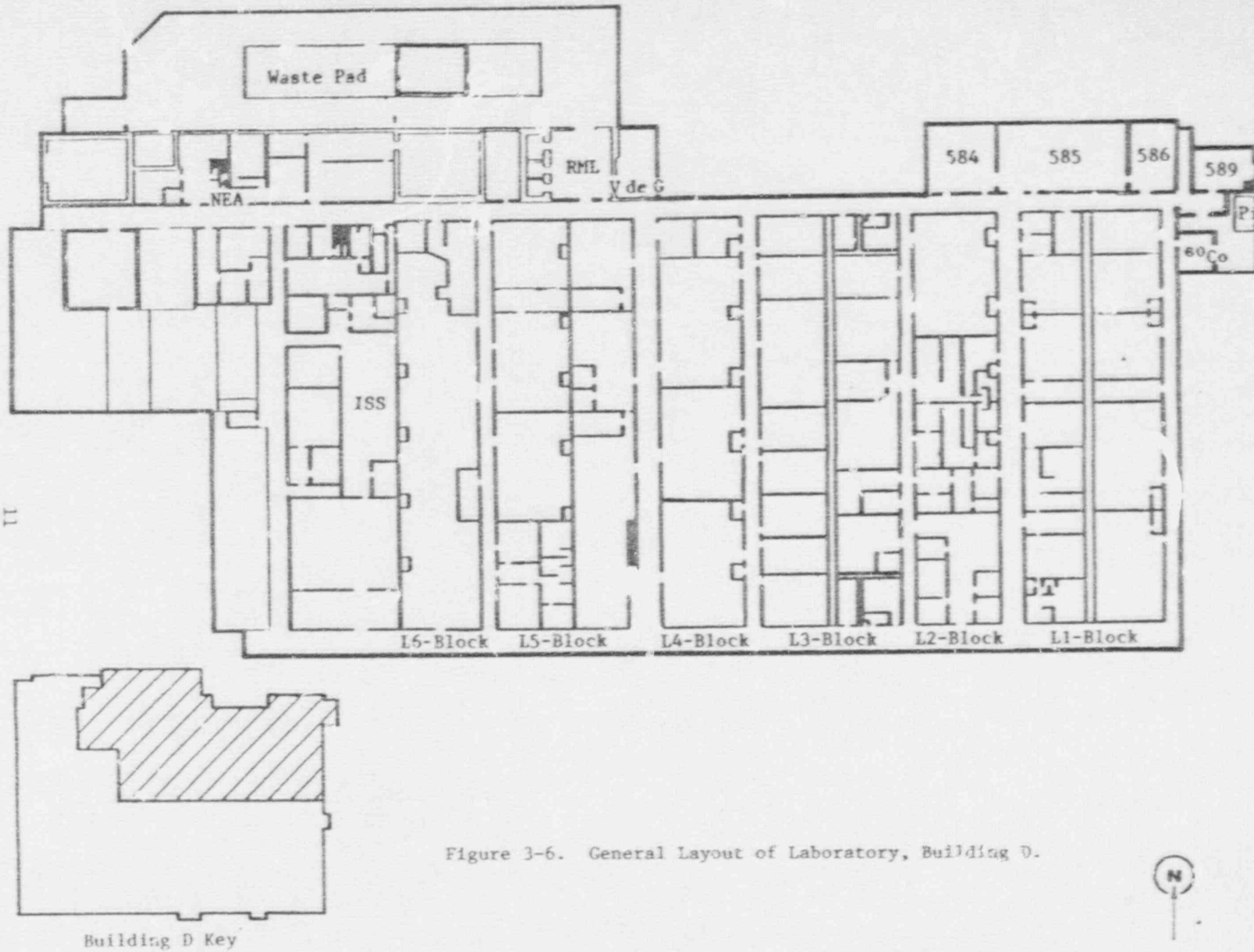


Figure 3-6. General Layout of Laboratory, Building D.

handled was filtered with high-efficiency particulate aerosol (HEPA) filters before being exhausted to the outside.

The liquid waste drain system for the Laboratory area was an extensive collecting system that flowed into retention tanks in the basement of the Laboratory. This waste was assayed for radioactive content and if within permissible limits, was discharged into the sanitary system outside the northeast corner of Building D.

The Laboratory was specifically designed for maximum safety to employees and the environment. Criticality safety was an overriding factor in many operations because moderator and fissionable materials were intimately mixed in small batches. It was necessary to employ engineering and administrative control measures to assure safe operating conditions.

3.2 PAST HISTORY AND USAGE

In 1961 the ANP Project was cancelled. General Electric continued as a Prime Contractor to the AEC for the development of high-temperature fuel elements and reactor materials. The AEC took lease of the Buildings from the Air Force.

Between 1961 and 1968 the Building D Laboratory was used for experimental work to support fuel element production in conjunction with the AEC 710 and 630A reactor development programs. The 710 program dealt with developing a compact fast-spectrum reactor which could be used as either an open-cycle hydrogen cooled system as a nuclear rocket engine or as an inert gas closed-cycle powerplant for space or terrestrial applications. The highly enriched fuel elements for this reactor concept were fabricated in Building C-West. The 630A program was aimed at using the ANP reactor technology to develop a gas or air-cooled powerplant for commercial merchant ships.

In 1970 the AEC terminated their Prime Contract with General Electric's Nuclear Materials and Propulsion Operation. General Electric became a licensee and performed subcontract work with other AEC Prime Contractors. At this time the AEC removed itself from the facility, and the Air Force resumed landlordship of the buildings.

In April of 1973 the Air Force, after extensive review within the Air Force and the Department of Defense, decided to decontaminate the facility. They contracted with General Electric to perform this task in Buildings D and C-West. All source and special nuclear materials were transferred to other AEC contract operations. Uncontaminated equipment, after monitoring, was surplused or scrapped. Contaminated equipment was either packaged and buried as radioactive waste or decontaminated and disposed of as noncontaminated equipment or waste. Some very specialized pieces of equipment were packaged and transferred to other government nuclear operations. Facility decontamination was then begun starting with those areas that had higher levels and then progressing to lower level contamination areas. By May 1975 the allotted funding was depleted. Decontamination work ceased, with the facilities more than 80% to 90% decontaminated.

In January 1976 the Air Force, undecided on the dispostion of Buildings D and C-West, sent a special radiological assessment team to evaluate and make recommendations on the future usefulness of the buildings. The team from the Air Force Weapons Laboratory (AFSC), Kirkland Air Force Base, conducted a Zero-Line Survey for Air Force Plant No. 36, Buildings D and C-West. Their survey delineated the areas within these two building where radioactive contamination remained. The team recommended that decontamination of the buildings be completed.

In December 1976 the Air Force, seeking alternative plans, requested an engineering evaluation study of the costs of various options for the proper disposition of the buildings. The study was performed by A.M. Kinney, Architects and Consulting Engineers, Cincinnati, Ohio. They submitted a report to the Air Force on June 15, 1977.

The Kinney Study answered the following questions requested by the Air Force:

- <u>Cost of partial demolition</u> - included the complete demolition of the contaminated portion of the buildings (the areas delineated by the Air Force survey where nuclear materials were once handled). These included the Laboratory area, or one-third of Building D and all of C-West. It also involved packaging, transportation, and disposal of the contaminated material to an approved radioactive burial ground. This estimate was $40 million in 1977 dollars.

- Cost of Partial Entombment (Mothballing) - required isolating only the contaminated portions of the buildings on an indefinite time basis. Areas covered were the same as the demolition study. This estimate was $9.7 million 1977 dollars plus an annual operating cost. It was noted that this option would not have solved the contamination problem. It would only delay a final decision on the proper disposition of the building.

- Cost of Full Entombment (Mothballing) - required isolating all of Building D and half of Building C on an indefinite time basis. This estimate was $8.6 million 1977 dollars plus an annual operating cost. This cost estimate was less than the cost estimate for Partial Entombment because relocation of utilities and construction of internal walls were not required. This option also would not have solved the problem. It would have only delayed a final decision.

In April 1977 the U.S. Air Force requested General Electric's Advanced Energy Programs (AEP) to submit an estimate for two options for completing decontamination of Buildings D and C-West.

- Limited Decontamination - This option covered decontamination of the remaining surface areas, flushing of controlled drains, and monitoring of controlled exhaust ducts w very limited removal of controlled drains and ducts. The cost estimate was $0.7 million 1977 dollars. This option was not recommended because or problems with U.S. NRC guideline criteria for the decontamination of facilities and equipment for unrestricted use.

- Full Decontamination - This option covered decontamination of the remaining surface areas with excavation and complete removal of laboratory controlled drains and complete removal of exhaust ducting systems. The cost estimate was $2.7 million 1977 dollars.

The Building D Laboratory area was maintained by General Electric from 1977 to 1982 as a restricted area with no operating activities being performed other than those related to preventive maintenance. In October 1982 the U.S. Air Force issued a contract to General Electric's Advance Energy Program to resume the decontamination project.

3.3 PREDECONTAMINATION STATUS

In 1969, before the start of decontamination, a survey was made by General Electric personnel of the contamination levels in Buildings D and C-West. Then again in 1976, the Air Force conducted a survey to establish a zero-line outside of which there was no contamination. Based on these surveys and other radiation monitoring file data, the laboratories, rooms, and facilities were identified in one of two categories: either contaminated or probably clean. In addition to the rooms themselves, the controlled exhaust ducts in the Attic and the controlled liquid waste drain system, with its retention storage tanks, had to be suspected of being contaminated because they could not be monitored properly. However, to assure that the facility was thoroughly decontaminated, it was required that all surface areas be surveyed and monitored for radiation contamination.

Several key problem areas were identified at the start of decontamination activities in 1982. The first was the controlled exhaust ducts: Portions of these systems below the Attic area had been removed during previous (1973-1975) decontamination activities. However, 24 exhaust systems and roof penetrations remained in the Attic. These systems included blowers, filter housings and plenums, vents and ducts. The ducts, vents, and plenums were extensive, covering more than 6000 feet in length. The extent of contamination inside these systems was unknown since access to their interior walls was impossible for the proper detection of alpha activity. For this reason, a decision was made to completely remove the entire controlled exhaust system which had a potential of being contaminated. Figures 3-7, 3-8, and 3-9 show the approximate locations of the controlled exhaust system ducting removed from the Laboratory Area, the Radioactive Materials Laboratory (RML), and the Nuclear Experimental Area (NEA) of Building D, respectively. The removal of this exhaust system was difficult because of its location, requiring extreme care during removal, and the unknown level of contamination as well as the possibility of spreading potential contamination by careless handling.

The second potential problem was the removal of the controlled liquid waste drain system shown in Figure 3-10. This system was distinct from the storm and sanitary sewer drains in the building. The condition of the controlled liquid waste drain system was unknown because there was no way to access the system for proper monitoring. Nevertheless, contamination could exist in concentrations exceeding the NRC guidelines, possibly high enough to constitute a hazard if uncovered. Also, small leaks at underground pipe joints

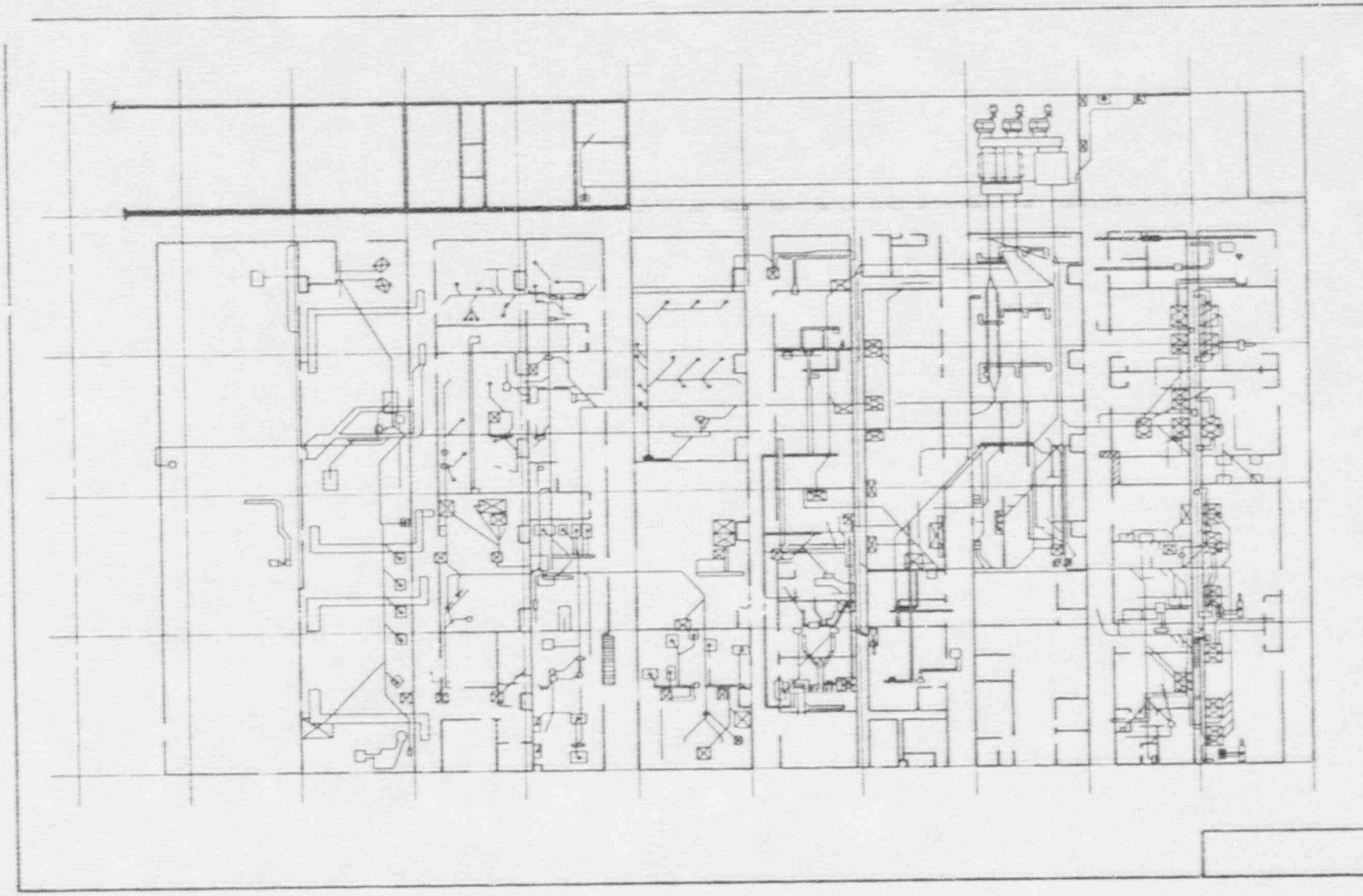
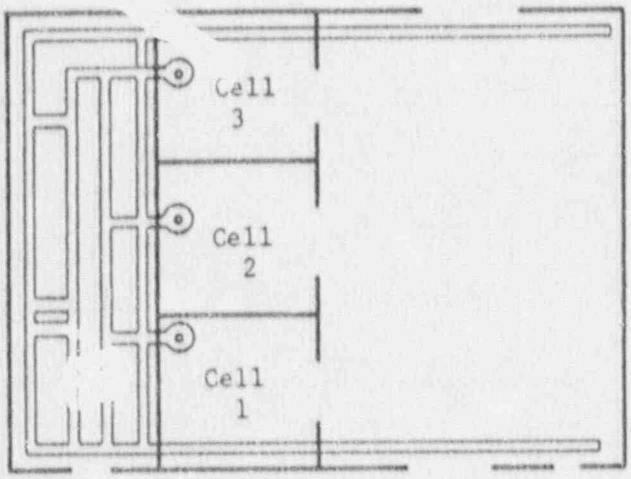


Figure 3-7. Approximate Location of Controlled Exhaust System Ducting Removed From Laboratory and Roof Areas, Building D.

RML Areas



First Floor

Figure 3-8. Approximate Location of Controlled Exhaust System Ducting Removed From the Radioactive Materials Laboratory, Building D.

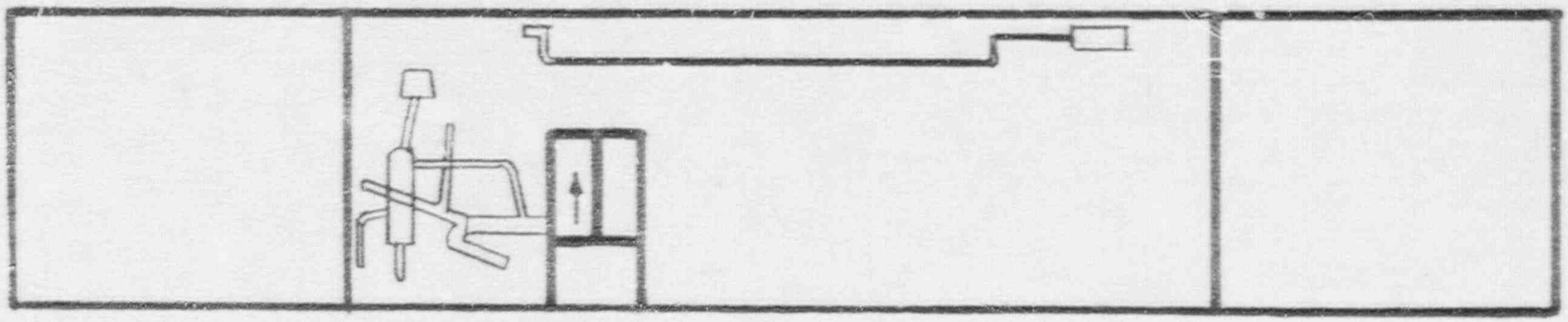


Figure 3-9. Approximate Location of Controlled Exhaust System Ducting Removed From Attic of Nuclear Experimental Area, Building D.

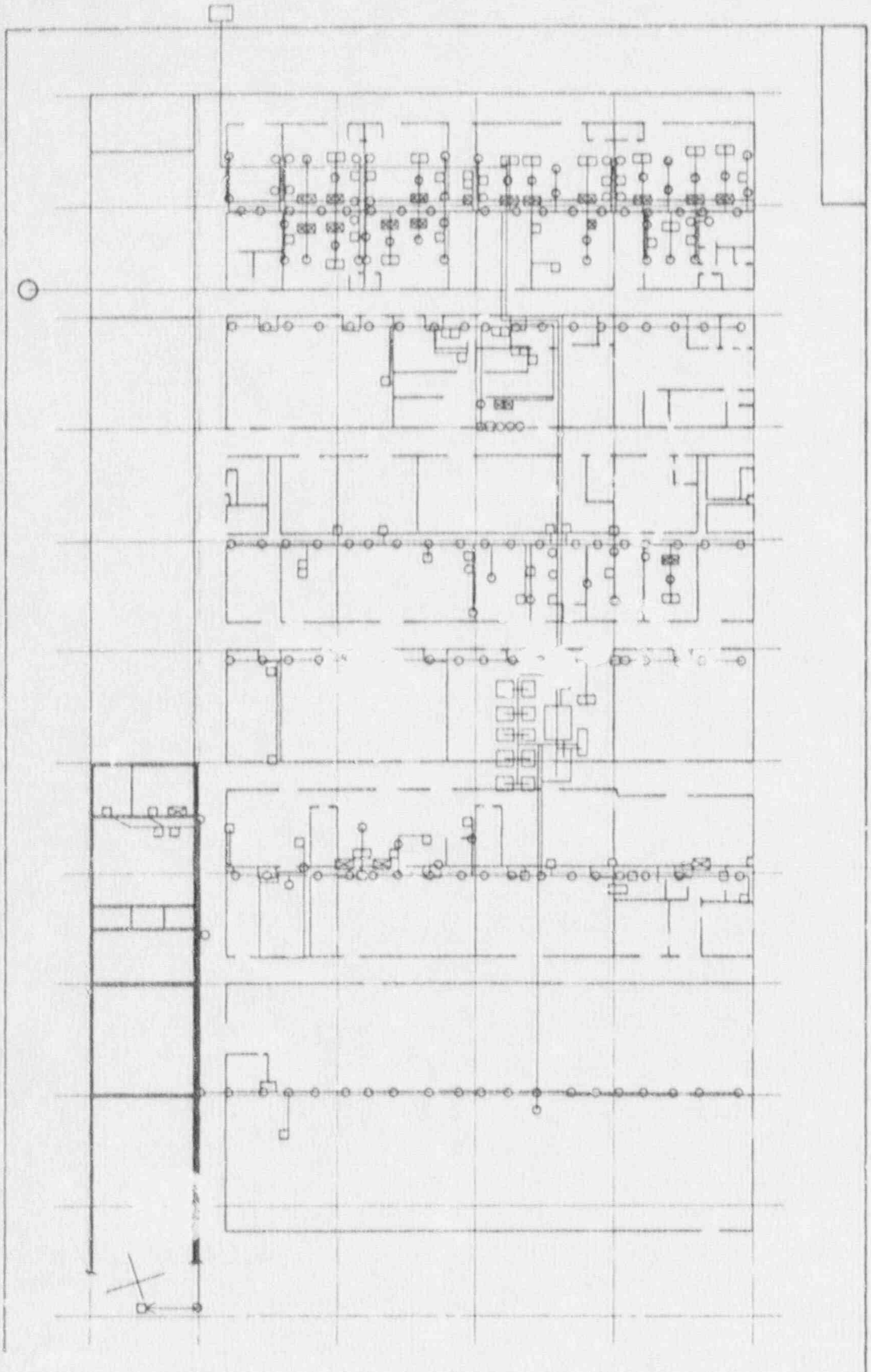


Figure 3-10. Approximate Location of Controlled Liquid Waste Drain System Removed From Building D.

could cause potential contamination of the adjacent soil. The presence and effect of such leaks could not be determined before actual excavation and removal of the drainpipes; more than 1600 feet of under ground drainpipe had to be removed.

The remainder of the decontamination (the bulk of the work) involved a combination of nondestructive decontamination such as cleaning, vacuuming, grinding and vacuum abrasive blasting, and destructive decontamination such as physically removing contaminated material. In addition to the controlled exhaust and liquid waste drain systems, the removal of some floor coverings and some wall sections was necessary. There were 425,126 square feet of surface area to be cleaned and monitored.

All materials that could not be decontaminated were sealed in approved radioactive waste containers and shipped for burial at an approved radioactive waste site in Richland, Washington. After thorough monitoring, uncontaminated materials were routinely disposed of as scrap or trash.

4.0 RADIATION MONITORING SURVEYS

This section describes the instrumentation and survey methods used to measure the radioactive contamination and the levels of radiation during the decontamination activity and afterward to establish, by means of a final monitoring survey, that all levels are well below the Nuclear Regulatory Commission (NRC) guidelines. These guidelines for acceptable surface contamination levels assure the release of Building D from licensing requirements and for unrestricted usage.

4.1 INSTRUMENTATION

The two classes of instruments used to detect and measure fixed radioactive contamination are portable survey instruments and laboratory assay instruments. Each are described below. The statistical accuracy of the measurements performed and estimates of the minimum detectable activity (MDA) of the various instruments used are also discussed.

4.1.1 Portable Survey Instruments

Table 4-1 shows the portable instruments used for radiation detection and measurement.

For detection and measurement of the alpha activity the following instruments were used:

- Eberline Model PAC-4G-3 LIN-LOG Alpha Survey Meter with AC-21 Gas Flow Proportional Probe, or with FM-4G Alpha Floor Monitor
- Eberline Model PRS-1 RASCAL Portable Ratemeter-Scaler with AC-3-7 Alpha Scintillation Probe.

For detection and measurement of beta-gamma activity, the following instruments were used:

- Technical Associates Model CP-3 Cutie Pie Survey Meter
- Eberline Model E-500B Geiger Counter
- Eberline Model E-120 Geiger Counter with FM-1 Floor Monitor
- Eberline Model PRM-7 Micro R/hr Meter
- Eberline Model PRM-6 Rate Meter with Model HP-260 Hand Probe

Table 4-1. Portable Survey Instruments.

Item No.	Number in Use	Instrument	Manufacturer	Type	Radiation Detected	Sensitivity Range	Window	Nominal Efficiency, Percent	Estimated Minimum Detectable Activity	Comments and Primary Use
1.	3	PAC-4G-3 with AC-21 Probe	Eberline Inst. Corp.	Gas Flow Proportional	Alpha	0-500K cpm	0.85 mg/cm² 50 cm² area	50	80-100 dpm/ 100 cm²	Portable Alpha Survey
2.	2	PAC-4G-3 with FM-4G Floor Monitor	Eberline Inst. Corp.	Gas Flow Proportional	Alpha	0-500 cpm	0.85 mg/cm² 335 cm² area	50	12-15 dpm/ 100 cm²	Alpha Floor Monitor
3.	1	PRS-1 with AC-3-7 Probe	Eberline Inst. Corp.	Scintillation	Alpha	2x10⁷ cpm/ μCi/cm²	1.5 mg/cm² 59 cm² area	28	100-120 dpm/ 100 cm²	Portable Alpha Survey
4.	3	CP-3	Technical Assoc. Inc.	Ion Chamber	Alpha Beta, Gamma	0-10,000 mR/hr	0.45 mg/cm² 38 cm² area		N/A	Portable Cutie Pie Survey
5.	5	E-500B	Eberline Inst. Corp.	Geiger	Beta, Gamma	0-200 mR/hr	N/A	(1)	N/A	Portable Geiger Counter
6.	1	E-120 with FM-1 Floor Monitor	Eberline Inst. Corp.	Geiger	Beta, Gamma	0-50 mR/hr	N/A	(1)	~30 μR/hr	Beta, Gamma Floor Monitor
7.	2	PRM-7	Eberline Inst. Corp.	Scintillation	Gamma	0-5 mR/hr	1-inch diameter	(1)	~10-12 μR/hr	Low Level Gamma Detector
8.	1	PRM-6 with HP-260 Hand Probe	Eberline Inst. Corp.	Geiger	Beta	0-500K cpm	2.0 mg/cm² 16 cm² area	30	1700 dpm/ 100 cm²	Low Energy Beta Detector
9.	1	ESP-1 with PG-2 Detector	Eberline Inst. Corp.	Scintillation	Gamma	0-50K cps	0.025 mm AL 20 cm² area	(1)	~15 μR/hr	Low Energy Gamma Detector

Note: (1) Energy Dependent

- Eberline Model ESP-1 Smart Portable with Model PG-2 Low Energy Gamma Detector.

The salient features of these instruments are summarized in the following paragraphs and in Table 4-1.

The Eberline Model PAC-4G-3 LIN-LOG Alpha Survey Meter with the Model AC-21 Gas Flow Proportional Probe detects and measures alpha surface radiation in the presence of high humidity, volatile solvent vapors, inlet or other atmospheres, and other types of radiation. This instrument has an operating range of 0 to 500,000 cpm in four linear, continuously progressive decades, calibrated to the 2π geometry value of 1-inch-diameter plutonium-239 sources. Linearity is ±8% of the full scale of the decade being read, nominal. Its gamma rejection is 5 R/hr on the middle of the alpha plateau and can be set to reject 50 R/hr by setting lower on the alpha plateau.

- The Model AC-21 Gas Flow Proportional Probe, used in conjunction with the PAC-4G-3, has a thin window (0.85 mg/cm^2 aluminized Mylar) and an area of 50 cm^2. Its efficiency permits detection of approximately 50% of the total alpha activity at 2π geometry over a 50 cm^2 surface area.

- The Model FM-4G Alpha Floor Monitor, also used with the PAC-4G-3, has a larger window area of 335 cm^2 and the same type of thin window. The probe is mounted in a wheeled carriage with a handle to allow easy monitoring of large floor areas. Its efficiency is the same as the Model AC-21 Probe.

- The minimum detectable activity of the two alpha counters is determined by their effective area and the lowest scale reading that can be read by a trained operator. Since both use the same counter, the minimum scale increment is the same, 50 cpm. A trained operator can read a minimum activity of 20-25 cpm by interpolation. There is essentially no alpha background. With a 50% efficiency, this gives a minimum detectable activity of 40-50 dpm. For the hand held AC-21 probe, (with an area of 50 cm^2) used for all measurements except floors, this gives a specific MDA of 80-100 dpm per 100 cm^2 area. For the floor monitor FM-4G with an area of 335 cm^2, this gives a specific MDA of 12-15 dpm per 100 cm^2.

The Eberline Model PRS-1 RASCAL Portable Ratemeter-Scaler with Model AC-3-7 Alpha Scintillation Probe is used for surface monitoring of alpha radiation. The PRS-1 is a scaler/ratemeter with a single channel analyzer. There is a 6-decade digital liquid crystal display of scaler and ratemeter information.

- The probe is a ZnS(Ag) scintillator with an active area of 59 cm^2. The aluminized plastic film window has a thickness of 0.5 mg/cm^2; a protective metal grid overlays the window.

- The efficiency of detection is 28% minimum and the sensitivity is 2×10^7 cpm per uCi/cm^2. The lower limit of detection is estimated to be 100-120 dpm per 100 cm^2 area.

The Technical Associates Model CP-3 Cutie Pie Survey Meter was used for intermediate-level beta-gamma surveys, especially in the first phase of decontamination activities where its high-scale readings allowed the radiation monitoring teams to avoid excessive personal exposure. This instrument was not used for the final radiation monitoring surveys.

- The detector consists of an air ionization chamber with an end window opening of 2-3/4 inches in diameter. A rubber hydrochloride screen of 0.45 mg/cm^2 covered the window. An alpha filter of cellulose acetate (36 mg/cm^2) and a beta filter of aluminum (720 mg/cm^2) allowed discrimination of alpha and beta radiation. The meter has three sensitivity ranges of 50, 500, and 10,000 mR/hr full scale.

The Eberline Model E-500B Geiger Counter was also used for intermediate beta-gamma monitoring. It was used primarily as a health physics monitoring device for the working decontamination crews; it was not used for the final survey monitoring. This instrument has a 0-20 mR/hr scale and five switch selected ranges. Linearity is ±8% for 0-0.2, 0-2, and 0-20 ranges and ±15% for a 0-200 range. The level of instrument saturation exceeds 1000 R/hr on all ranges. A ^{137}Cs check source permits verification that the instrument is operating within ±20% of its calibration.

The Eberline Model E-120 Geiger Counter provides the circuitry for pulse processing and registration for use with the FM-1 Floor Monitor. The floor monitor was used for measurement of beta-gamma radiation on floors.

The counter has three linear switch-selected ranges 0-0.5, 0-5, and 0-50 mR/hr ^{137}Cs equivalent. Linearity is within ±5% of full scale.

- The floor monitor assembly consists of a lead shielded tubular steel case containing two 10-inch-long Geiger tubes. It has a lead shield whose thickness is 1 inch. A window in the shield limits the view of the detectors to an area of about 100° with an effective length of 24 inches. The shield can be rotated forward 45° to monitor such frontal areas as baseboards. The monitor is mounted on three wheels with the trailing wheel being on a swivel.

- The counter is set in a box on the handle from the detector assembly. The counter is marked in increments of 0.02 mR/hr so that the background fluctuates between 0.01 and 0.03 mR/hr at 1 cm due to the random nature of the background beta-gamma radiation. Thus, its MDA is approximately 30 μR/hr at 1 cm.

The Eberline Model PRM-7 Micro R/hr Meter is a self-contained instrument used in field monitoring of low levels of gamma radiation fields from typical natural background (10 μR/hr) up to 5000 μR/hr, cesium-137 equivalent. The meter operates over four linear ranges: 0-25, 2-50, 2-500 and 2-5000 μR/hr. Its response is linear within ±5% of full scale (±2% typical).

- The detector is an internally mounted NaI(Tl) scintillator, 1-inch diameter by 1-inch length. Its photomultiplier tube is an end-window photocathode with a nominal 1-inch-diameter window.

- The PRM-7 response is energy dependent, as illustrated in Figure 4-1. The gamma energy levels of ^{238}U, ^{235}U, ^{232}Th, and their decay daughters ranged from 30 to 180 keV, allowing an error on the positive side of between 2 and 10 times the actual reading. The lower limit of detection for the PRM-7 Micro R/hr Meter is restricted by the normal background, 4-10 uR/hr at 1 cm. The lowest scale of the meter is marked in increments of 1 μR/hr so that the background level restricts the MDA to approximately 10-12 μr/hr at 1 cm for the PRM-7 Meter.

The Eberline Model PRM-6 Pulse Rate Meter with the Model HP-260 Hand Probe was used to detect low energy beta surface radiation. The PRM-6 is a general-purpose survey meter with a four-range switch that provides 0-500, 0-5K, 0-50K, and 0-500K cpm scales. The linearity is ±5% and a continuously variable response time from 10 to 2 seconds.

- The detector features a "Pancake" Geiger tube with a thin (1.4-2.0 mg/cm^2) mica window 1.75 inches in diameter. The window is protected by a sturdy wire screen.

- This instrument has a useful beta sensitivity down to 40 keV; it is sensitive to alpha radiation above 3 MeV. The efficiency for beta emitters is approximately 45% for ^{90}Sr-^{90}Y, 30% for ^{99}Tc, and 10% for ^{14}C with the screen in place. The lower limit of detection is set by normal background which fluctuates between 20-80 cpm. The lowest scale of the meter is marked in increments of 20 cpm; hence, the estimated MDA of 1700 dpm/100 cm^2 for the radioisotope energies most prevalent.

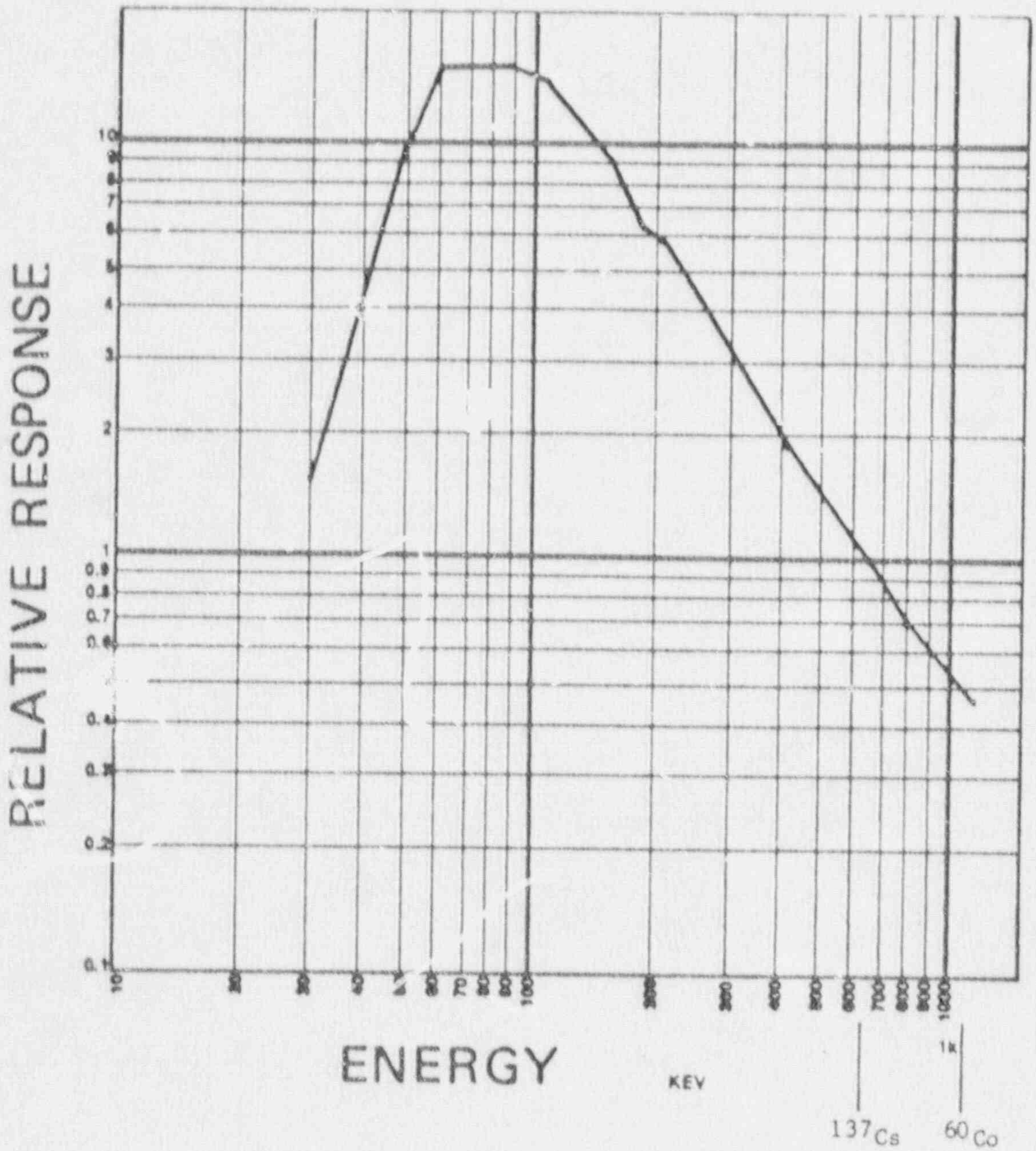


Figure 4-1. Energy Response of the Model PRM-7 Portable Micro R/hr Meter.

The Eberline Model ESP-1 Smart Portable with the Model PG-2 Low Energy Gamma Detector was used for detection of low-energy gamma radiation. The ESP-1 is a microcomputer based portable ratemeter/scaler with a liquid crystal display.

- The detector is a large area (5 cm diameter x 2 mm thick) NaI(Tl) scintillator with a 0.025 mm thick aluminum window and a protective stainless steel wire grid cover. The energy response is shown in Figure 4-2. Its efficiency is 5% minimum for ^{241}Am. The lower limit of detection is set by a normal background which fluctuates around 800 cpm at the operating voltage. The minimum detectable activity is approximately 15 μR/hr.

All of these radiation detection and measurement instruments are routinely calibrated on a monthly basis, with sources traceable to the National Bureau of Standards. Both types are field calibrated with check sources to assure proper operation during use.

4.1.2 Laboratory Measurement Instruments

Table 4-2 shows the characteristics of the laboratory instruments used to measure removable alpha and beta-gamma activity.

Nuclear Measurements Corporation gas flow proportional counters, Model PC-55, was used to provide radioassay of samples collected for removable alpha, beta, and gamma contamination as well as assay of air samples and small objects. The Model PC-3B was used for the assay of air samples during the initial decomtamination work.

The PC-55 counter counts alpha plus beta-gamma emissions separately but simultaneously. Each counter has a 7-decade beta-gamma count storage readout and a 6-decade alpha readout, each with a 0.3-inch LED-type numeral display. The maximum counting rate is 10^7 cpm and the resolution loss is less than 1% per 300,000 cpm.

The counting chamber is a hemispherical shape 2-1/4 inches in diameter. Ionization was collected by a loop-type center wire assembly. The gas purge, using P-10 (90% argon, 10% methane), was automatically pretimed.

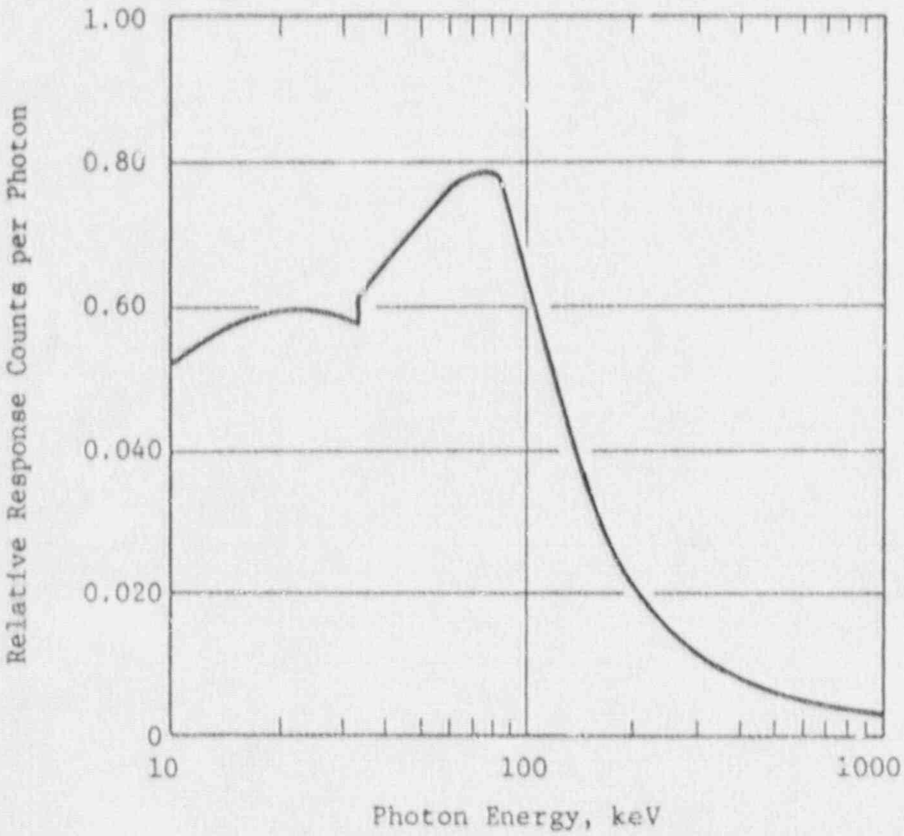


Figure 4-2. Calculated Energy Response per Photon of the Model PG-2 Detector (With Screen).

Table 4-2. Laboratory Nuclear Measurement Instrumentation.

Item No.	Number in Use	Instrument	Manufacturer	Type	Radiation Detected	Sensitivity Range	Window	Nominal Efficiency, Percent	Comments and Primary Use
1.	4	PC-55	Nuclear Measurements Corp.	Gas Flow Proportional	Alpha, Beta, Gamma	Six-decade Seven-decade beta-gamma Max. Counting Rate 10^7 cpm	0.1 mg/cm^2 5.6 mg/cm^2	35α 43βγ	Radioassay of Smears, Air Samples, and Small Objects
2.	6	PC-3B	Nuclear Measurements Corp.	Gas Flow Proportional	Alpha, Beta, Gamma	Six-decade	None	50, α 55, β	Radioassay of Air Samples

A preset time mode of instrument system operation was used for the bulk of smear counting. The timer was presettable from 1 to 999.9 minutes in increments of 0.1 minutes.

The following procedures were used (1) to measure the background level of each instrument, (2) to test the performance of each instrument and (3) to count samples. The bulk of the reported data are based on smears randomly wiped as 12 individual swipes 1 foot long in a 1 m^2 area. Being conservative, the area wiped was called 100 cm^2. The smears were then counted using the procedures describes in the next section.

The procedures used were as follows:

- A 10-minute background count was taken on each instrument at the beginning of each workday and the results recorded. Figure 4-3 shows a typical background control chart used to determine if the background for each instrument remained within a $\pm 1.96\sigma$ control limit. Control charts on each instrument, for both alpha and beta-gamma, were prepared.
- An NBS-calibrated standard alpha source and an NBS-calibrated standard beta-gamma source were each counted for 1 minute and their results were recorded. The results were compared with $\pm 1\sigma$ limit for each calibrated source. If a reading fell outside of this narrow band, additional readings were taken to ensure that the first deviation was only a statistical event.
- If the above counts fell within the acceptable limits (as discussed above), the instruments were deemed to be working properly.
- These procedures were repeated during the day if evidence of contamination or malfunction were observed.
- The smears were then counted for 1 minute.
- These gross counts were corrected for the efficiency of the instrument (35% for alpha or 43% for beta) and for the background.

a. Since the normal, acceptable alpha background is between 0 and 1 count per minute, this correction had little effect on the statistics of the alpha counting.

b. The normal, acceptable beta-gamma background is about 50 cpm and is a significant correction to both the final reported dpm and, to a lesser extent, the statistics.

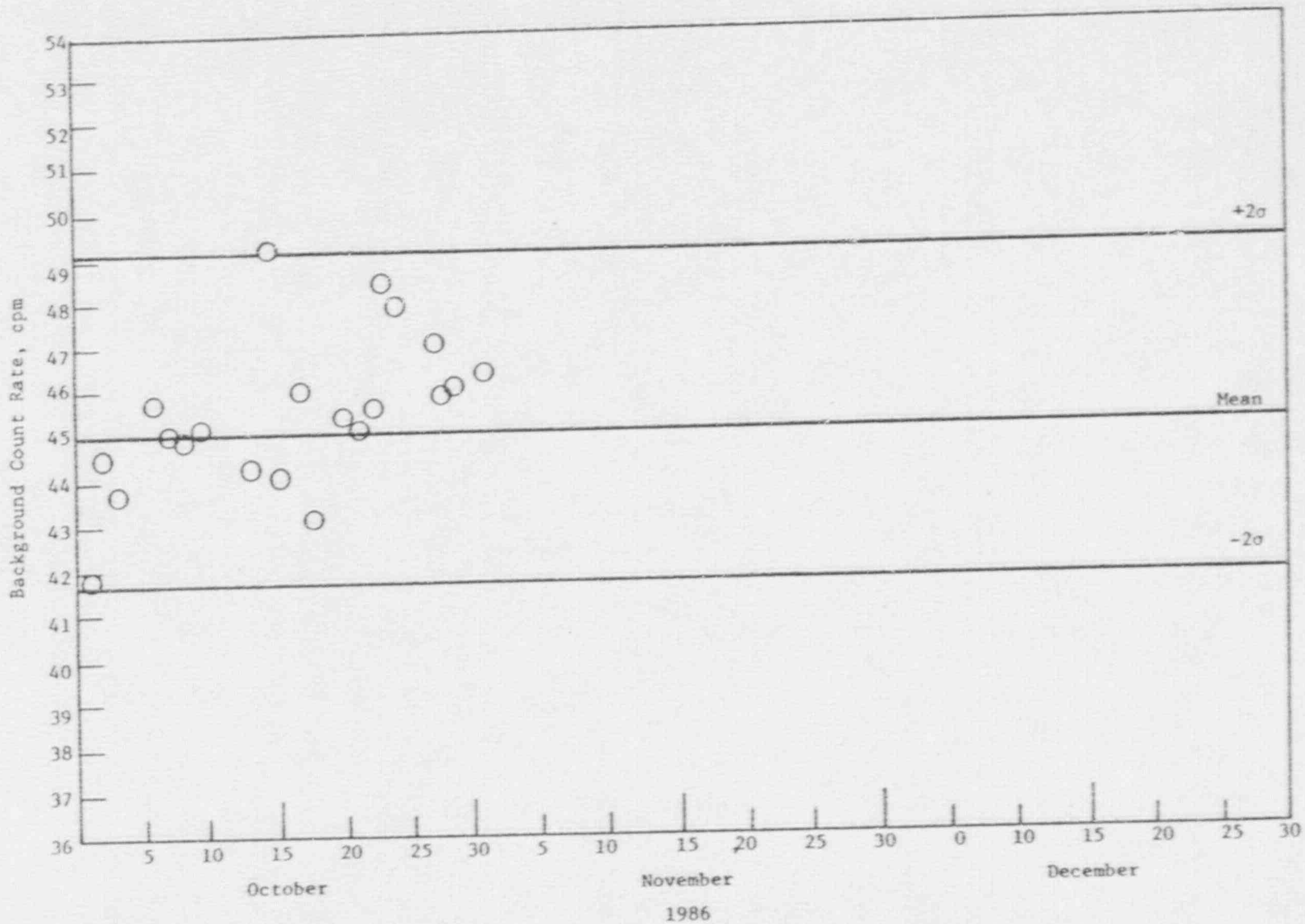


Figure 4-3. Beta-Gamma Background Control Chart PC-55, S/N 2712-07.

c. No correction was attempted for alpha radiation self-absorption due to the thickness of the deposited sample for smears, air samples, or any other objects counted.

Figures 4-4 and 4-5 show the 95% error band (1.96σ) associated with the reported activities in dpm for the alpha and beta-gamma counting of smears using the PC-55 counters. Note that the MDA for alphas is approximately 4-5 dpm, while the MDA for beta-gamma is approximately 35 dpm. A sample calculation, following standard statistical procedures*, is given below for beta-gammas.

Data: Counter efficiency, 43% (PC-55)

Background Count Time, t_B = 10 Minutes (Normal Procedure)

Sample Count Time, t_G = 1 Minutes (Normal Procedure)

Background Count, N_B = 500 (Normal Experience)

Sample Count, N_G = 60

Calculation:

Background Rate, $R_B = \frac{500}{10} = 50$ cpm

Gross Rate, $R_B = \frac{60}{1} = 60$ cpm

Net Count Rate, $R_N = 60 - 50 = 10$ cpm

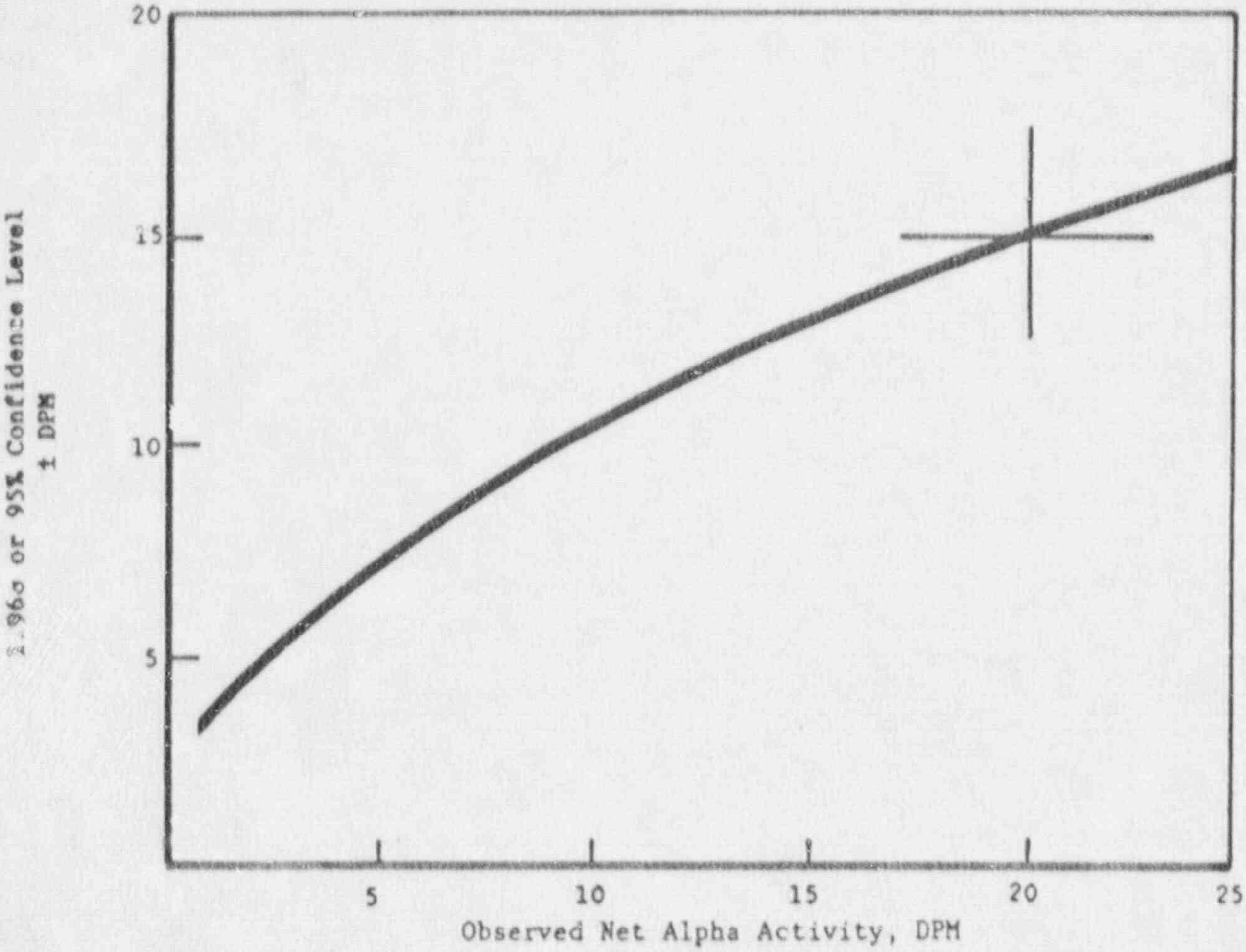
Background Standard Deviation, $S_B = \frac{\sqrt{500}}{10} = 2.236$

Gross Standard Deviation, $S_G = \frac{\sqrt{60}}{1} = 7.746$

Net Standard Deviation, $S_N = \sqrt{2.236^2 + 7.746^2}$

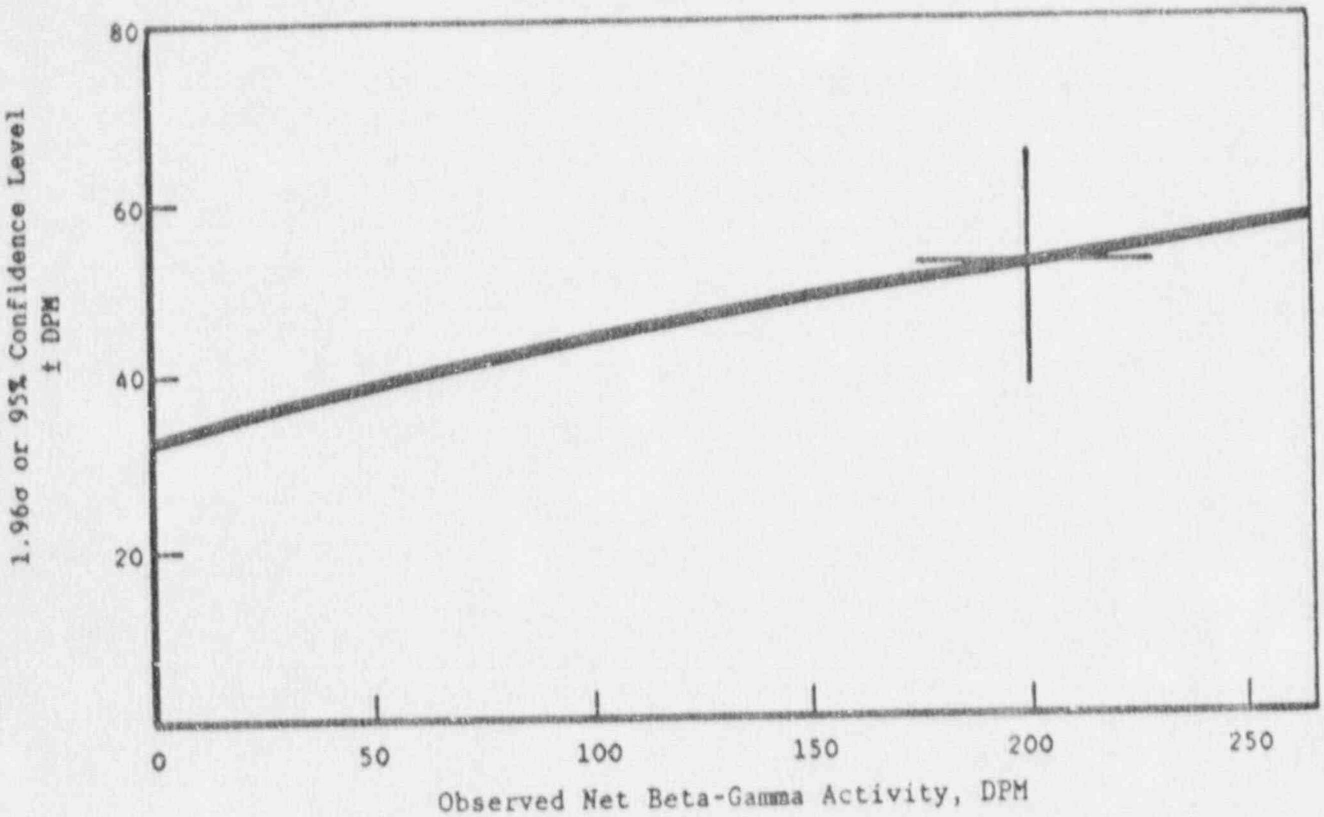
$= 8.062$

*For example: Volchock, H.L., and de Planque, G. (Editors), "EML Procedure Manual" HASL-3000-EI.25, 1982, EML, U.S. Dept. of Energy, 376 Hudson Street, New Work, NY 10014, Section A-06.



1. Background ≤1 DPM Averaged for 10 Minutes
2. 35% Counter Efficiency
3. 1.96σ or 95% Confidence Level
4. 1 Minute Counts

Figure 4-4. Statistical Probability Error of Counting Data at 95% Confidence Level for Alpha Activity.



(1) Background = 116 DPM Averaged for 10 Minutes

(2) 43% Counter Efficiency

(3) 1.96σ or 95% Confidence Level

(4) 1 Minute Counts

Figure 4-5. Statistical Probability Error of Counting Data at 95% Confidence Level for Beta-Gamma Activity.

Correcting for efficiency to dpm:

$$D_N = \frac{10}{0.43} = 23.3$$

$$S_{DN} = \frac{8.062}{0.43} = 18.8$$

Using two standard deviations for 95% probability gives a net value of 23 ± 38 dpm. Figure 4-4 gives the same answere when entered with 23 dpm.

4.2 SURVEY METHODS

The general survey procedure used for each room or area illustrated in Figure 4-6, was as follows:

- Scale layout drawings were prepared for each room or area. Separate layout drawings were required for the floor, walls, and ceiling. Any special fixtures, such as lighting, were identified.
- Each drawing was subdivided into small areas, typically 1 m^2. A number is assigned to each area in sequence. Separate numbers are assigned to any special fixtures.
- The same series of numbers are assigned to blank smear samples, a separate number for each smear sample.
- Next, trained radiation monitoring technicians survey for removable contamination. Each small area of the room is "wiped" with the smear samples numbered to correspond to the same number of the area of that room, as designated on the prepared map. An area of 100 cm^2 of the 1 m^2 area are covered when the smear paper is wiped over the surface using a moderate pressure. The area covered by the smear is not a small 10 x 10 cm^2 but 100 cm^2 over the entire area. To err on the safe side, the majority of the wipe samples had an area much greater than 100 cm^2 wiped.
- The smear samples are then counted using the PC-55 Gas Flow Proportional Counters.
- Areas where removable contamination is identified are subsequently cleaned using one of the several procedures applicable to removable contamination. As discussed in Section 5.0 of this report, these range from simply wiping or dry vacuuming to scrubbing with detergents or strong solvents followed by wet vacuuming.
- The area is rechecked using the smear technique and recleaned as necessary until the measured removable contamination is

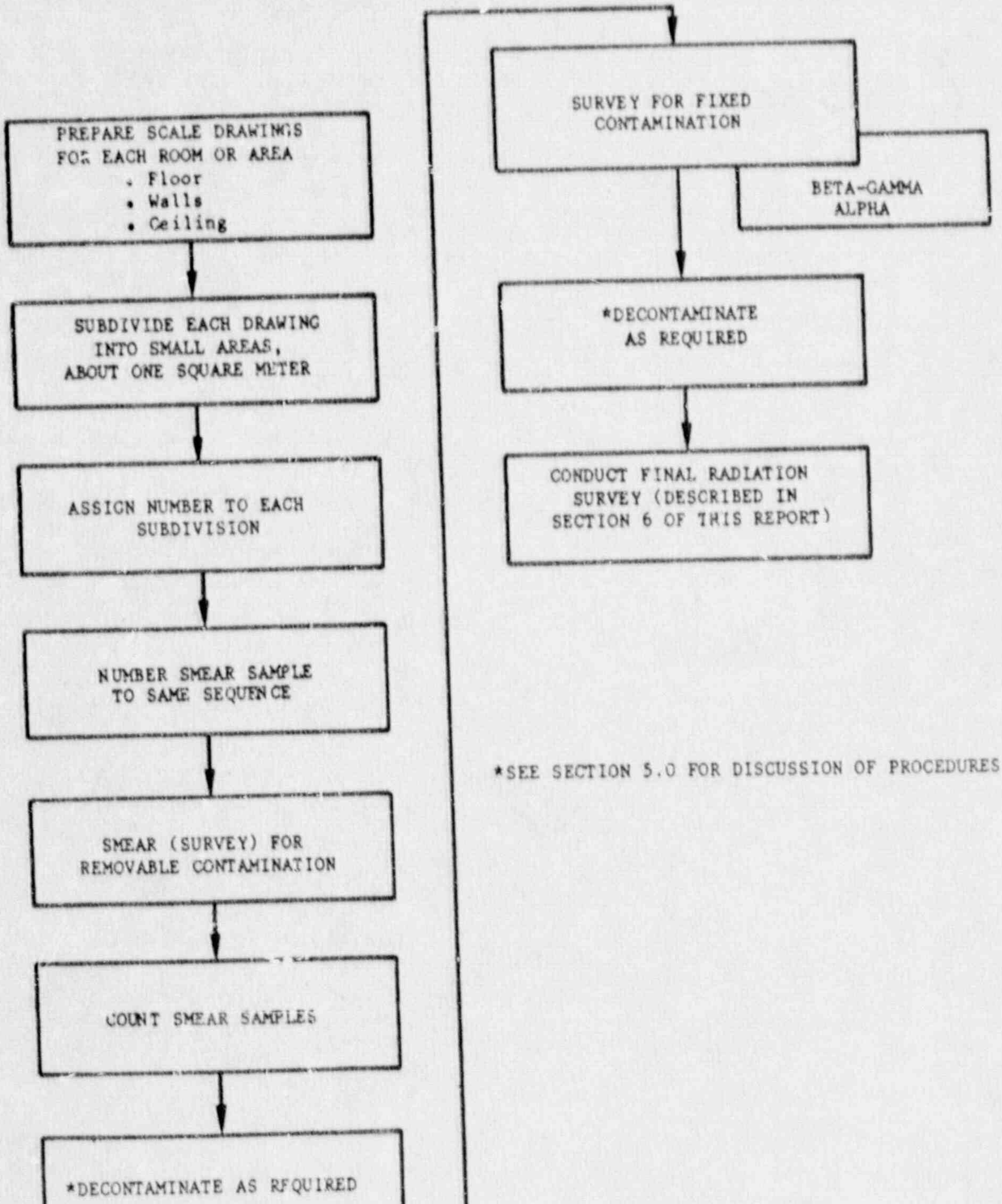


Figure 4-6. Summary Flowchart - Radiation Survey Procedures.

reduced to less than 20 dpm/100 cm^2 for alpha and less than 200 dpm/100 cm^2 for beta-gamma. These levels can be expressed at the 95% confidence level as <20 ±15 dpm/100 cm^2 for alpha activity and <200 ±53 dpm/100 cm^2 beta-gamma activity.

- Next, the area is surveyed for fixed alpha and beta-gamma contamination, using two or more of the survey instruments identified in Table 4-1. The beta-gamma survey proceeds rapidly, moving the instrument probe at a rate of about 1 foot/second across all surfaces. The alpha survey proceeds much more slowly. The instruments have a response time of about 12 seconds for alpha detection of low-level contamination. Therefore, the probe or sensor must be moved and stopped, moved and stopped many times to cover the total room surfaces.

- Areas where fixed contamination is found are decontaminated by one of the several methods discussed in Section 5.0 of this report. These range from vacuum abrasive blasting to destructive removal of the floor, wall, ceiling and/or fixtures.

In general, the initial radiation survey focused on areas where there was a high probability of finding contamination. This approach, permitted by knowledge of the prior uses of the facility by the personnel involved, proved effective and time saving. The final radiation survey, discussed in Section 6.0 of this report, was more extensive. Over 100-rooms in Building D were surveyed with nearly equal intensity. In this monitoring effort well over 55,000 smears were taken and counted for the total surface area in Building D. Alpha and beta-gamma surveys for fixed contamination were much more thorough. As delineated in Section 6.0 of this report, alpha surveys for fixed contamination covered the complete floor area, and a scan was made of every square foot of the wall and ceiling surfaces, with stationary readings taken approximately every square foot. Beta-gamma surveys were essentially continuous with floor monitors used for the floor area and the Micro-R/hr meter for all other surfaces.

4.3 ACCEPTABLE CONTAMINATION LEVELS

Table 4-3 presents the NRC guidelines for acceptable surface contamination levels as issued in July 1982 for the decontamination of facilities and equipment prior to release for unrestricted use or termination of licenses. Table 4-. shows the working limits used by the decontamination contractor.

Table 4-3. Acceptable Contamination Levels (NRC Guidelines).

Nuclides[a]	Average[b],[c],[f]	Maximum[b],[d],[f]	Removable[b],[e],[f]
U-nat, U-235, U-238, and associated decay products	5000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm α/100 cm^2	300 dpm α/100 cm^2	20 dpm α/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm α/100 cm^2	3,000 dpm α/100 cm^2	200 dpm α/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5,000 dpm $\beta\gamma$/100 cm^2 (0.2 mrad/hr at 1 cm)[f]	15,000 dpm $\beta\gamma$/100 cm^2 (1.0 mrad/hr at 1 cm)	1,000 dpm $\beta\gamma$/100 cm^2

[a] Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Measurements of average contaminant should not be averaged over more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[d] The maximum contamination level applies to an area of not more than 100 cm^2.

[e] The amount of removable radioactive materials per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbant paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined the pertinent levels should be reduced proportionally and the entire surface should be wiped.

[f] The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

Table 4-4. Decontamination Contractor Working Contamination Limits.

Radiation	Average[(b),(c),(f)]	Maximum[(b),(d),(f)]	Removable[(b),(e),(f)]
Alpha Contamination[(a)]	200 dpm/100 cm^2	600 dpm/100 cm^2	< 20 dpm/100 cm^2
Beta-Gamma Contamination	0.05 mrad/hr at 1 cm	0.2 mrad/hr at 1 cm	< 200 dpm/100 cm^2

(a) Due to the nature of the use of Building D, natural uranium, enriched uranium, thorium, and associated decay products are the principle contamination sources.

(b) As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

(c) Measurements of average contaminant should not be averaged over more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

(d) The maximum contamination level applies to an area of not more than 100 cm^2.

(e) The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbant paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

(f) The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitter should not exceed 0.05 mrad/hr at 1 cm and 0.2 mrad/hr at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

These are lower than the NRC-proposed levels by at least a factor of four. The working limits were those used in the radiation surveys to identify areas where decontamination was required.

It should be noted that the combinations of a low working limit and a 1-minute counting time for each smear allows both a rapid counting of the over 55,000 smears and assurance of low residual activity that approaches natural background levels. Also, note that the 20 dpm alpha working limit for removable contamination allows not more than 35 dpm with better than 95% confidence, and the 200 dpm beta-gamma working limit for removable contamination allows no more than 253 dpm with 95% confidence. These values are well below NRC-proposed limits, and they provide assurance that successful decontamination has been achieved.

If any contamination was located, the appropriate steps necessary to remove it were performed. These methods are described in Section 5.0. Surveys and decontamination were repeated as necessary so that the final radiation survey was below working limits in all areas. The final radiation survey is documented in the detailed reports for each room or area and is summarized in Section 6.0 of this report.

5.0 DECONTAMINATION PROCEDURES

This section describes the overall decontamination process, including personnel training, equipment used, procedures used, and waste disposal methods.

5.1 ORGANIZATION

The organization of the decontamination project is ented in Figure 5-1. Its two elements, Quality Control and Decontamination, are under the direction of the Program Manager. The decontamination crew monitors its own work as decontamination proceeds. The separate quality control function performs the final radiation monitoring survey. This approach provides an independent verification that radiation contamination has been reduced well below the guideline levels set forth by the Nuclear Regulatory Commission (NRC) for unrestricted use of the facilities.

The Quality Control organization is supervised by an experienced radiation specialist who, in turn, is supported by trained Radiation Monitoring and Measurements Technicians. The key responsibilities of the Radiation Monitoring Technicians included:

- Predecontamination surveys
- Final radiation monitoring surveys
- Calibrating radiation survey and measurement instruments
- Fitting and cleaning respirators
- Collection of air, soil, and residue samples
- Calibration of air sampling equipment.

The key responsibilities of the Measurements Technicians included:

1. Calibration and operation of radiation counting equipment
2. Processing of large numbers of smear samples collected during decontamination surveys for alpha and beta-gamma contamination, both during decontamination and in support of the final radiation survey
3. Receiving and recording in an organized format data from all aspects of the decontamination work.

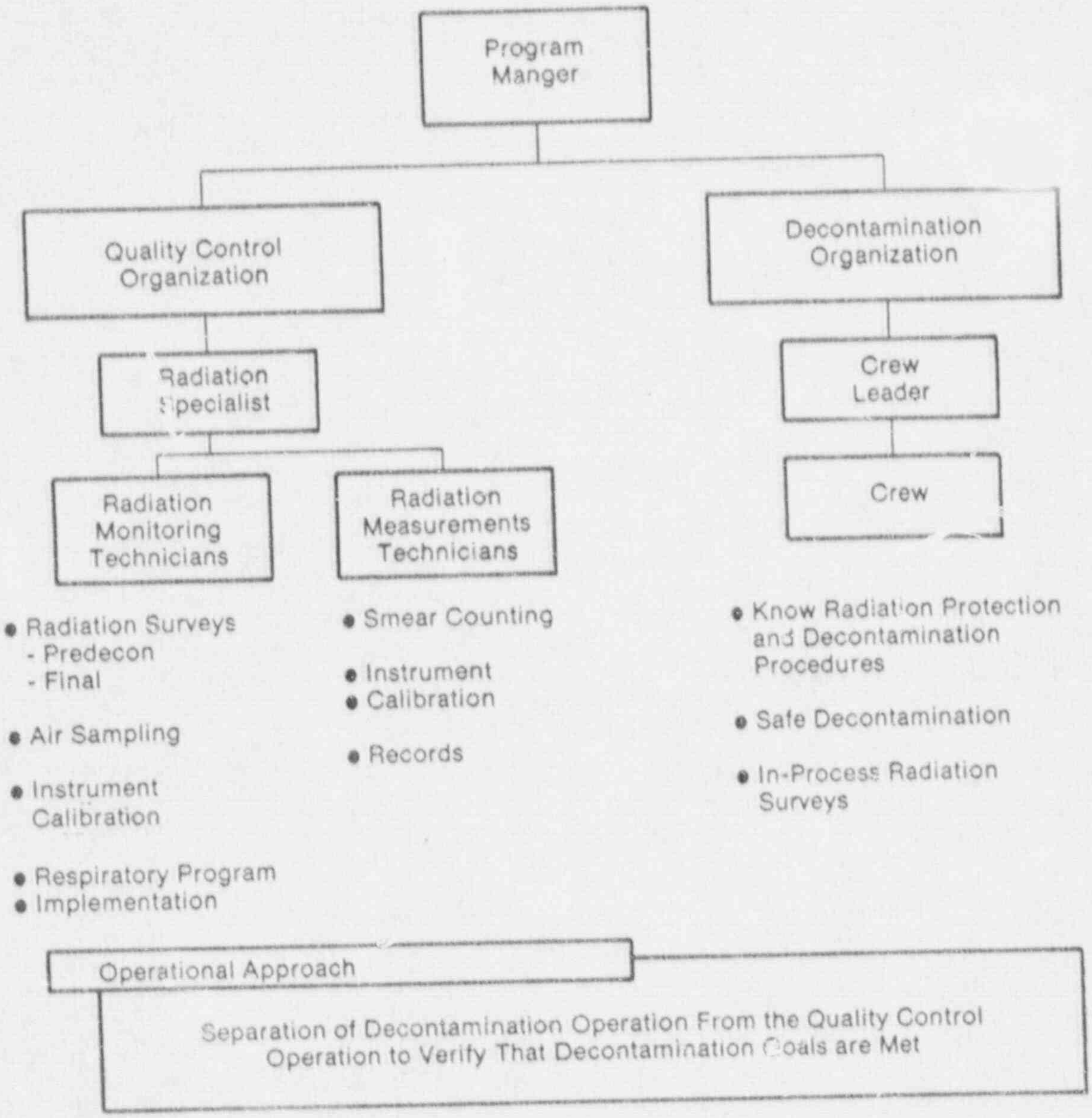


Figure 5-1. Decontamination Program Organization to Assure Independent Verification That Decontamination Goals are Met.

4. Maintaining the files necessary to (a) permit efficient recovery of information, (b) assist in the evaluation of the status of the decontamination progress, and (c) support full documentation of the results of the decontamination of Building D.

The Decontamination Organization is led by a supervisor and two crew leaders. All personnel are trained in, and are required to demonstrate their knowledge of, radiation protection and decontamination procedures, including the use and limitations of radiation detection and survey instruments. The key responsibilities of the Decontamination Organization included:

- Assist in predecontamination surveys
- Perform the decontamination work in a safe and prescribed manner
- Conduct radiatiou contamination surveys as the work progresses
- Use protective clothing and equipment (such as respirators)
- Perform decontamination activities without further spreading the contamination being removed.

5.2 TRAINING

All personnel engaged in the decontamination program were trained in radiation safety, inc. ling safe decontamination procedures. This training program was organized and instructed by two specialists in the area of nuclear health physics and safety, each with over 30 years of experience in this field. The key elements of this training program addressed:

- Characteristics of nuclear radiation
- Principles and practices of radiation protection
- Radioactivity measurements standardization and monitoring techniques and instruments
- Calculations basic to use and measurement of radioactivity
- Biological effects of radiation
- Decontamination procedures
- Respiratory protection
- Written examination.

These are further amplified in the following paragraphs.

5.2.1 Characteristics of Nuclear Radiation

Neutron, alpha, beta, and gamma radiation were described and reviewed to the level necessary to provide a basic understanding of their sources and characteristics and to provide the basis for the balance of the training; that is, radiation effects, detection, measurement, and protection. The major portion of this instruction employed a course developed for and published by the AEC*. Emphasis was placed on the radiation types known to be present in the decontamination of Building D: alpha and beta-gamma, no neutron sources.

5.2.2 Principles and Practices of Radiation Protection

The critical element of the training addressed the safe principles and practices of radiation protection with emphasis on the procedures targeted for this decontamination program. The care, selection, and use of protective apparel and equipment was addressed, including respirators, safety glasses, coveralls, and shoe covers. Surveying and monitoring procedures required for day-to-day operations were explained and delineated. Requirements for posting and control of access to the contaminated areas were defined. The care and use of personnel monitoring devices (such as, film badges, pocket dosimeters, and air samples) and requirements for bioassay were presented. The requirements for packaging the contaminated material removed during decontamination for shipping and burial were reviewed. This included the requirement to safely solidify all liquid waste that results from scrubbing operations.

5.2.3 Radioactivity Measurements

Monitoring techniques and the use of the instruments described in Section 4.0 of this report were covered, including the need and procedures to calibrate these instruments to standard sources traceable to the National Bureau of Standards. Survey and monitoring techniques were defined and practiced with the various instruments for both area surveys and for a contamination survey of equipment and small items. Removable and fixed contamination were

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*Wade, J.E. and Cunningham, G.E., "Radiation Monitoring, A Programmed Instruction," USAEC Division of Technical Information, 1967.

described: for example, fixed contamination is defined as that radioactivity remaining on a surface after repeated decontamination attempts fail to significantly reduce the contamination level. The different monitoring approaches for removable (smear technique) and fixed contamination were reviewed and practiced. Air sampler techniques for both personnel and area samples were revie[illegible] and demonstrated, including air sampler calibration procedures.

5.2.4 Calculations

The calculations necessary to support and use radiation monitoring data were reviewed and practiced. These included such items as the calculation of allowable exposure time and calibration of air samplers.

5.2.5 Biological Effects

The potential effects of exposure to internal and external radiation were reviewed. Emphasis was placed on the "as low as reasonably achievable" (ALARA) exposure guideline to minimize the biological effects.

5.2.6 Decontamination Procedures

The procedures employed in the decontamination of Building D are detailed in Paragraph 5.4 below. The training program provided instruction in these areas and was followed by practice work conducted in noncontaminated areas.

5.2.7 Respiratory Protection

As an essential requirement of the training program, all personnel were instructed on the respiratory protection program already in place at the contractor's decontamination facility. The scope of this documented program included the following:

- The need for air sampling and other surveys sufficient to identify the hazard, to evaluate individual exposures, and to allow the proper selection of respiratory protection equipment
- Adequate individual personnel fitting of respirators and the procedures to ensure their testing for operability before each use. (All personnel underwent a qualitative fit test using amyl acetate and an acid fume smoke tube to emphasize the need for a proper fit.)

- Procedures for maintenance to ensure the full effectiveness of respiratory protective equipment, including procedures for cleaning and disinfection, decontamination, inspection, and storage

- Operational and administrative procedures for control, proper use, and return of respiratory protective equipment

- As appropriate, bioassays and other surveys to evaluate individual exposures and to assess the protection actually provided

- Requirement for records sufficient to permit periodic evaluation of the adequacy of the respiratory program

- The need for a medical examination by a physician, prior to assignment of any individual to tasks requiring the use of respirators, to verify that such an individual has no respiratory ailment and is physically able to perform the work while using respiratory protection equipment. The medical status of each respirator user is to be reviewed at least annually.

- The requirement to use only equipment approved under appropriate Approval Schedules in 30 CFR Part II of USBOM/NIOSH.

5.2.8 Final Examination

At the conclusion of the formal training, all personnel were required to take and pass a final exam. A grade of 90% or better was that of all radiation monitoring personnel. Continuing education and discussion of problem areas were held on a monthly basis, and more frequently when deemed necessary.

5.3 EQUIPMENT

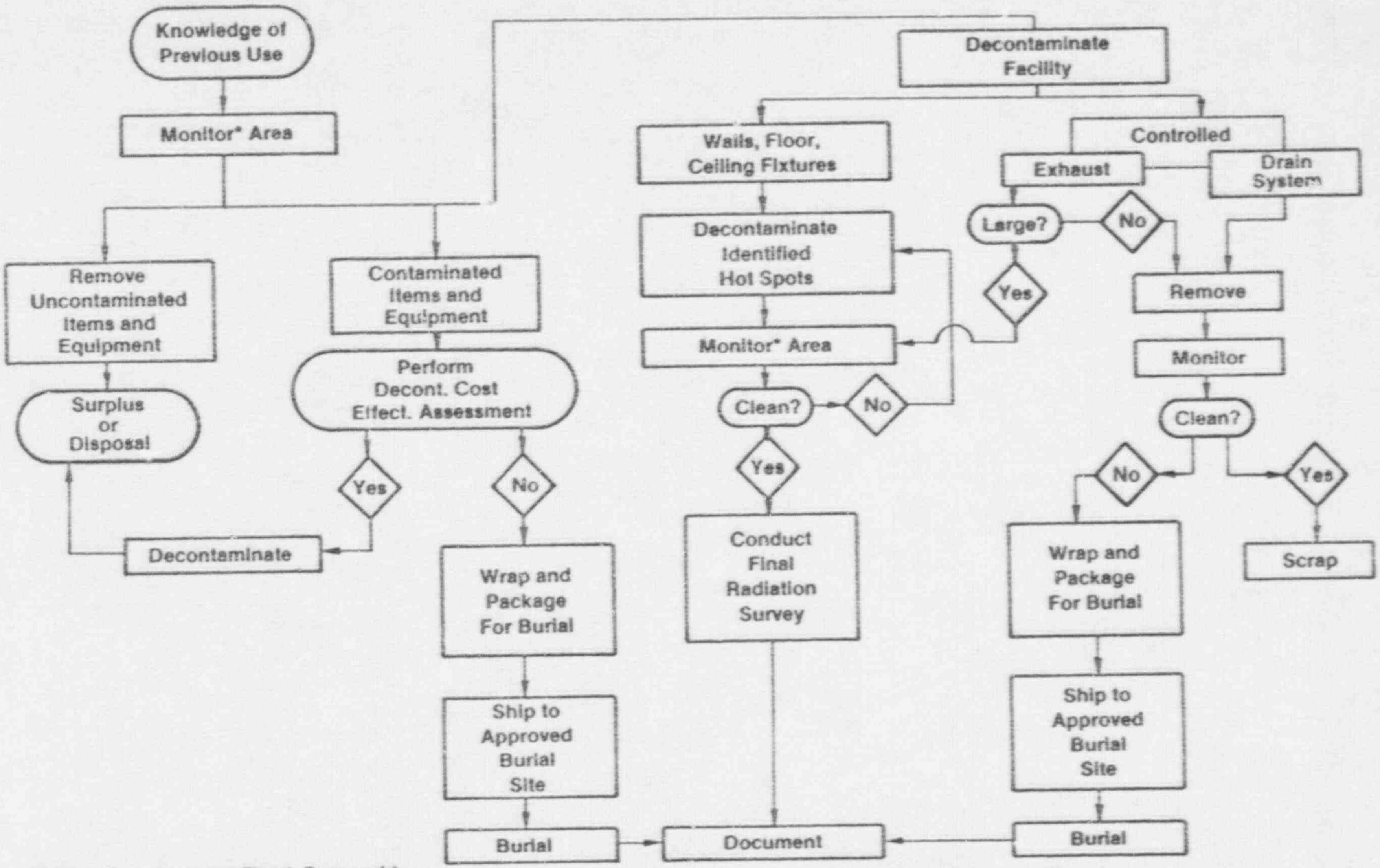
The equipment used to clean or otherwise remove contaminated material included HEPA-filtered vacuum cleaners, steam cleaners, water evaporators, HEPA-filtered vacuum grit blasters, and power grinders for removal of surface contamination in ways that avoided spreading the contamination. Also required were devices for removing larger amounts of material, such as air hammers, electric saws, and power drills. In order to reach the upper areas of several rooms, safety scaffolding and platform lifts were used.

5.4 OPERATIONAL APPROACH

This paragraph details the operational approach employed in the decontamination of Building D. This delineation of effort integrates and expands the monitoring and survey work outlined in Section 4.0, showing the close interrelation between the decontamination work and the survey work needed to assess the decontamination status throughout the decontamination process to or below the levels previously set forth in Table 4-3. As presented in Paragraph 5.1, final radiation monitoring was accomplished by the separate Quality Control Organization to assure that these goals were met.

The operational approach, summarized in Figure 5-2, generally included the following steps:

- Monitor rooms; α, $\beta\gamma$; Fixed, Removable; Predecontamination report written or file maintained
- Monitor all furniture, materials, equipment; α, $\beta\gamma$; Fixed, Removable
- Remove all items free of contamination for surplus and/or disposal
- Remove all hazardous chemicals for disposal, decontaminate containers if needed
- Decontaminate all easily decontaminatable items for surplus or disposal
- Wrap and seal all contaminated items (equipment) for surplus or disposal
- Monitor ceilings; α, $\beta\gamma$; Fixed, Removable. Decontaminate hot spots. Remonitor.
- Monitor all ceiling light and electrical fixtures; inside, outside; α, $\beta\gamma$; Fixed, Removable. Decontaminate hot spots. Remonitor.
- Monitor all walls; α, $\beta\gamma$; Fixed, Removable. Decontaminate hot spots. Remonitor.
- Monitor all wall fixtures; α, $\beta\gamma$; Fixed, Removable. Decontaminate hot spots. Remonitor.
- Monitor all floors; α, $\beta\gamma$; Fixed, Removable. Decontaminate hot spots. Remonitor.
- Remove controlled exhaust systems.
- Monitor all removed exhaust systems; α, $\beta\gamma$; Fixed, Removable. Wrap contaminated ducting for subsequent burial. Move clean ducting to scrap metal for disposal.



*Alpha, Beta-Gamma; Fixed, Removable

Figure 5-2. Operational Procedure Summary.

- Monitor large exhaust plenums. Decontaminate hot spots. Remonitor.

- Remove controlled drain system, retention storage tanks, pumps, underground and above ground piping. Wrap and crate contaminated elements for subsequent burial. Monitor all openings from which controlled drains were removed. Remove any contaminated soil for disposal. Remonitor.

- Restore all excavations or access holes in floors, ceiling, walls, roof, etc., to safe condition.

- Conduct final monitoring by the separately trained Quality Control organization:

  a. Smears taken randomly over a 1 m^2 area α, $\beta\gamma$. (Exception: Attic area smears taken randomly over 9 m^2 areas; α, $\beta\gamma$.)

  b. β, γ instrument survey taken by moving instrument or probe across surface being monitored at about 1 ft/s, to 2 inches from surface while observing all readings greater than background.

  c. Alpha instrument survey taken by holding probe 0.25 inch or closer to surface being monitored and allowing the 12-second instrument response time for correct readings. Observe all readings greater than background. Move instrument across surface taking one reading per foot.

  d. Instrument kept close to the surface being monitored. If a reading or instrument needle indication is observed, check area immediately around probe area to see if there is any evidence of contamination.

  e. Decontamination crew required to reclean any spots or areas where any radiation is detected. For these areas, return to Step a and reinitiate the final monitoring process.

  f. The final monitoring process was conducted for all surfaces and fixtures (such as, lighting) in all rooms and areas of Building D.

5.5 METHODS OF DECONTAMINATION

Decontamination procedures followed acceptable industrial practices for maintaining cleanliness and removing contaminants such as surface dirt, oils, scale deposits, chemical stains, oxide film, etc. Decontamination methods ranged from simple procedures such as hand wiping to comp.ex operations involving heavy mechanical equipment. Techniques used also depended on the type of material contaminated.

5.5.1 Nondestructive Decontamination

Nondestructive decontamination refers to those methods such as manual or mechanical cleaning, soaking and spraying, grinding, or vacuum blasting that do not remove more than a thin surface layer.

There were a number of localized areas in Building D that required non-destructive decontamination of low-level fixed alpha and/or beta-gamma radiation. The techniques used are discussed in the following paragraphs.

5.5.1.1 Manual Cleaning

Manual cleaning includes such procedures as wiping, scrubbing, mopping, etc., and in general is an effective method of removing low or moderate levels of contamination on nonporous or nearly nonporous surfaces. Water and a variety of detergents, solvents, chelating agents, and other chemicals were used. Manual cleaning usually presents minimal airborne and surface contamination control problems. Care was taken in surface cleaning to remove alpha contamination to assure that any residual activity is not coated or shielded in any manner that would prevent its detection by self-absorption. For example, a floor that is monitored for alpha contamination immediately after washing and apparent initial drying will not indicate any alpha activity. But if allowed to dry thoroughly for 24 hours, gross contamination can be detected.

5.5.1.2 Mechanical Cleaning

Mechanical cleaning includes such decontamination methods as vacuuming, high-pressure steam and water cleaning, and soaking. These methods are generally associated with decontamination of highly contaminated equipment but have application with lower levels of contamination on facilities.

Vacuuming, Wet or Dry - Vacuuming is generally effective in removing loose particulate contamination, and is frequently used as an initial decontamination step preparatory to manual cleaning. Vacuum systems were properly filtered with High Efficiency Particulate Aerosol (HEPA) filters to prevent the spread of contamination to surrounding areas and reduce the hazard of airborne contamination. The operation of one type of HEPA-filtered vacuum unit used is shown in Figure 5-3. The Hild unit is designed so that it can be mounted on a standard 55-gallon drum, as illustrated. The vacuumed waste, wet or dry, is collected in this drum. The salient feature of this vacuum system is that the electric motor cooling airflow is separate and independent from the HEPA-filtered vacuum airflow. The vacuum airflow does not cool the electric motor. This feature, therefore, assures that the electric motor does not become contaminated.

The Nilfisk HEPA-filtered vacuum unit was also used in this work. This system is illustrated schematically in Figure 5-4. It features a first-stage centrifugal separation, a main filter to collect the larger dust particles, and a final prefiltering micro filter to protect the motor, followed by an absolute or HEPA exhaust filter. The dust is collected in sealable bags for safe disposal.

The retention efficiency of the HEPA-filtered vacuum units exceeds absolute standards of 99.9% at 0.3 microns. Care was taken to ensure that the concentration of radioactive material in the vacuum hose or filtered collection tank did not create excessive radiation exposure rates to personnel.

Jet Cleaning - High-pressure steam and water used alone or mixed with chemicals and detergents are effective methods for attaining high decontamination factors. Equipment of this type is ideally suited for remote operation and for cleaning large surface areas. High-pressure jet cleaning has the disadvantage of spreading contamination over a large area. However, it can be effective when used in an area where preplanning countermeasures assure that this spreading problem is avoided.

Soaking and Spraying - Soaking and spraying is used extensively for decontamination of small and moderate size material and equipment. Both methods make use of chemical solutions and may require support services like catch tanks, liquid recycle ability, and filtered ventilation systems. Spraying has the advantage of combining mechanical action as well as chemical action; however, in some cases the shape of the object being cleaned prevents

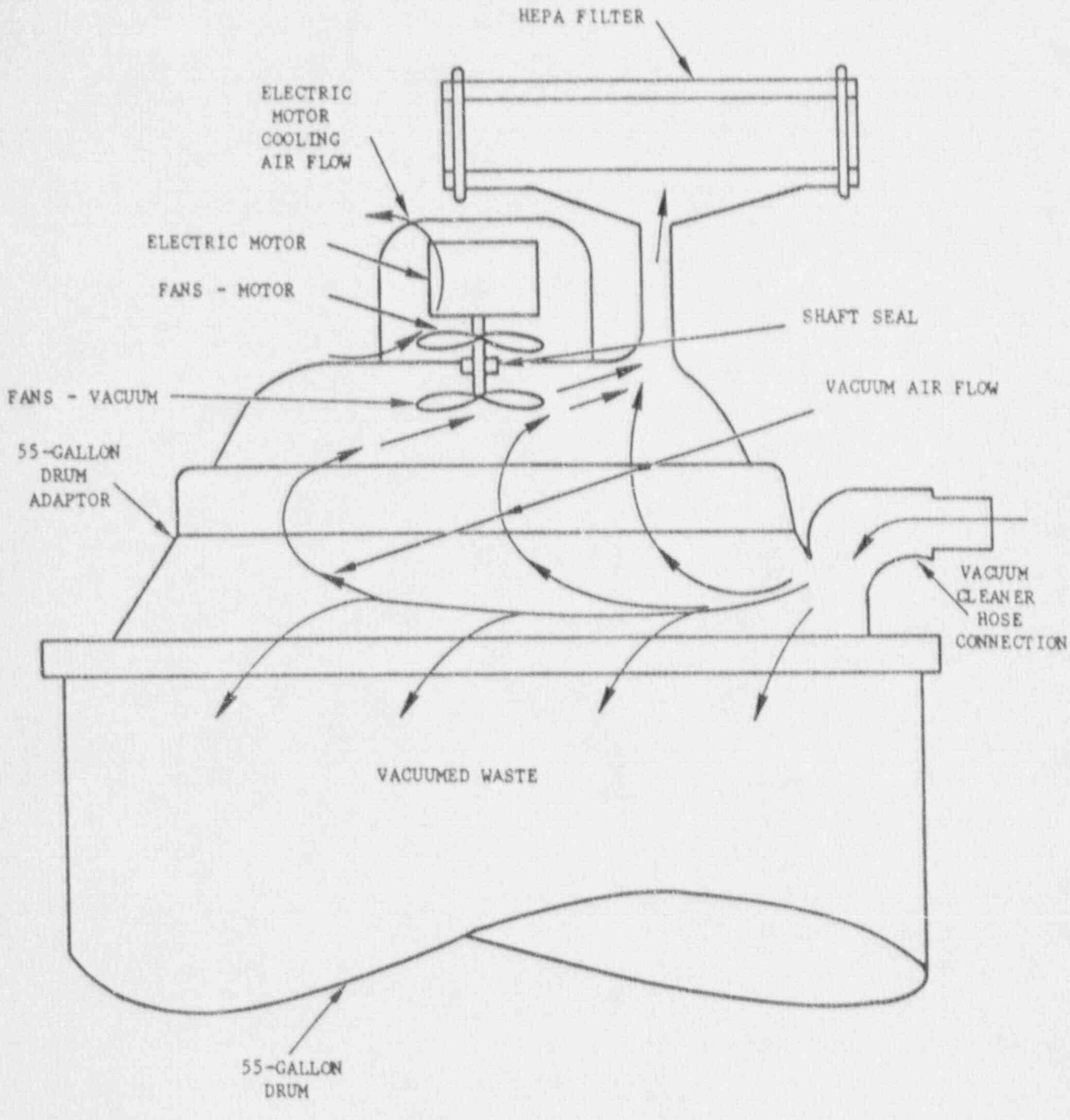


Figure 5-3. Operating Schematic - Hild Wet-or-Dry Vacuum Cleaner

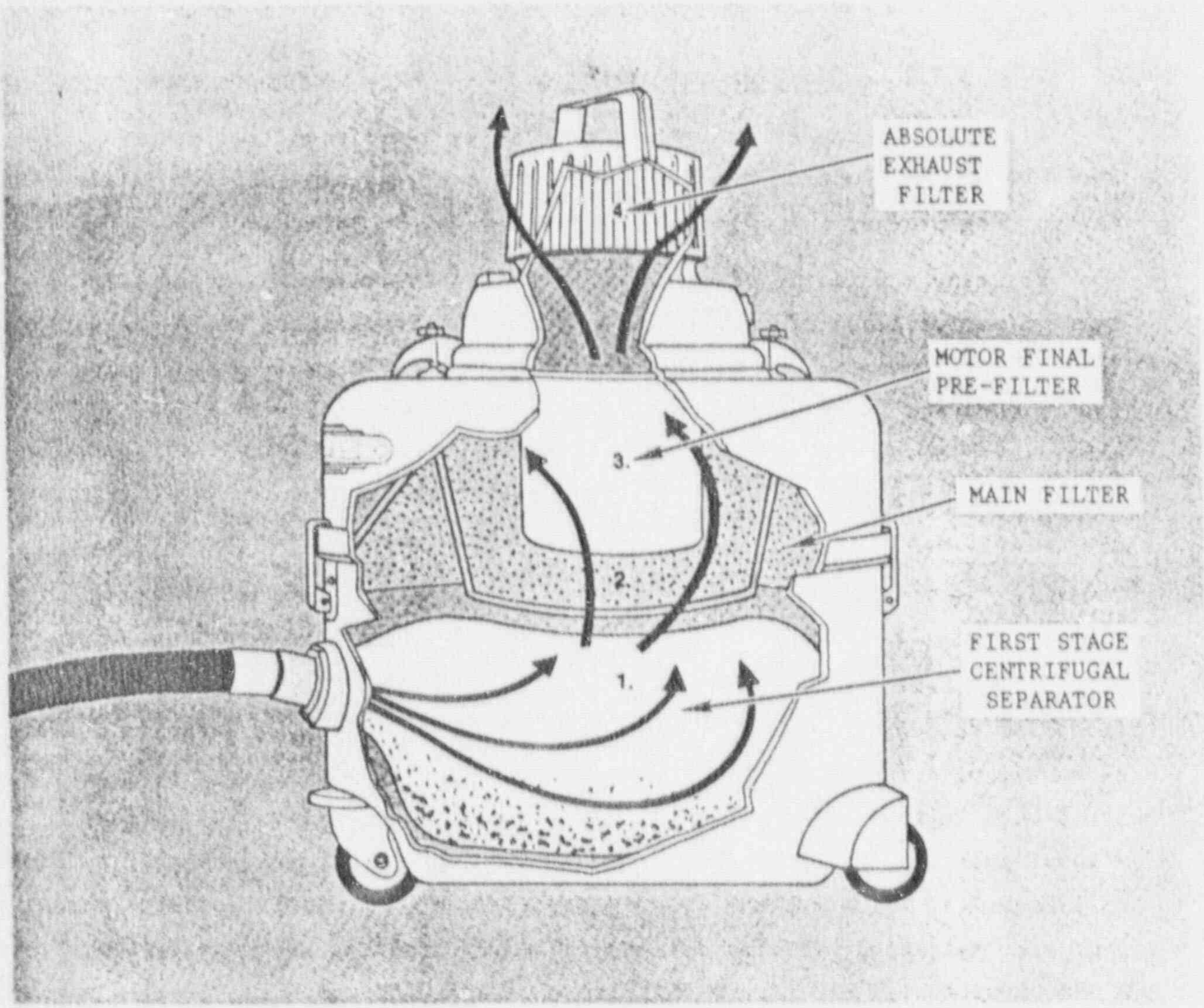


Figure 5-4. Nilfisk HEPA Wet-or-Dry Vacuum.

effective cleaning action on all surfaces. Soaking provides good access to surfaces but does not provide mechanical action.

5.5.1.3 Grinding and Abrasive

Cleaning procedures employing grinding or abrasive action are effective means of decontaminating metal and concrete surfaces provided alteration of the surface area of the object being cleaned can be tolerated.

Grinding - Grinding of surfaces to remove contamination is usually limited to small objects or isolated spots of contamination where the surface is reasonably smooth. Grinding normally produces a high decontamination factor (DF) and is economical. Commercial grinders were used. Grinding inherently leaves residual contamination on the surface of the object being cleaned and therefore usually requires final cleaning by some other method (vacuuming, wiping, etc.). Grinding frequently produces particulate air activity and is generally not economical for large surface areas.

Vacuum Abrasive Blasting - Vacuum abrasive blasting has a number of advantages over grinding. It is rapid, provides a high DF, is effective on irregular shaped surfaces, and can be used for large areas. Abrasive blasting makes use of a large variety of abrasives (sand, shells, glass beads, metals, etc.) with velocity, shape, and size of the abrasive influencing surface removal characteristics. Airborne contamination and the spreading of surface contamination, which are the prime disadvantages of ordinary abrasive cleaning, were minimized by using a vacuum abrasive blasting cleaning system equipped with high efficiency filters. Operation of the HEPA-filtered vacuum abrasive blaster is illustrated in Figure 5-5.

Operation of the vacuum blaster unit is conventional in that the air hose, connected to a 100-psi shop-air supply, entrains the abrasive material and delivers the mixture to the standard gun (see Figure 5-6) which is in contact with the surface being abraded. The mixture of air, abrasive, and abraded products are immediately and continuously removed through the vacuum hose. The abrasive material and medium weight dust (abraded products) are separated by the vacuum blaster unit as shown in Figure 5-5.

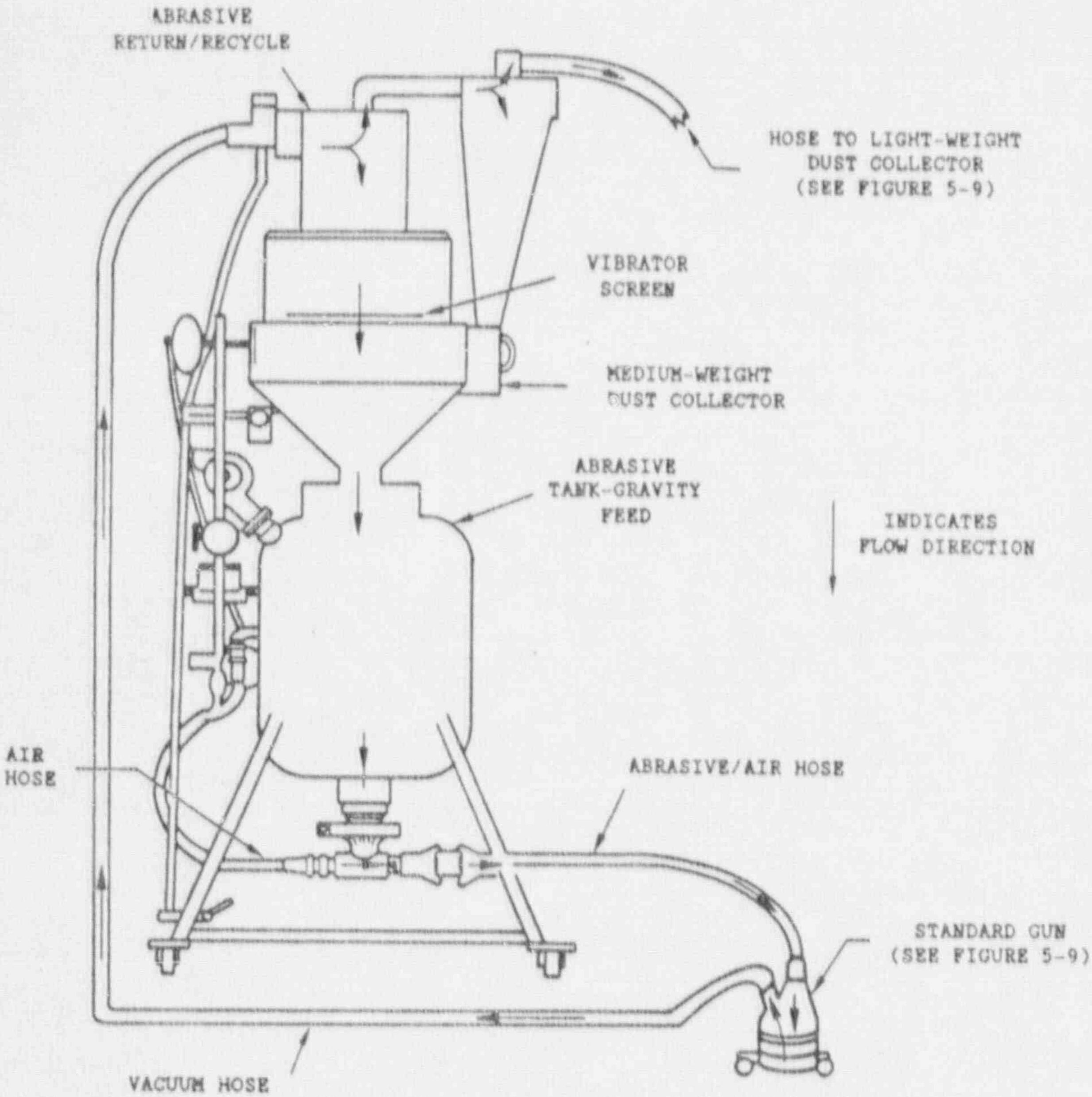


Figure 5-5. Schematic - Operation of Super Utility Vavu-Blast System.

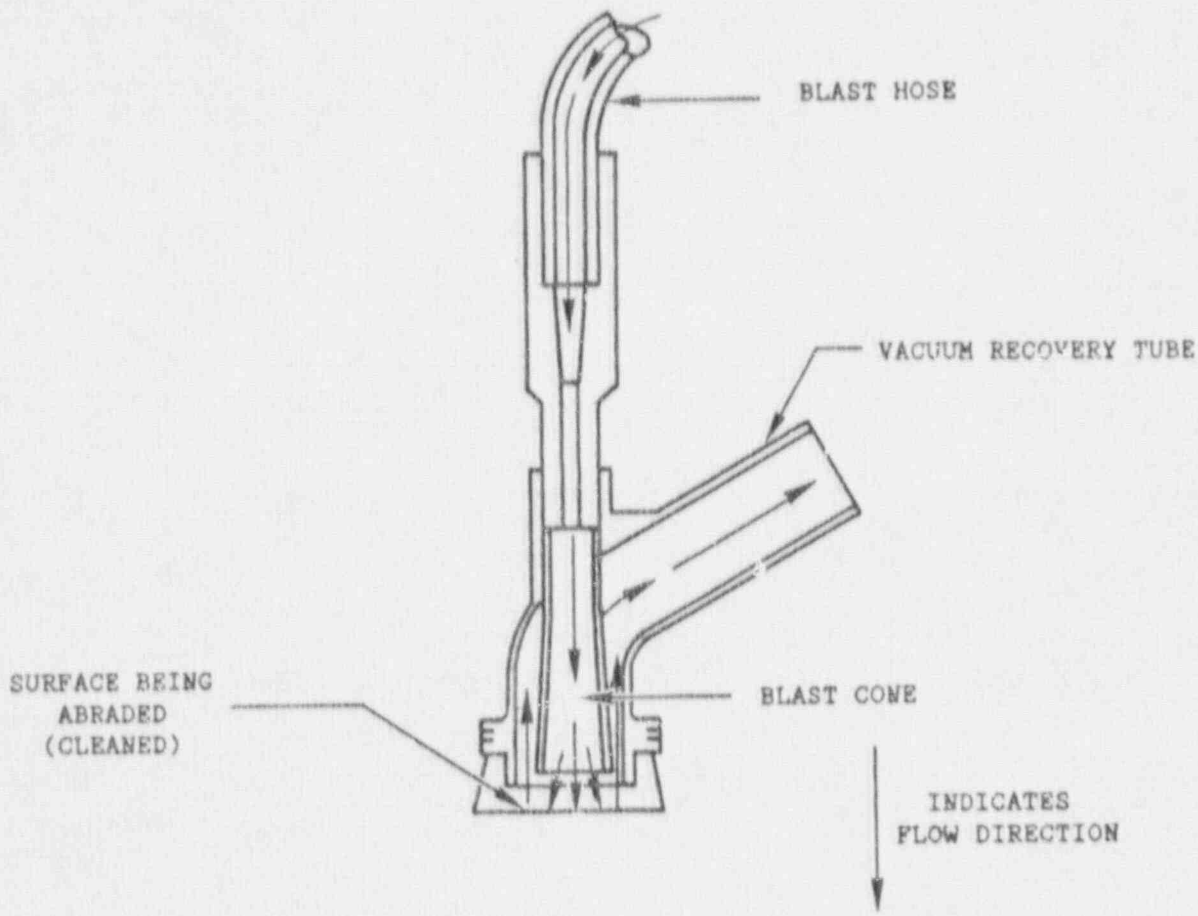


Figure 5-6. Schematic - Details of Standard Gun Operation, Vacu-Blast System.

The air and the lightweight dust (abraded products) then travel by means of a hose to the vacuum unit shown schematically in Figure 5-7. The "as purchased" vacuum and filter unit was encased in a wooden structure which is airtight except for the large HEPA filter through which the exhaust passes. This HEPA filter feature was especially added for this decontamination program in order to minimize, to the greatest extent possible, the chance of spreading contamination.

This method of decontamination was used most effectively and predominantly for the removal of fixed contamination from Building D.

5.5.2 Destructive Decontamination

Destructive decontamination requires physical removal of contaminated parts or sections. Generally, little or no effort is made to clean the contaminated items prior to disposal as radioactive contaminated waste. Containment and other radiological controls associated with destructive removal are dependent on contamination levels, nature of containment and physical characteristics of the part.

There were three major items that required destructive decontamination in Building D.

- Controlled liquid waste drain system
- Controlled exhaust ventilation system
- Floors in the Radioactive Materials Laboratory.

In addition, there was some small destructive decontamination in the form of partial removal of walls and floors required in a few areas of Building D Laboratory.

5.6 WASTE DISPOSAL

Disposal of contaminated waste was performed by properly packaging and sealing all radioactive waste in DOT-approved shipping containers with burial at NRC approved sites.

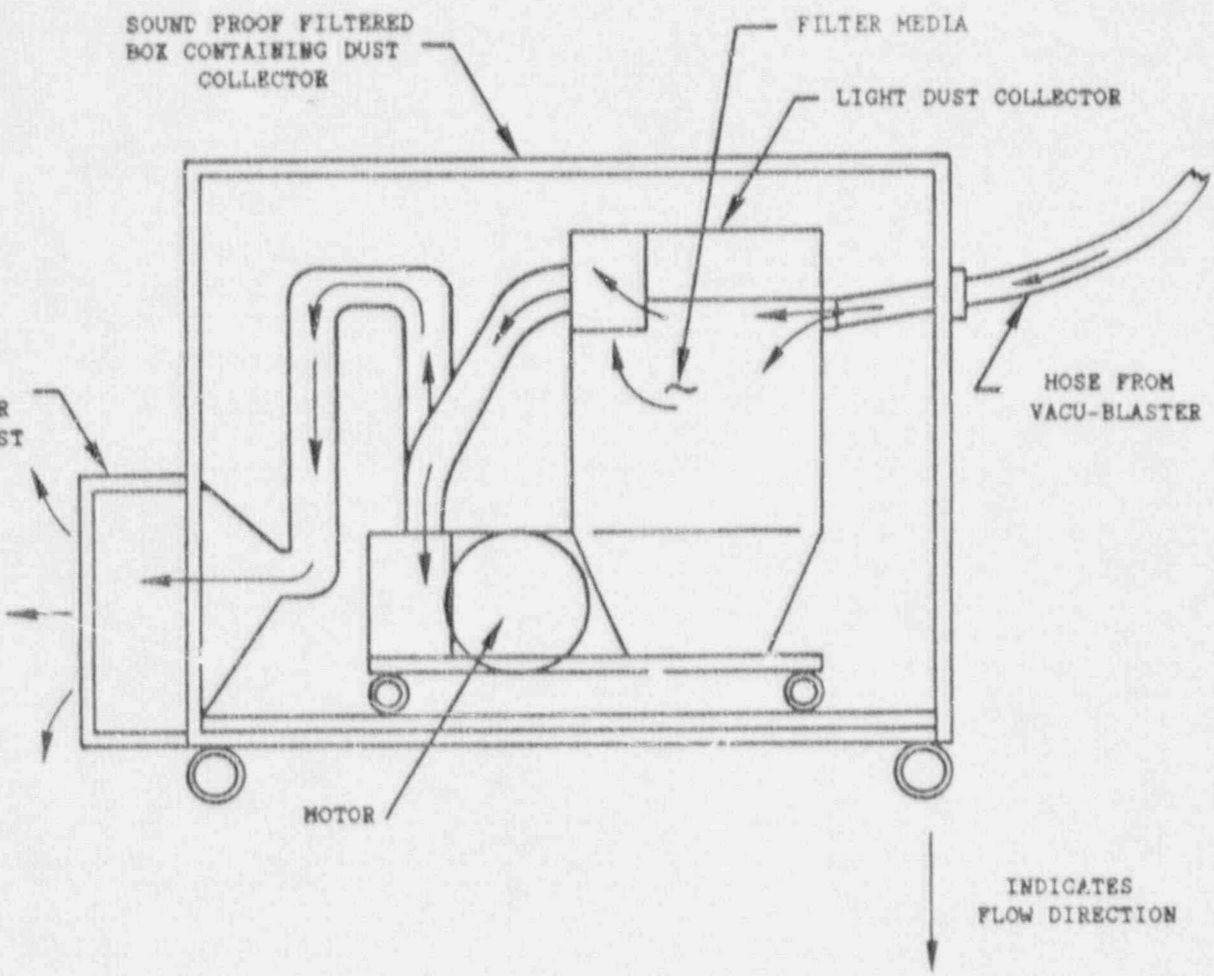


Figure 5-7. Schematic - Operation of Vacuum and HEPA Filter Unit, Vacu-Blast System.

6.0 FINAL RADIATION SURVEY

This section describes how the final radiation survey was accomplished and summarizes the results of this survey of Building D at the conclusion of decontamination.

6.1 OPERATIONAL APPROACH

The final monitoring of the various rooms and areas in Building D was initiated when it was demonstrated by radiation surveys that all contamination had been removed. Ideally, the final monitoring would prove that all contamination had indeed been removed. Realistically, the final monitoring initially identified additional localized contamination in about 10% of the rooms and areas of Building D. These contaminated spots were then decontaminated and the monitoring of that location repeated until the levels consistent with the goals established for this program were achieved (previously presented in Table 4-3).

The operational approach used in the final monitoring process is presented in Figure 6-1 and includes the following steps:

1. Scale maps of the floor, walls, and ceiling were prepared for each room or area.

2. Each map was then divided into separate areas, usually about 1 m^2. Each of these areas was given a separate number which forms the basis for the records of this final survey.*

3. Smear paper samples were prepared by numbering each with a number assigned to each area of the floor, walls, and ceiling maps for each room or area.

4. Each room or area was smeared to determine the presence of removable contamination. This was performed using the numbered smear papers and their corresponding maps.

5. The smear samples were then counted for alpha, beta, or gamma contamination using either the PC-3A/B or the PC-55 Gas Flow Proportional Counter.

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*These numbered maps, together with the corresponding survey results, are included in the detailed reports prepared for each room or area of Building D.

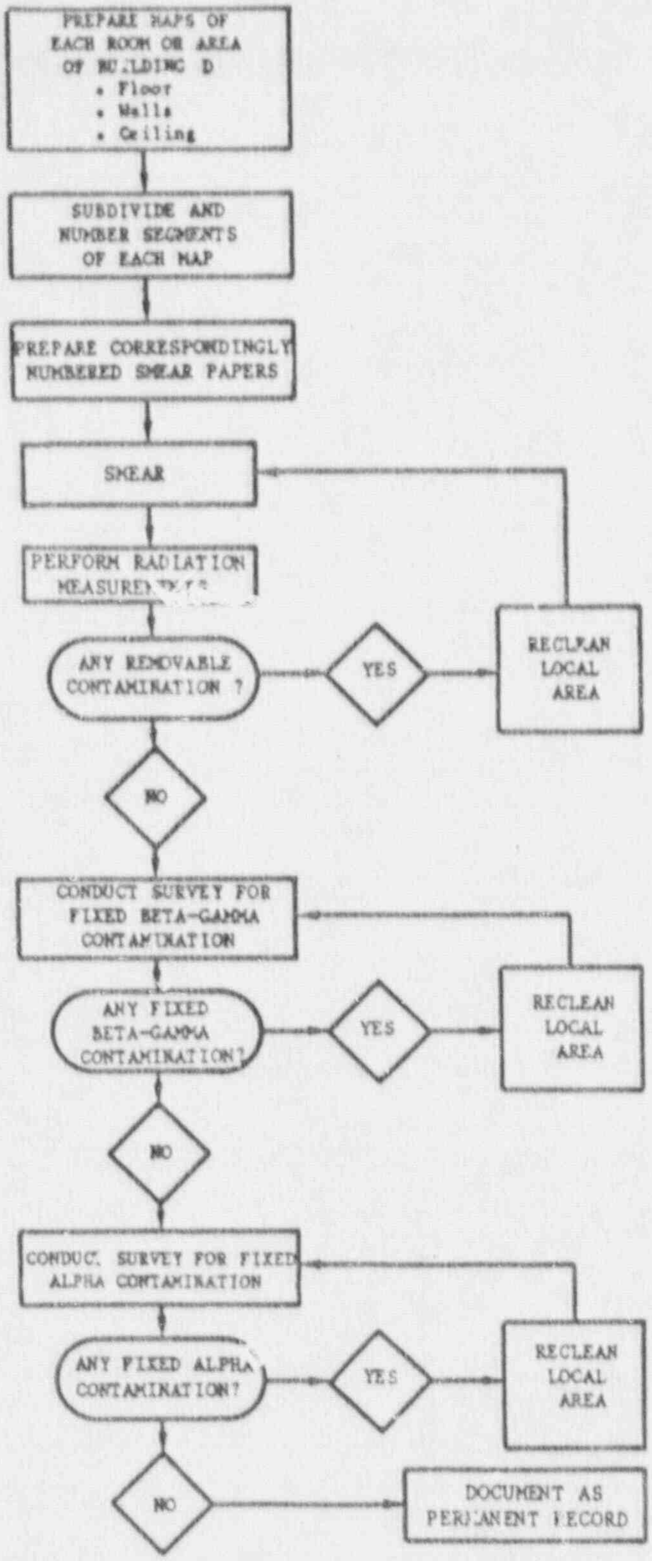

Figure 6-1. Summary Flow-Chart - Final Radiation Monitoring Survey Procedures.

6. All smear counts were tabulated against the number established for the map of the floor, walls, and ceiling of the room or area being monitored. When any removable contamination was found, the necessary decontamination was completed in the appropriate local area, and Steps 4 and 5 are repeated for that particular map area. This was repeated as necessary until the levels of removable contamination were reduced to below the guidelines delineated in Table 4-3.

The final monitoring process than continued as follows:

7. The final survey for fixed beta-gamma contamination was conducted using the appropriate instrument such as the FM-1 Geiger Counter or the PRM-7 Scintillation Counter (see Table 4-1). This survey was conducted using the same maps prepared for the final monitoring of removable contamination (Step 2).

8. The final survey for fixed alpha contamination was conducted using the appropriate instrument such as the PAC-4G-3 or FM-4G alpha counter (see Table 4-1). This survey was also conducted using the same maps prepared for the final monitoring of removable contamination (Step 2). When any fixed contamination was found, the necessary cleaning was completed in the appropriate local area and Steps 7 or 8 were repeated for that area of that particular map. These steps were repeated as necessary until the levels of fixed contamination were removed.

6.2 RESULTS OF FINAL MONITORING

The results of the final monitoring, summarized in Table 6-1, show that Building D has been decontaminated to levels below the NRC guideline levels for unrestricted usage. The detailed results of the final survey are reported in the area-specific reports.

Table 6-1. Building D - Summary List of Decontamination Reports Postdecontamination Status.

Individual Area Report Number	Room or Area	Prior Usage	Postdecontamination Status (1)			
			Removable		Fixed	
			Alpha dmp/100cm2	Beta Gamma dpm/100cm2	Alpha dpm/100cm^2	Beta-Gamma mR/hr @ 1.0 cm
AEBG-36-111	L1-1	Uranium Analysis Lab	< 20	< 200	< 200	< 0.05
-112	L1-3	Analytical Chemistry Lab	< 20	< 200	< 200	< 0.05
-113	L1-5	Sample Center Lab	< 20	< 200	< 200	< 0.05
-114	L1-7	Metal Research Lab	< 20	< 200	< 200	< 0.05
-115	L1-9	Research/Dev. Metals Lab	< 20	< 200	< 200	< 0.05
-116	L1-11	Research/Dev. General Lab	< 20	< 200	< 200	< 0.05
-117	L1-2	Spectrographic Lab	< 20	< 200	< 200	< 0.05
-118	L1-4	Moderator Research/Dev. Lab	< 20	< 200	< 200	< 0.05
-119	L1-6, -8	Radiochemistry Lab	< 20	< 200	< 200	< 0.05
-120	L1-10	Material Dev. Lab	< 20	< 200	< 200	< 0.05
-121	L1-12, -14	Office Area	< 20	< 200	< 200	< 0.05
-122	L2-2, -4	Lab and Offices Area	< 20	< 200	< 200	< 0.05
-123	L2-6, -8	Metallography Lab	< 20	< 200	< 200	< 0.05
-124	L2-10	Measurements Lab	< 20	< 200	< 200	< 0.05
-125	L3-1	General Purpose Lab	< 20	< 200	< 200	< 0.05
-126	L3-3	Mechanical Testing Lab	< 20	< 200	< 200	< 0.05
-127	L3-5	Fuel Element Processing	< 20	< 200	< 200	< 0.05
-128	L3-7, -9	Development Fuel Lab	< 20	< 200	< 200	< 0.05
-129	L3-2	Instrument Calibration Room	< 20	< 200	< 200	< 0.05
-130	L3-4	Fuel Element Development	< 20	< 200	< 200	< 0.05
-131	L3-6	Moderator Development	< 20	< 200	< 200	< 0.05
-132	L3-8	General Purpose	< 20	< 200	< 200	< 0.05
-133	L3-10	Moderator and Shielding Lab	< 20	< 200	< 200	< 0.05
-134	L3-12	High-Temp Fuels Research	< 20	< 200	< 200	< 0.05
-135	L3-14, -16	Health Physics Office	< 20	< 200	< 200	< 0.05
-136	L4-1	Metallurgical Dev. Lab	< 20	< 200	< 200	< 0.05
-137	L4-3	Mechanical Testing Lab	< 20	< 200	< 200	< 0.05
-138	L4-5	Special Metals Shop	< 20	< 200	< 200	< 0.05
-139	L4-7, -8	Warm Cell; Met. Lab	< 20	< 200	< 200	< 0.05
-140	L5-1	Powder Met. Lab	< 20	< 200	< 200	< 0.05
-141	L5-3	Powder Met. Lab	< 20	< 200	< 200	< 0.05
-142	L5-5	Powder Met. Lab	< 20	< 200	< 200	< 0.05
-143	L5-2	X-ray Inspection Lab	< 20	< 200	< 200	< 0.05
-144	L5-4	Welding, Joining Lab	< 20	< 200	< 200	< 0.05
-145	L5-6	Heat Treat Lab	< 20	< 200	< 200	< 0.05
-146	L5-8	Quality Control Lab	< 20	< 200	< 200	< 0.05
-147	L5-10	Cleaning, Plating Lab	< 20	< 200	< 200	< 0.05
-148	L6	Fuel Element Prod. Area	< 20	< 200	< 200	< 0.05
-149	L-6 Annex	General Purpose Area	< 20	< 200	< 200	< 0.05
-150	Laboratory Halls	Corridors and Elevator	< 20	< 200	< 200	< 0.05
-151	Laboratory Restrooms	Restrooms and Janitorial	< 20	< 200	< 200	< 0.05
-152	Laboratory Pipechases and Closets	Utility Service Area	< 20	< 200	< 200	< 0.05
-153	Laboratory Area Attic	Controlled Exhaust	< 20	< 200	< 200	< 0.05
-154	Laboratory Basement and Vaults	SS Materials, Regular Storage	< 20	< 200	< 200	< 0.05
-155	Controlled Waste Drain System	Controlled Waste Drain	< 20	< 200	< 200	< 0.05
-156	Cobalt-60, Plasma, Van De Graaff Facilities	Irradiator, Particle Mass Electron Accel.	< 20	< 200	< 200	< 0.05
-157	Dynamic Air, Hydraulic Test, Burner Rig	Gas Dynamics Facil.	< 20	< 200	< 200	< 0.05
-158	Instrument Service Shop Nondestructive Test Lab.	Office, Computer Instr. Serv.	< 20	< 200	< 200	< 0.05
-159	North, Middle Mezzanine	Change Room, General Lab	< 20	< 200	< 200	< 0.05
-160	Water Test Area, Blockhouse Lab., Betatron	Misc. Nucl. Test Area High-Temp Furnace Electron Accel.	< 20	< 200	< 200	< 0.05
-161	Radioactive Mat. Lab.	Irradiated Mat. Lab.	< 20	< 200	< 200	< 0.05
-162	Nuclear Exper. Area	Nuclear Critical Exper.	< 20	< 200	< 200	< 0.05
-163	Radioactive Waste Storage Pad	Radioactive Waste Storage	< 20	< 200	< 200	< 0.05
-164	Special Source Vault	Special Source Storage	< 20	< 200	< 200	< 0.05
-165	717, 718, 738 High Bay Area	General Lab, Dispensary, Air Conditioner, High Bay	< 20	< 200	< 200	< 0.05

(1) See Table 4-3 for Full NRC Acceptable Guideline Values