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# Formerly Utilized MED/AEC Sites Remedial Action Program

**Radiological Survey of the E.I. DuPont DeNemours and Co.,  
Deepwater, New Jersey**

**December 1978**

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## **FINAL REPORT**

Prepared for

**U.S. Department of Energy**  
Assistant Secretary for Environment  
Division of Environmental Control Technology  
Washington, DC 20545



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BY  
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## PREFACE

This series of reports results from a program initiated in 1974 by the Atomic Energy Commission (AEC) for determination of the condition of sites formerly utilized by the Manhattan Engineer District (MED) and the AEC for work involving the handling of radioactive materials. Since the early 1940's, the control of over 100 sites that were no longer required for MED/AEC nuclear programs has been returned to private industry or the public for unrestricted use. A search of MED and AEC records indicated that for some of these sites, documentation was insufficient to determine whether or not the decontamination work done at the time nuclear activities ceased is adequate by current guidelines.

This report contains the results of a survey of the current radiological condition of the E. I. Du Pont De Neumours Co., Deepwater, New Jersey. Results of this radiological survey show that a portion of the Chambers Works at the E. I. Du Pont plant at Deepwater, New Jersey is presently contaminated with radioactive residues from previous contract operations for the MED/AEC. Under current conditions of use, this contamination does not cause employees working at the site to receive radiation exposures appreciably different from those due to naturally occurring environmental radioactivity. However, under different conditions of use, i.e., use of the contaminated soils for growing crops or

actions which involve agitation or abrasion of dry contaminated surfaces, there could be a potential for radiation exposure to people. For that reason, the DOE will conduct further evaluations to enable appropriate actions to be identified that will preclude any concerns for radioactivity at this site.

The work reported in this document was conducted by the following members of the Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee:

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RADIOLOGICAL SURVEY OF THE E. I. DUPONT COMPANY,  
DEEPWATER, NEW JERSEY

ABSTRACT

The results of a radiological survey of the E. I. DuPont Company, Deepwater, New Jersey, are presented in this report. During the 1940's this site was used for development of a process for the conversion of uranium oxide to produce uranium tetrafluoride and small quantities of uranium metal. The survey included measurements of the following: residual alpha and beta-gamma contamination levels, both fixed and transferable, in the one remaining uranium tetrafluoride operations building; external gamma radiation levels at 1 m above the surface inside this building and at outdoor locations where radioactive materials were handled; radon and radon daughter concentrations in the air in the operations building; uranium, radium, actinium, and thorium concentrations in soil and water on and near the site; and the airborne concentrations of uranium, thorium, and radium in the operations building. Elevated concentrations of uranium were found in residues from the operations building and in some surface and subsurface soil samples. Alpha and beta-gamma contamination levels in some areas of the operations building were above the limits of current federal guidelines set for the release of property for unrestricted use.

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## INTRODUCTION

At the request of the Department of Energy, Oak Ridge Operations, a radiological survey was conducted in Deepwater, New Jersey, at the Chambers Works of the E. I. DuPont Company. The Chambers Works is located on the north shore of the Delaware River near the Delaware Memorial Bridge. This 700 acre complex is adjacent to the residential communities of Deepwater, Pennsville, and Penns Grove, New Jersey. This company performed chemical conversion of uranium for the Manhattan Engineer District (MED) during the 1940's. Operations included the development of a process for converting uranium oxide to uranium tetrafluoride, production of uranium tetrafluoride, research into the conversion of the uranium oxide to uranium metal, and some production of uranium metal.

The locations at which these uranium products were handled are shown in Fig. 1. A building located at (1) in Fig. 1, and designated J-16, was used as a unit operations test facility for the uranium oxide to uranium tetrafluoride conversion process and as a research laboratory. This building was demolished sometime between 1943 and 1945 after its final release to the DuPont Company. Several feet of earth were removed as part of the demolition. A new building, designated J-26, now stands at this location.

The "F" parking facility, located at (2) in Fig. 1, was constructed on the former site of Building 708, a uranium tetrafluoride production building which was demolished and removed in two stages. A portion of the building was removed in 1945, and the remainder was removed along with several feet of earth in 1953. Building 845, located at (3) in Fig. 1, is a four-story structure which still stands and is currently

used as a warehouse. It is located approximately 100 ft southeast of the "F" parking facility. At the termination of uranium operations, all contaminated equipment was removed and taken to the federal waste repository at Elmira, New York. Building decontamination included sand-blasting, vacuuming and washing of all building surfaces. A radiation survey was made by the Health Division of the U. S. Atomic Energy Commission, and the buildings were subsequently released to Dupont on November 15, 1948.

The waste burial area, located at (4) in Fig. 1, served as the disposal site for some contaminated material which was removed from the two process buildings. It currently serves as a radioactive materials burial facility approved by the State of New Jersey.

#### RADIOLOGICAL SURVEY PLAN

The present survey was performed to characterize the existing radiological status of the property. It was conducted by four members of the Health and Safety Research Division and one member of the Industrial Safety and Applied Health Physics Division of the Oak Ridge National Laboratory (ORNL) from March 14, 1977, through March 25, 1977. The survey included the following:

1. measurement of both fixed and transferable alpha and beta-gamma contamination levels on the inside surfaces of Building 845,
2. measurement of external gamma radiation levels at 1 m above the surface inside and in the immediate vicinity of Building 845,
3. measurement of external gamma radiation levels at 1 m above the ground in the "F" parking facility and in the waste burial area,

- ~~Low-volume~~ air sampling for  $^{222}\text{Rn}$  daughter progeny on each floor of Building 845 and high-volume air sampling for total activity on 1st and 4th floors,
- = ~~Measurement~~ of external gamma radiation levels at 1 m above ~~the surface~~ and the concentrations of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{226}\text{Ra}$  in ~~the sediments~~ along the effluent ditch which received the ~~process~~ train lines from Buildings 708 and 845,
- = ~~Measurement~~ of the concentrations of  $^{238}\text{U}$  and  $^{226}\text{Ra}$  in subsurface ~~soil and~~ characterization of the distribution of these radio-~~nucleides~~ as a function of depth in the vicinity of Building ~~845~~, in the "F" parking facility, and the waste burial area,
- = ~~Soil and~~ water sampling in the area around the DuPont property ~~where~~ sampling points were chosen to establish background radio-~~nucleide~~ concentrations in the local area. It is unlikely that ~~these~~ samples were influenced by radioactive materials formerly ~~located~~ (presently buried on the DuPont property),
- = ~~Measurement~~ of external gamma radiation levels at 1 m above ~~the surface~~ at each background sampling point, and
- = ~~Measurement~~ of the concentrations of  $^{238}\text{U}$ ,  $^{230}\text{Th}$ , and  $^{226}\text{Ra}$  in the Delaware River both upstream and downstream of the ~~plant~~ facilities.

#### RADIOLOGICAL SURVEY TECHNIQUES

##### ~~Measurement~~ of Alpha and Beta-gamma Contamination Levels

~~Surface~~ ~~readings~~ of alpha contamination were taken on the floors, walls, ~~ceilings~~ and structural supports throughout Building 845. Surfaces were

scanned to identify those points where alpha contamination levels exceeded surface contamination limits set forth in Nuclear Regulatory Commission Guidelines<sup>1</sup> for the release of property for unrestricted use.

Smear samples (covering 100 cm<sup>2</sup> each) were used to determine the levels of transferable contamination and were taken at uniformly spaced areas on floor, wall, and ceiling surfaces. Approximately 430 smears were taken on the interior surfaces of Building 845. The counting systems used for the transferable contamination survey are described in Appendix I.

Beta-gamma contamination levels were determined for surfaces throughout Building 845. Both the location and extent of surface area where contamination levels were above applicable guidelines were identified. Survey results reflect averages of the contamination levels per square meter as well as maximum contamination levels for smaller areas.

#### Measurement of Radon Daughter Concentrations in Building 845

For the measurement of radon daughter concentrations, air samples were taken using membrane filters. Air was pumped for 4 to 10 min at flow rates which ranged from 18 to 19 liters per min through a membrane filter whose maximum pore size was 0.45  $\mu\text{m}$ . Radon daughter concentrations were calculated from alpha spectroscopy counting results using a technique refined by Kerr.<sup>2</sup> This technique is described in Appendix II.

#### Measurement of Airborne <sup>238</sup>U, <sup>226</sup>Ra, and <sup>232</sup>Th in Building 845

High-volume air samples were taken on the 1st and 4th floors of Building 845 using a Staplex Model TF-1A sampler and Hollingsworth and

Vose HV-70 filter paper. These filters were analyzed at ORNL for  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$ , and these results were used to estimate the airborne concentration of these nuclides in Building 845.

#### Measurement of External Gamma Radiation Levels

External gamma radiation levels were measured at 1 m above the surface with NaI scintillation survey meters which are described in

Appendix I. Readings were taken at 1 m above the surface:

1. at 3 m intervals along the centerline of Building 845 on each floor,
2. at 3 m intervals both at 3 m and 6 m from all outside walls of Building 845,
3. at 3 m intervals (14 locations) along the drainage ditch between the "F" parking facility and Building 845,
4. on a 5 m grid in the area adjacent to the east wall of Building 845,
5. on a 15 m grid in the "F" parking facility,
6. on a 3 m grid in the waste burial area, and
7. at 3 m intervals along the outside walls of Building J-26 and on a 1 m grid at points in Building J-26 corresponding to the former location of uranium operations in Building J-16.

#### Surface and Subsurface Soil Sampling and Analysis

Surface soil samples were collected at fourteen points along the effluent drainage ditch which served the former uranium process buildings. Fourteen holes were drilled, using a motorized drilling rig, to depths varying from 3 to 15 ft at outdoor locations shown in Figs. 2 and 3. An

auger with a 5 in. diameter hollow core was used for the drilling. Gamma radiation levels were measured as a function of depth in the core holes by lowering a shielded scintillation probe inside a sealed polyvinyl chloride (PVC) pipe used to line the hole. These "loggings" provide a profile of the relative intensity of subsurface deposits of radioactivity as a function of depth. Soil samples were collected at varying depths from all of these holes in order to define areas and quantities of source material and contaminated material.

Both surface and subsurface samples were packaged in plastic bags and returned to ORNL where they were dried for 24 hr at 110°C and then pulverized to a particle size no greater than 500  $\mu\text{m}$  in diameter. Aliquots from each sample were then transferred to plastic bottles, weighed, and then stored to allow buildup of radon daughters. The samples were counted using a Ge(Li) detector, and the spectra obtained were analyzed by computer techniques. Descriptions of the Ge(Li) detector and soil sample counting procedures are given in Appendix III. Radium-226 concentrations were determined for all samples; and  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{227}\text{Ac}$  concentrations were determined for selected samples.

#### Measurement of Radioactivity in Surface and Subsurface Water

Three 2-liter water samples were taken from the Delaware River for the determination of background radionuclide content. Also, 2-liter water samples were collected at core holes (hole numbers 9, 11, 12, and 13) where groundwater was encountered. The samples were analyzed at ORNL to determine the concentrations of  $^{226}\text{Ra}$ ,  $^{238}\text{U}$ , and  $^{232}\text{Th}$ .

## Measurement of Background Radiation Levels and Radionuclide Concentrations

Measurements of beta-gamma and gamma radiation levels and of uranium and radium concentrations in soil were made at points on the DuPont property well-removed from the area where radioactive materials were handled. In addition, background radiation levels and radionuclide concentrations were measured at off-site locations in the southern part of New Jersey. Locations and results are described in the section "Survey Results." It should be pointed out here that the concentrations of each radionuclide in the  $^{238}\text{U}$  chain in background soil samples is typically less than 2 pCi/g and the background external gamma radiation level in the Deepwater area appears to average approximately 5  $\mu\text{R/hr}$ .

All direct meter readings reported in this document represent gross readings; background radiation levels have not been subtracted. Similarly, background levels have not been subtracted from radionuclide concentrations measured in environmental samples and building materials.

### SURVEY RESULTS

Building 845 is a four-story structure formerly used for the conversion of  $\text{UO}_2$  to  $\text{UF}_4$  by reaction with anhydrous HF. This building, currently a warehouse, has been modified since its use in MED operations. All windows, window casements, and sills have been replaced. Therefore, these items were excluded from the survey of alpha and beta-gamma contamination on wall surfaces.

Guidelines<sup>1</sup> issued by the Nuclear Regulatory Commission (NRC) for the release of property for unrestricted use state that average\* and maximum\* contamination levels by direct reading shall not exceed 5000  $\alpha$  dpm/100  $\text{cm}^2$  and 15,000  $\alpha$  dpm/100  $\text{cm}^2$ , respectively, provided the contaminant is known to be uranium with natural isotopic abundances. The general content of these guidelines is given in Appendix IV. Also, transferable contamination shall not exceed 1000 dpm/100  $\text{cm}^2$ , either alpha or beta. Average\* and maximum\* beta-gamma dose rates at 1 cm from the surface shall not exceed 0.2 mrad/hr and 1.0 mrad/hr, respectively.<sup>1</sup>

The survey results follow. They are presented on a floor-by-floor basis for the sake of clarity.

#### Building 845, First Level

##### Floor

Alpha contamination levels were measured at randomly chosen locations over 50% of the floor area in the north end of the first floor and over approximately 33% of the floor area in the south end of the first floor. Some areas in the north end were covered with a floor sealant. The readings averaged 450 dpm/100  $\text{cm}^2 \pm 80\%$  in the north end and 350 dpm/100  $\text{cm}^2 \pm 60\%$  in the south end. These mean values were determined by taking the average of random measurements made within 1  $\text{m}^2$  areas. A list of the direct readings is given in Table 1. In grid block A-15, over an area of 600  $\text{cm}^2$ , the alpha contamination level was 30,000 dpm/100  $\text{cm}^2$ . This reading was due to the presence of  $\sim 500$  g of solid material which was found on the floor. The material was found to contain approximately 51,000 pCi of  $^{238}\text{U}$  per gram.

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\*Measurements may not be averaged over more than 1  $\text{m}^2$ . The maximum value applies to an area of not more than 100  $\text{cm}^2$ .

Beta-gamma dose rates were measured at 1 cm from the floor over essentially the entire surface in the north end and over approximately 33% of the surface in the south end of the first floor. The average beta-gamma dose rate per  $1 \text{ m}^2$  for each grid block is given in Table 1. The magnitude and location of those areas where beta-gamma dose rates exceeded 1 mrad/hr are given in Fig. 4. The location of areas where beta-gamma dose rates exceeded 0.2 mrad/hr per  $1 \text{ m}^2$  is shown in Fig. 5. The numbers in this figure indicate the percentage of the individual areas where readings exceeded that value. Those points where the beta-gamma dose rate exceeded 1 mrad/hr were typically small areas not greater than  $500 \text{ cm}^2$  but ranged in six cases (grid blocks E-29, G-28, G-29, K-10, K-15, and K-25) up to  $5000 \text{ cm}^2$ .

#### Walls

Because of the size of Building 845, a decision was made to present the results of beta-gamma direct readings in tabular form. Reference is made to Fig. 6 wherein a typical wall elevation view is presented. Note that the lower left corner of the wall represents the origin. In all cases, data for beta-gamma contamination above guidelines presented in Table 2 is preceded by a coordinate legend for each wall, floor-by-floor. For example, the notation (42, 0.5) refers to a point 42 ft to the right of the origin and 0.5 ft above the floor.

Alpha contamination levels on the vertical wall surfaces ranged from 200 dpm/ $100 \text{ cm}^2$  to 500 dpm/ $100 \text{ cm}^2$  while on horizontal wooden beams and structural support members, levels ranged from 200 dpm/ $100 \text{ cm}^2$  to 5000 dpm/ $100 \text{ cm}^2$ .

Beta-gamma dose rates on vertical wall surfaces ranged from 0.15 mrad/hr to 0.20 mrad/hr with no  $1 \text{ m}^2$  area averaging over 0.15 mrad/hr; however, the beta-gamma dose rate of the horizontal surfaces of beams and structural members ranged from 0.5 mrad/hr to 5.5 mrad/hr (see Table 2).

#### Ceiling

Alpha contamination levels by direct measurements on concrete horizontal ceiling surfaces were uniform at approximately 500 dpm/100  $\text{cm}^2$  while beta-gamma dose rates at 1 cm from these surfaces were approximately 0.05 mrad/hr. Alpha contamination levels on structural beam surfaces were also uniform at approximately 500 dpm/100  $\text{cm}^2$ . Beta-gamma dose rates at 1 cm from all concrete ceiling surfaces and structural beams in the south end averaged approximately 0.15 mrad/hr. At 43 points on beams in the north section, beta-gamma dose rates ranged from 0.3 to 13 mrad/hr. Each reading represents an average over an area of  $\sim 300 \text{ cm}^2$ . These points are shown in Fig. 7.

#### Other areas of first level

Two rooms have been partitioned off on the first level. One serves as a lunchroom and the other serves as a cold storage room (see Fig. 8). In the cold storage room direct alpha readings were approximately 200 dpm/100  $\text{cm}^2$  on all floor, wall, and ceiling surfaces. Beta-gamma dose rates averaged over  $1 \text{ m}^2$  were approximately 0.05 mrad/hr on ceiling surfaces while on the wall and floor surfaces the beta-gamma dose rates averaged 0.1 mrad/hr with the exception of three locations. The contamination levels at these locations are indicated in Fig. 8 and the areas exceed  $1 \text{ m}^2$  unless otherwise noted. }

The lunchroom has a tile floor and the walls are painted; however, at several locations where the paint has been chipped away, direct alpha readings were approximately 200 dpm/100 cm<sup>2</sup>. Beta-gamma radiation levels averaged 0.03 mrad/hr on the floor, 0.05 mrad/hr on the walls, and 0.08 mrad/hr on the ceiling with the exceptions noted on Fig. 8. The contaminated area on the wall and floor in the northeast corner is larger than 1 m<sup>2</sup>; all other areas are noted.

The bottom of the elevator shaft is located along the west wall. Alpha contamination levels were 1000 dpm/100 cm<sup>2</sup> on wall surfaces in this area, but were not detectable on the floor surfaces because of water covering a thick sludge. A sample of this sludge was analyzed and found to contain <sup>226</sup>Ra and <sup>227</sup>Ac to the extent of 35 pCi/g and 55.7 pCi/g, respectively. Uniform beta-gamma dose rates at 1 cm were approximately 0.15 mrad/hr for both floor and wall surfaces.

A total of 169 smears were taken on the first level. Those areas where transferable alpha contamination exceeded 10 dpm/100 cm<sup>2</sup> and where transferable beta contamination exceeded 100 dpm/100 cm<sup>2</sup> are listed in Table 3.

#### Building 845, Second Level

##### Floor

Approximately 50% of the floor surface is covered by shelving. Alpha contamination levels on all accessible surfaces were uniform at 300 to 500 dpm/100 cm<sup>2</sup> while the beta-gamma dose rates at 1 cm from these surfaces were nearly uniform at 0.1 mrad/hr. At several points, readings ranged up to 0.4 mrad/hr, but area weighted averages of the

readings within individual  $1 \text{ m}^2$  areas yielded beta-gamma dose rates of approximately 0.1 mrad/hr.

#### Walls

Alpha contamination levels on the vertical wall surfaces were generally  $200 \text{ dpm}/100 \text{ cm}^2$  and beta-gamma dose rates from these surfaces were 0.05 mrad/hr to 0.10 mrad/hr. On horizontal beams and structural supports, alpha contamination levels ranged from 1000 to 4000  $\text{dpm}/100 \text{ cm}^2$  while beta-gamma dose rates from these surfaces ranged from 0.5 mrad/hr to 3.5 mrad/hr (see Table 2).

#### Ceiling

Alpha contamination levels ranged from 200 to 500  $\text{dpm}/100 \text{ cm}^2$  and beta-gamma dose rates averaged 0.1 mrad/hr on ceiling and beams, however, at 14 locations, over areas not greater than  $400 \text{ cm}^2$ , the beta-gamma dose rate exceeded 1 mrad/hr. The magnitude and location of these 14 beta-gamma readings are shown in Fig. 9.

A total of 59 smears were taken on the second level. Those areas where transferable alpha contamination exceeded  $10 \text{ dpm}/100 \text{ cm}^2$  and where transferable beta contamination exceeded  $100 \text{ dpm}/100 \text{ cm}^2$  are listed in Table 3.

### Building 845, Third Level

#### Floor

Alpha contamination levels by direct reading were uniform in the range of 250 to  $1000 \text{ dpm}/100 \text{ cm}^2$ . Beta-gamma dose rates at 1 cm from all accessible floor surfaces were uniform in the range of 0.05 to 0.1 mrad/hr.

### Walls

Alpha contamination levels on vertical wall surfaces were generally less than 300 dpm/100 cm<sup>2</sup> while beta-gamma dose rates from these surfaces ranged from 0.05 to 0.1 mrad/hr. Horizontal beam and support member surfaces showed alpha contamination levels of 200 to 3500 dpm/100 cm<sup>2</sup> while beta-gamma dose rates from these surfaces ranged from 0.05 mrad/hr to 1 mrad/hr in small areas (see Table 2). The average beta-gamma dose rate when taken over a typical area of 1 m<sup>2</sup>, which includes these small areas, was approximately 0.1 mrad/hr.

### Ceiling

Alpha contamination levels on the concrete ceiling surfaces and structural beam surfaces ranged from 200 to 500 dpm/100 cm<sup>2</sup> while beta-gamma dose rates on these surfaces were generally 0.1 mrad/hr.

A total of 73 smears were taken on the third level. Those areas where transferable alpha contamination exceeded 10 dpm/100 cm<sup>2</sup> and where transferable beta contamination exceeded 100 dpm/100 cm<sup>2</sup> are listed in Table 3.

Building 845, Fourth Level

### Floor

Alpha contamination levels on the floor surfaces ranged from 100 to 300 dpm/100 cm<sup>2</sup> while beta-gamma dose rates from these surfaces ranged from 0.05 to 0.15 mrad/hr with the exception of one location approximately 15 ft from the east wall and 20 ft from the north wall where for over an area of approximately 1 m<sup>2</sup>, the beta-gamma dose rate averaged 0.2 mrad/hr with a maximum of 0.6 mrad/hr.

### Walls

Alpha contamination levels on vertical wall surfaces averaged less than 300 dpm/100 cm<sup>2</sup>, while beta-gamma radiation levels averaged 0.05 to 0.1 mrad/hr. The alpha contamination levels on horizontal beams and support members ranged from 300 to 4000 dpm/100 cm<sup>2</sup>, while beta-gamma dose rates averaged 0.15 mrad/hr except along the south wall where from 0 to 3 ft up the wall the beta-gamma dose rate ranged from 0.25 to 0.5 mrad/hr (see Table 2). Also, at three locations on the west wall (covering ~300 cm<sup>2</sup> each) the beta-gamma dose rates were 0.5 mrad/hr, but area weighted averages over 1 m<sup>2</sup> of beam surface yielded a beta-gamma dose rate of 0.15 mrad/hr.

### Ceiling

Alpha contamination levels and beta-gamma dose rates were measured on structural beams, ceiling beams and ceiling surfaces. Alpha contamination levels ranged from 200 to 4000 dpm/100 cm<sup>2</sup> except on one structural beam (above floor grid C-8) where the alpha contamination level was >10,000 dpm/100 cm<sup>2</sup>. Beta-gamma dose rates ranged from 0.1 to 2.5 mrad/hr. The magnitude and location of beta-gamma dose rates on ceiling surfaces are given in Fig. 10. The beta-gamma dose rates at 1 cm from ceiling surfaces were generally 0.1 mrad/hr unless otherwise indicated. Maximum beta-gamma dose rates from structural and ceiling beams are also given in Fig. 10. Average beta-gamma rates are given in parentheses. The average readings are representative of a 1-m<sup>2</sup> area and the maximum values represent readings over approximately 100 cm<sup>2</sup>.

## Building 845, Fourth Level Mezzanine

On the mezzanine at the north end of the fourth level, beta-gamma dose rates exceeding NRC limits were measured on a concrete section of the floor, on horizontal ledges on the adjacent wall, and on the steps leading to the mezzanine from the fourth floor. Beta-gamma dose rates in these areas were uniformly higher than 0.20 mrad/hr and were in the range of 1.0 to 1.2 mrad/hr in isolated spots. Direct alpha readings in the same area did not exceed 3000 dpm/100 cm<sup>2</sup> but were higher than 2000 dpm/100 cm<sup>2</sup> at several points. Most of the mezzanine floor is constructed of wood and appears to have been built recently; no contamination was found on this part of the floor. A ceiling vent in the north end of the building and directly over the mezzanine showed alpha contamination levels of 200 to 2000 dpm/100 cm<sup>2</sup> by direct reading while beta-gamma dose rates were generally near 0.2 mrad/hr; however, at one spot on this vent the beta-gamma dose rate was 1.0 mrad/hr over an area of 100 cm<sup>2</sup>.

A total of 128 smears were taken on the fourth level including the mezzanine. Those areas where transferable alpha contamination exceeded 10 dpm/100 cm<sup>2</sup> and where beta contamination exceeded 100 dpm/100 cm<sup>2</sup> are listed in Table 3.

## External Gamma Radiation Levels in Building 845

External gamma radiation levels at 1 m above the floor were measured at points on a grid defined by lines separated by 5 m on each level of Building 845. The external gamma radiation level averaged 10  $\mu$ R/hr in the north end of the first level and 6  $\mu$ R/hr in the south end of the first level. Individual readings for the first level are

shown in Fig. 11. On the second level the gamma radiation level ranged between 8 and 11  $\mu\text{R/hr}$  while on the third level it was uniform at 8  $\mu\text{R/hr}$ . The external gamma radiation level on the fourth level averaged 8  $\mu\text{R/hr}$  with a range of 4 to 11  $\mu\text{R/hr}$ .

#### Measurements of Radon Daughter Concentrations in Building 845

Low-volume 5 to 10 min air samples were taken on each floor of Building 845 for the measurement of airborne  $^{222}\text{Rn}$  daughter concentrations. Radon daughter concentrations did not exceed  $6 \times 10^{-4}$  WL.\* The results for each sampling location are given in Table 4. According to federal guidelines<sup>3</sup> based on recommendations of the Surgeon General,<sup>4</sup> radon daughter concentrations below 0.03 WL do not require remedial action in structures other than private dwellings and schools.

#### Results of Analyses of Residue and Drain Scale Samples in Building 845

Four samples were taken on the first level; two from former drains (grid blocks J-20 and K-1) and two (grid blocks A-15 and E-25) where residues were found. Concentrations of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  in these samples are presented in Table 5. The samples taken from grid squares A-15 and E-25 contained 51,500 pCi/g of  $^{238}\text{U}$  and 26,900 pCi/g of  $^{238}\text{U}$ , respectively, while the samples taken from the scale and fill in the drains in grid squares J-20 and K-1 contained 1000 pCi/g of  $^{238}\text{U}$  and 290 pCi/g of  $^{238}\text{U}$ , respectively. Materials containing more than 0.05% uranium by weight, or approximately 172 pCi/g of  $^{238}\text{U}$ , are considered as source material.<sup>5</sup>

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\*A working level is defined as any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of  $1.3 \times 10^5$  MeV of alpha particle energy.

### Results of High-Volume Air Sampling in Building 845

High-volume air samples were taken at grid square E-15 on the first floor and at grid square B-6 on the fourth floor. Results of analyses of the filters for concentrations of  $^{238}\text{U}$ ,  $^{230}\text{Th}$ , and  $^{226}\text{Ra}$  are presented in Table 6. For purposes of comparison, the Concentration Guides ( $\text{CG}_a$ )<sup>6</sup> for these nuclides are also presented.

The measured concentrations of  $^{238}\text{U}$ ,  $^{230}\text{Th}$ , and  $^{226}\text{Ra}$  were observed in this short sampling period (24 hr) to range from a factor of 64 to several orders of magnitude below the  $\text{CG}_a$  for uncontrolled areas.<sup>6</sup>

### External Gamma Radiation Level Measurements

External gamma radiation level measurements at 1 m above the surface were made on a grid with lines separated by 15 m in the "F" parking facility (Fig. 12), on a grid with lines separated by no more than 5 m in a 316-m<sup>2</sup> area adjacent to the east side of Building 845 (Figs. 12 and 13), and on a grid with lines separated by 3 m in the east burial facility. The external gamma radiation level was uniform at 4 to 5  $\mu\text{R/hr}$  over the entire grid area in the "F" parking corral. In the area adjacent to the east wall of Building 845, the average gamma radiation level was 9  $\mu\text{R/hr}$  with a range of 5 to 23  $\mu\text{R/hr}$  (see Fig. 13). The external gamma radiation levels at 1 m above the surface in the waste burial area are shown in Fig. 14. The range of measured exposure rates was 4 to 13  $\mu\text{R/hr}$ . The amount of area within a specific exposure rate range is also indicated in Fig. 14.

In the area between the "F" parking facility and Building 845, there is an open drainage ditch which carried process wastes to the

waste treatment plant. External gamma radiation level measurements were made at 14 points (Fig. 15) along the edges of the ditch. These readings, presented in Table 7, averaged 5  $\mu\text{R/hr}$  with a range of 3 to 23  $\mu\text{R/hr}$ .

External gamma radiation levels were measured in and around Building J-26, the site where Building J-16 once stood. The relationship between these two buildings is shown in Fig. 16. The external gamma radiation level was nearly uniform at approximately 4  $\mu\text{R/hr}$  at both indoor and outdoor locations.

#### Results of Surface and Subsurface Soil Analyses

Surface soil samples were taken at the 14 points (Fig. 15) along the effluent drainage ditch where external gamma radiation level and beta-gamma dose rate measurements were made. The concentrations of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  were determined in all samples. These results are presented in Table 7. The average concentration of  $^{226}\text{Ra}$  in these samples was 0.5 pCi/g  $\pm$  38%. In samples of undisturbed soil at locations near but not influenced by the operations at the DuPont facilities, the average concentration of  $^{226}\text{Ra}$  was 0.7  $\pm$  38%. The concentration of  $^{238}\text{U}$  in five samples exceeded 4 pCi/g, which was the maximum concentration of  $^{238}\text{U}$  in the background soil samples. The concentration of  $^{238}\text{U}$  in sample 14 was 12,600 pCi/g (3.7% uranium).

Fourteen core holes whose depth ranged from 3 to 15 ft were drilled at locations in the east burial area, along the drainage ditch, near the east wall of Building 845 and in the "F" parking facility (see Figs. 2 and 3). Polyvinyl chloride pipes with one end sealed were inserted into these core holes and gamma radiation levels as a function of depth

were measured using a collimated NaI scintillation detector and/or a collimated glass walled G-M tube. The "core hole loggings" were used to determine the thickness of the contaminated layer and the depth at which it occurred. After this determination soil samples were taken through a depth which included the contaminated layer. The concentrations of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  were measured in each sample. These results are presented in Table 8. The  $^{226}\text{Ra}$  concentration exceeded the maximum  $^{226}\text{Ra}$  background concentration in two samples, one from core hole 3 at a depth of 0.0 to 0.5 ft (15 pCi/g), and one from core hole 4 from a depth of 0.5 to 1.0 ft (16 pCi/g). It is seen by the data in Table 8 that, as expected,  $^{238}\text{U}$  is the principal radionuclide found in subsurface deposits. In the east burial area, uranium contaminated material in source quantities was found in three locations ranging from near the surface to a depth of about 4.5 ft. The maximum  $^{238}\text{U}$  concentration was in core hole number 4 at a depth of 0.5 to 1.0 ft. At this depth the material sampled was 3.2% uranium by weight. On the east side of Building 845, uranium in source material quantities was found to a depth of 4.5 ft. The maximum concentration of uranium (2%) in this area was between 0.5 and 0.75 ft in core hole number 12.

#### Results of Groundwater Sample Analyses

Samples of groundwater were collected from four core holes (hole numbers 9, 11, 12, and 13) where water was encountered during coring operations. The concentrations of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{230}\text{Th}$ , and  $^{210}\text{Pb}$  were measured in each sample. In most cases, the concentrations of these radionuclides were less than the most restrictive concentration guide

(CG<sub>w</sub>) for uncontrolled areas by at least two orders of magnitude. These results are presented in Table 9.

#### Background Radiation Levels and Radionuclide Concentrations

At six locations on the DuPont property, at distances ranging from 1000 to 6000 ft from the nearest area in which radioactive materials were handled or stored, surface soil samples were taken for determination of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  concentrations. External gamma measurements at one meter above the ground were made at these same points. Locations are shown in Fig. 17, and results are listed in Table 10. Concentrations of  $^{238}\text{U}$  in the background samples ranged from 0.3 to 4.0 pCi/g and averaged 2 pCi/g. Background external gamma readings were in the range of 3 to 6  $\mu\text{R/hr}$  and averaged 4.5  $\mu\text{R/hr}$ . In addition to these background data, reference is made to a series of samples collected throughout the state of New Jersey (see Fig. 18). Six samples (NJ-1 through NJ-6) were collected in the southern part of the state near Deepwater. The average concentrations of  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  found in these samples were 0.62 pCi/g and 0.66 pCi/g respectively. External gamma-ray exposure rate measurements were made at these sample locations. The range of these measurements was 3  $\mu\text{R/hr}$  to 8  $\mu\text{R/hr}$  with an average of 5.3  $\mu\text{R/hr}$ .

River water samples were taken upstream at the plant outfall and downstream of the DuPont facilities. The concentration of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{230}\text{Th}$ , and  $^{210}\text{Pb}$  were measured in each sample. The results are given in Table 11 and the sampling locations are shown in Fig. 17. In all cases the concentration of each radionuclide was less than the most restrictive concentration guide by five orders of magnitude or greater.

Beta-gamma dose rates measured with G-M meters in buildings on the DuPont site that have not been contaminated with radioactive materials were less than 0.03 mrad/hr. Background levels for direct alpha measurements of the type made at this site are negligible.

#### SUMMARY

A radiological survey was conducted at the E. I. DuPont, Chambers Works facility in Deepwater, New Jersey. Records indicate that three buildings were used for uranium processing. Only Building 845 remains, and it is used as a warehouse. Measurements were made over representative fractions of the former uranium processing areas in order to determine the current radiological status of the property. This report provides a comprehensive characterization of the quantities and areas of uranium and uranium contaminated property.

The alpha and beta-gamma contamination levels on some interior surfaces of Building 845 are in excess of the surface contamination guidelines for the release of property for unrestricted use.<sup>1</sup> External gamma radiation levels ranging from 5 to 23  $\mu\text{R/hr}$  were found in the area adjacent to the outside east wall of Building 845. Along the drainage ditch the exposure rate ranged from 3 to 23  $\mu\text{R/hr}$  and in the east burial area the range was 4 to 13  $\mu\text{R/hr}$ . Annual exposure rates are in the range 8 to 46 mrem/year based on an exposure time of 2000 hours per year. These exposure rates correspond to areas where significant quantities of  $^{238}\text{U}$  in surface and subsurface soil were noted. Uranium was found on the surface and in underground deposits. The maximum

surface concentration was 2% at the site of core hole number 3 in the east burial area. The maximum subsurface concentration was 3.2% and was found between 0.5 and 1.0 ft at the site of core hole number 4. In grid block A-15 of Building 845, first level, solid uranium contaminated material was found on the floor. The concentration of uranium in this sample was 51,000 pCi/g (14.8% uranium). In grid block E-25 of the same level residues containing 7.8% uranium were found. Scale from drains in the first level floor were found to range from 0.03% to 0.08% uranium.

Samples of airborne particulate matter were taken on the first and fourth level of Building 845, and measurements of radon daughter concentrations were made on all four floors. Results of these measurements indicated that existing airborne radionuclide concentrations were considerably less than guideline concentrations.

Groundwater samples were collected from four core holes drilled on site. In addition, three samples were collected from the Delaware River and were assumed to represent background concentrations. In these river water samples, the average concentrations of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{230}\text{Th}$ , and  $^{210}\text{Pb}$  in pCi/ml were  $1 \times 10^{-3}$ ,  $1.4 \times 10^{-5}$ ,  $2.1 \times 10^{-5}$ , and  $<7 \times 10^{-4}$ , respectively. In groundwater samples the concentration of  $^{238}\text{U}$  in pCi/ml ranged from  $6.7 \times 10^{-4}$  to  $2.5 \times 10^{-1}$ ; however, the concentrations of  $^{226}\text{Ra}$ ,  $^{230}\text{Th}$ , and  $^{210}\text{Pb}$  were more uniform and averaged  $5.6 \times 10^{-4}$  pCi/ml,  $1.2 \times 10^{-3}$  pCi/ml, and  $1 \times 10^{-2}$  pCi/ml, respectively. All of these groundwater concentrations were at least a factor of 10 below the most restrictive concentration guide.

Measurements were made in the vicinity of two buildings which were demolished after completion of uranium processing. Radiation and contamination levels in these areas were indistinguishable from normal background levels for those areas.

## REFERENCES

1. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct Source, or Special Nuclear Material, U. S. Nuclear Regulatory Commission, December, 1975.
2. G. D. Kerr, Measurement of Radon Progeny Concentrations in Air by Alpha-Particle Spectroscopy, ORNL/TM-5924, 1975.
3. Code of Federal Regulations, Title 10, Part 712, "Grand Junction Remedial Action Criteria," Federal Register, Vol 41-No. 252, December 30, 1976.
4. Department of Health, Education, and Welfare, "Recommendations of Action for Radiation Exposure Levels in Dwellings Constructed on or With Uranium Mill Tailings," Letter from P. Peterson, acting Surgeon General, to R. L. Cleere, Executive Director, Colorado State Department of Health, July 27, 1970.
5. Code of Federal Regulations, Title 10, Part 20.3. "Standards for Protection Against Radiation," Appendix B.
6. United States Energy Research and Development Administration, ERDA Manual Chapter 0524, Annex A, April 8, 1975.
7. Code of Federal regulations, Title 40, Part 190, "Environmental Radiation Protection for Nuclear Power Operation."

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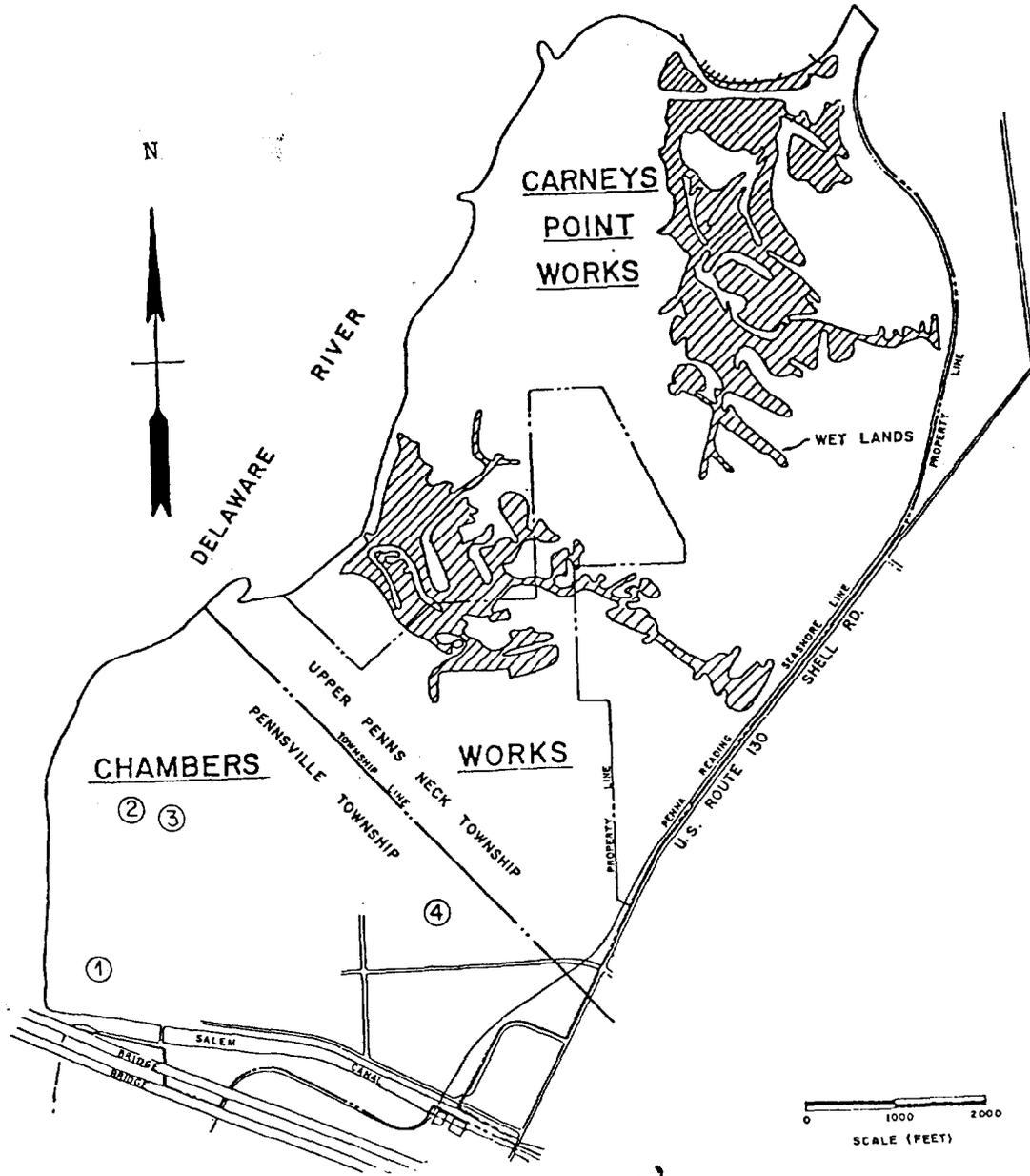


Fig. 1. E. I. DuPont Chemical Company - Manhattan Engineer District Operations.

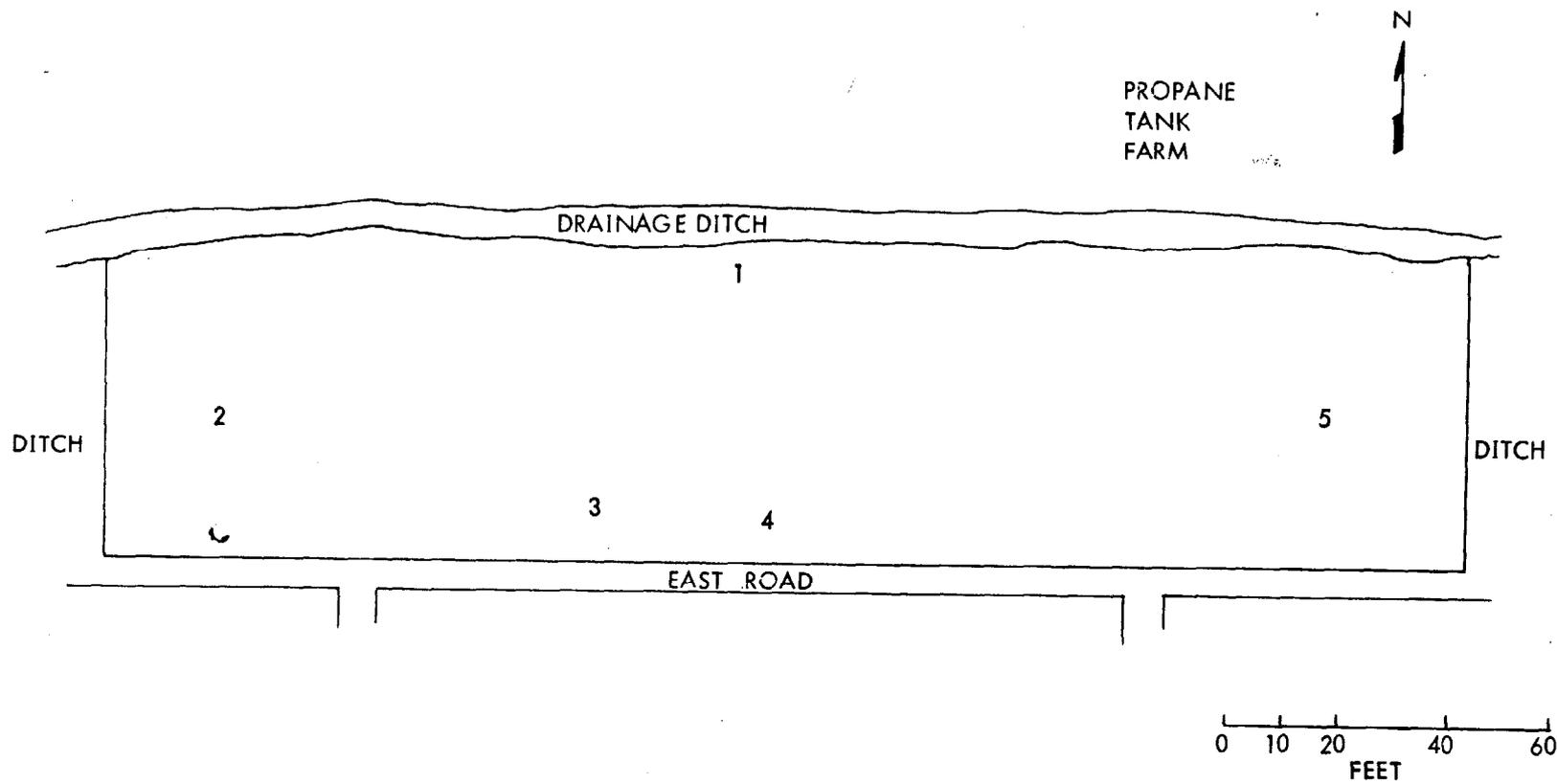


Fig. 2. Core sampling locations in the east burial facility.

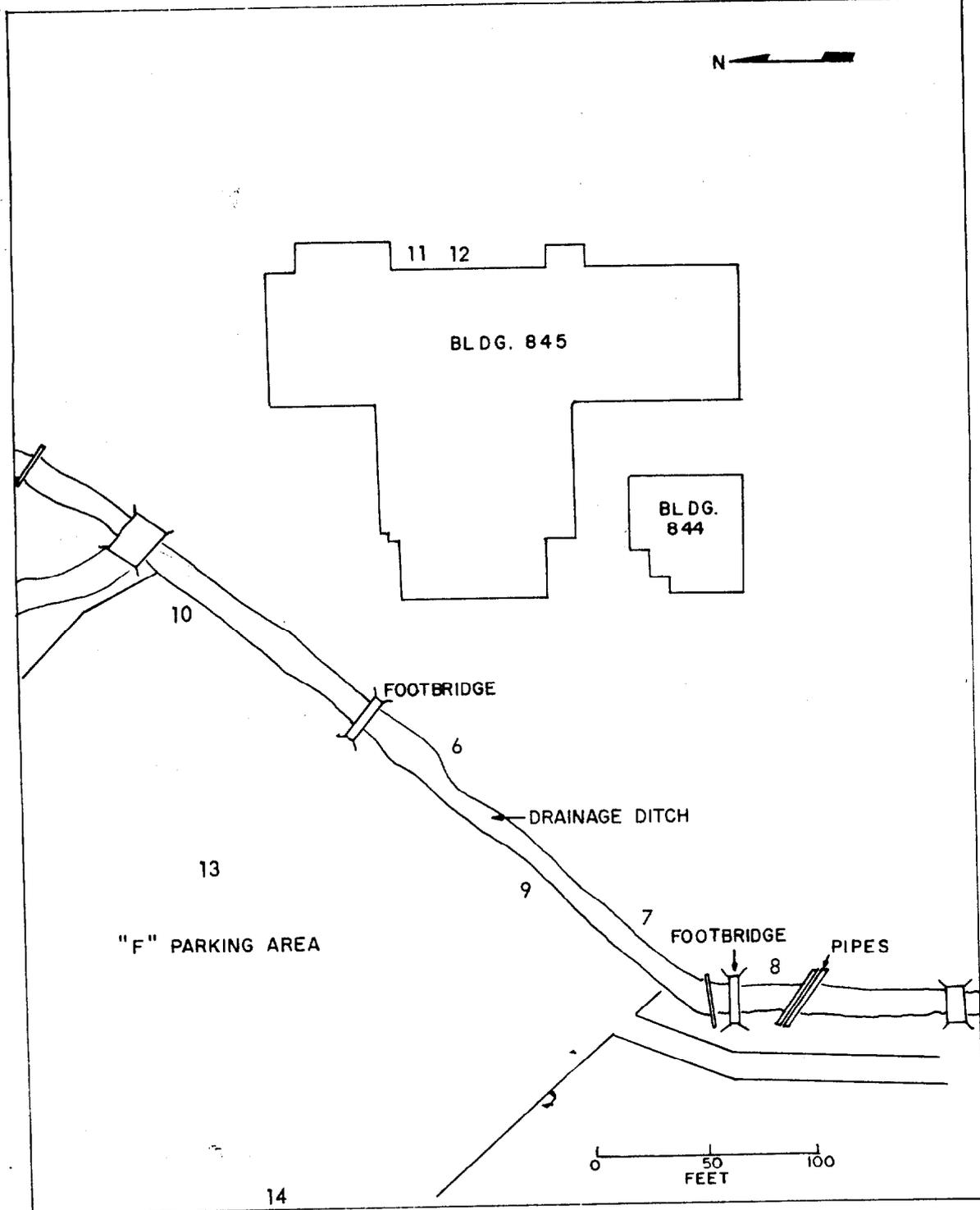


Fig. 3. Core sampling locations in the "F" parking facility and drainage ditch area.

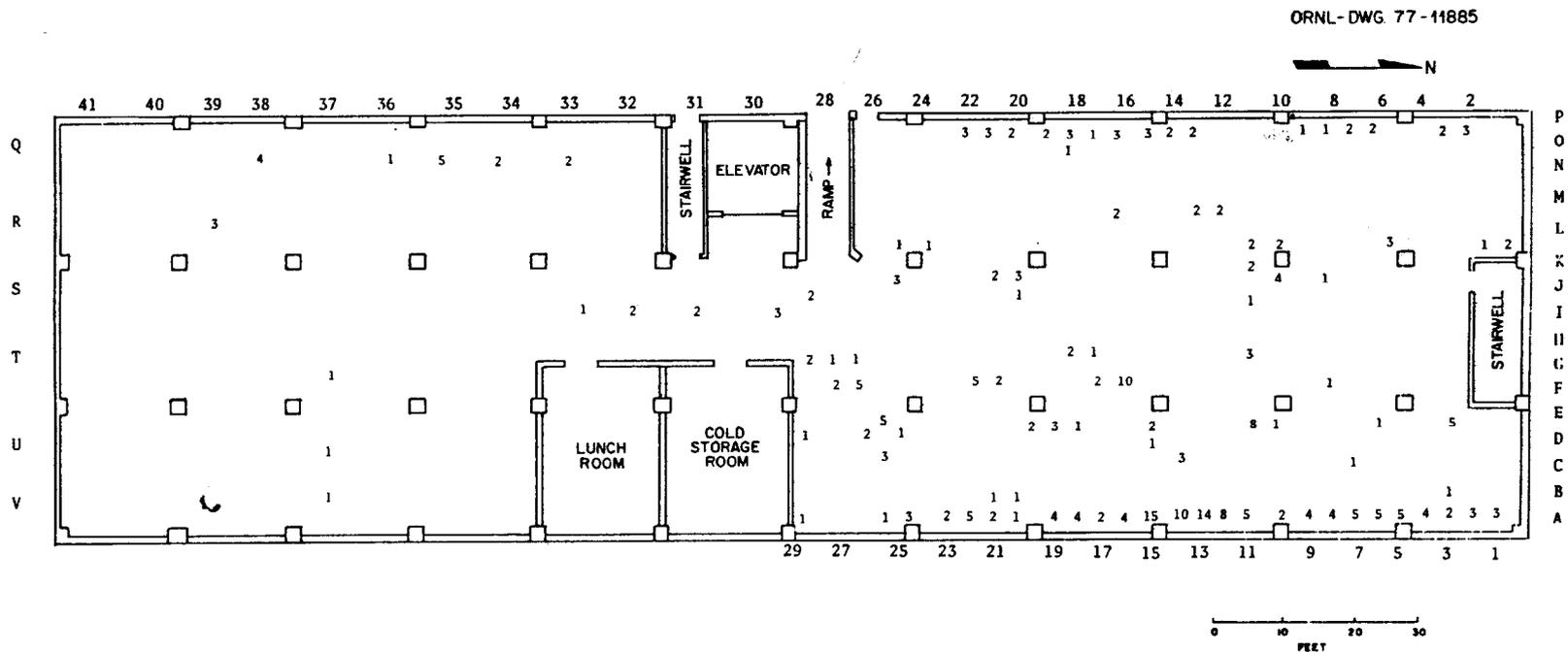


Fig. 4. Maximum beta-gamma dose rates (mrad/hr) at 1 cm from the floor on the first level of Building 845.

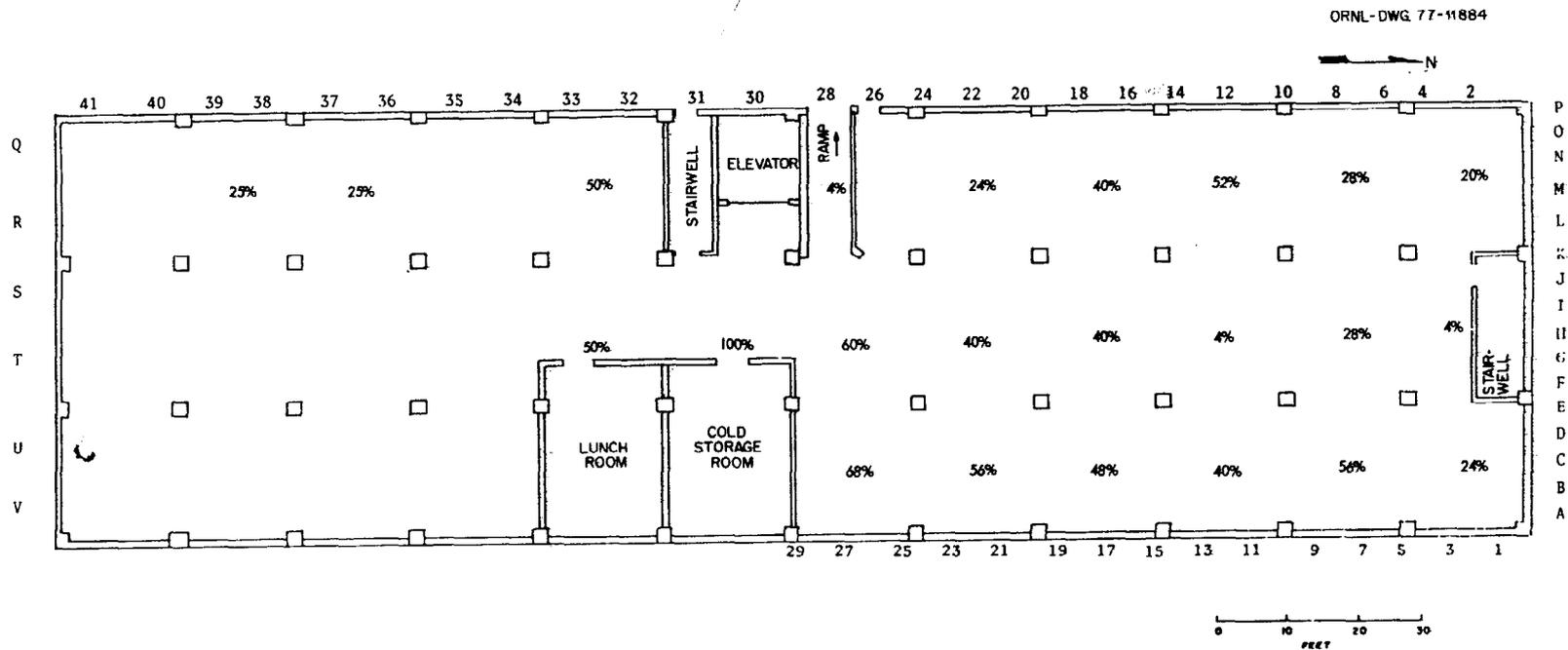


Fig. 5. The percentage of individual floor areas where the beta-gamma dose rate exceeds 0.2 mrad/hr at 1 cm from the floor on the first level of Building 845.

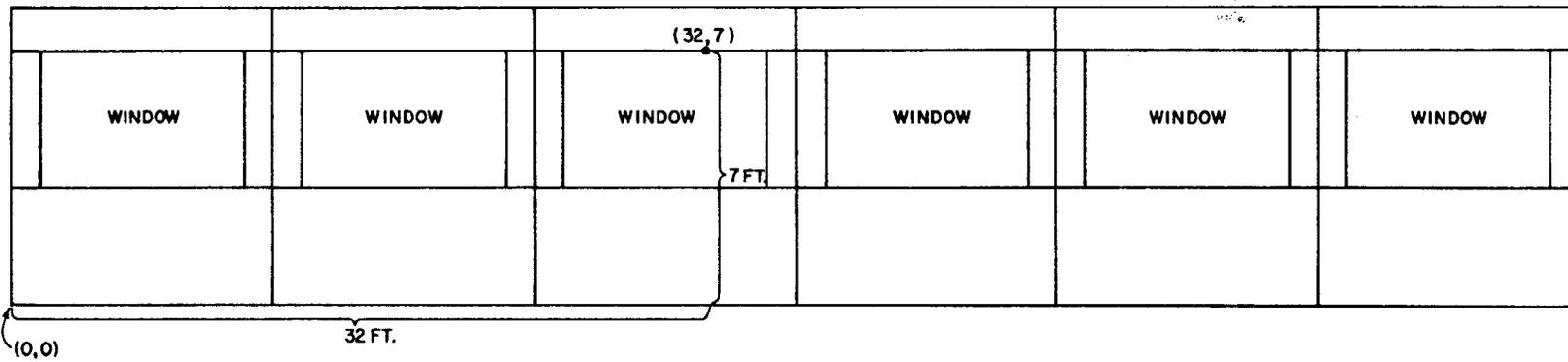


Fig. 6. Typical wall elevation view and example of coordinates used in Tables 2 and 3.



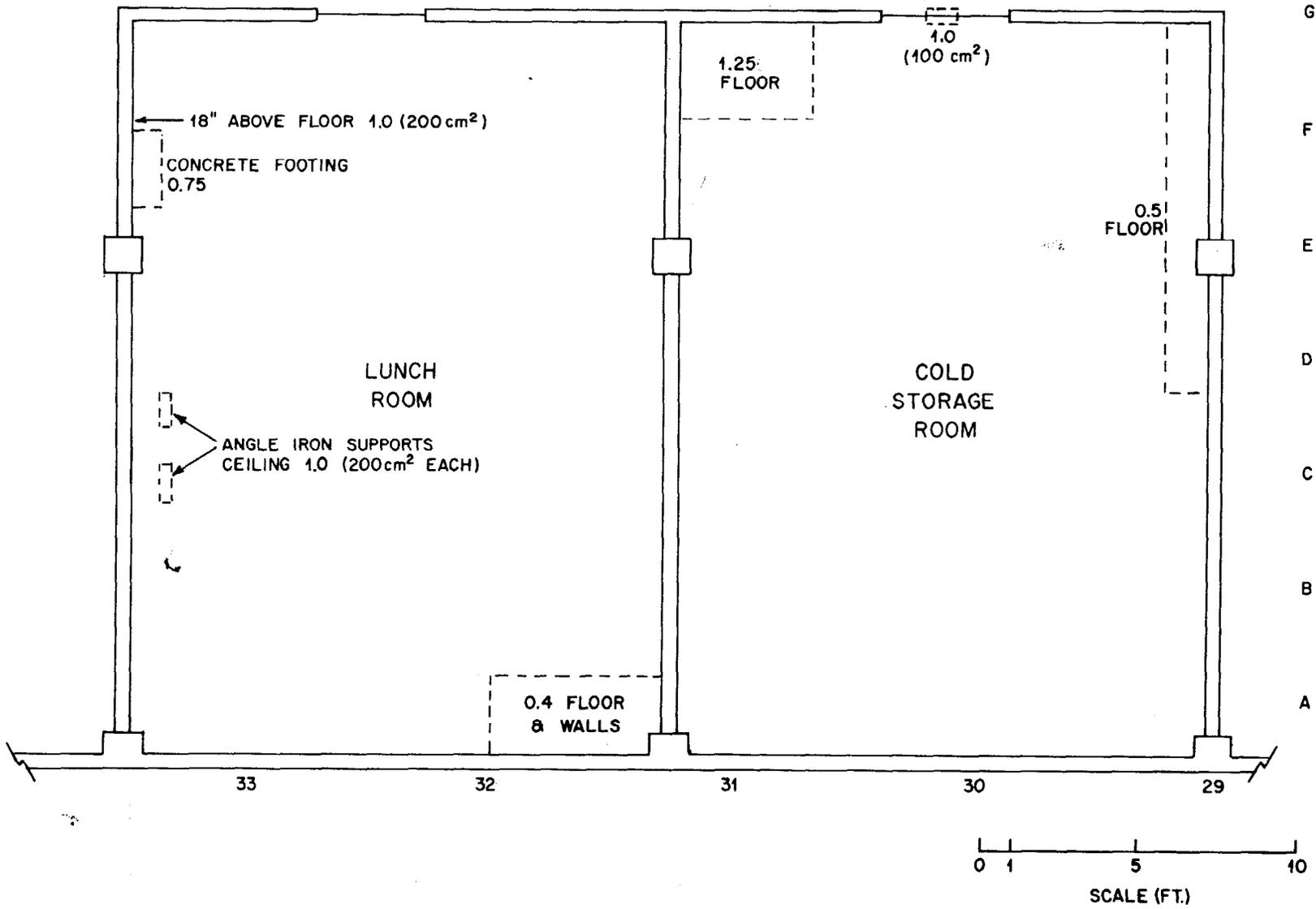


Fig. 8. Beta-gamma dose rates (mrad/hr) at 1 cm from surfaces in the cold room and lunchroom on the first level of Building 845.

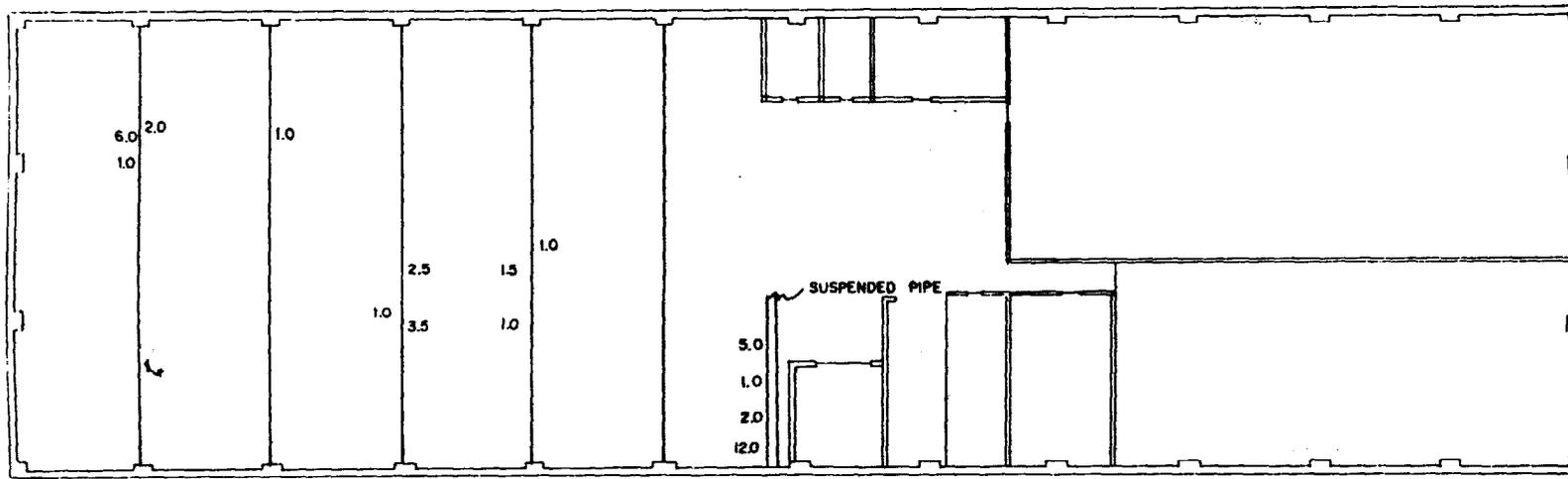


Fig. 9. Beta-gamma dose rates (mrad/hr) at 1 cm from ceiling surfaces on the second level of Building 845.

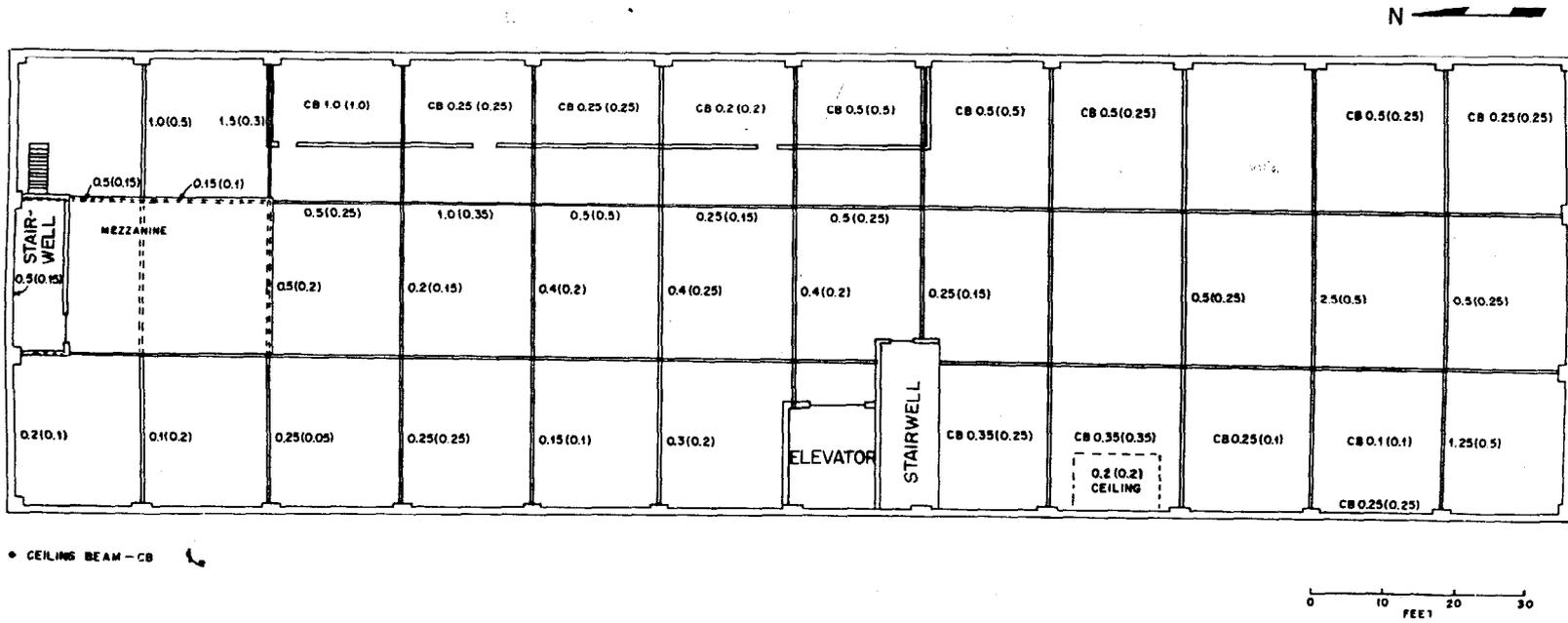


Fig. 10. Beta-gamma dose rates (mrad/hr) at 1 cm from ceiling surfaces on the fourth level of Building 845.

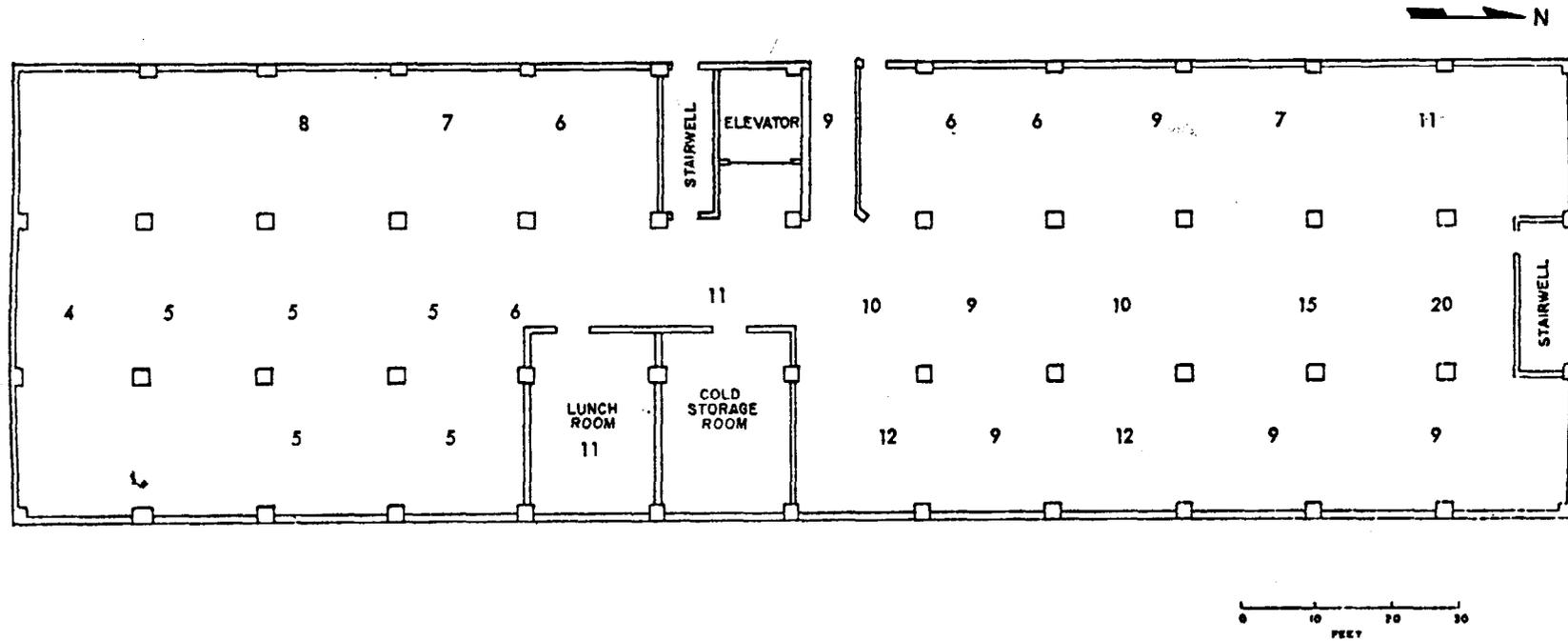


Fig. 11. External gamma radiation levels ( $\mu\text{R/hr}$ ) at 1 m from floor surfaces on the first level of Building 845.

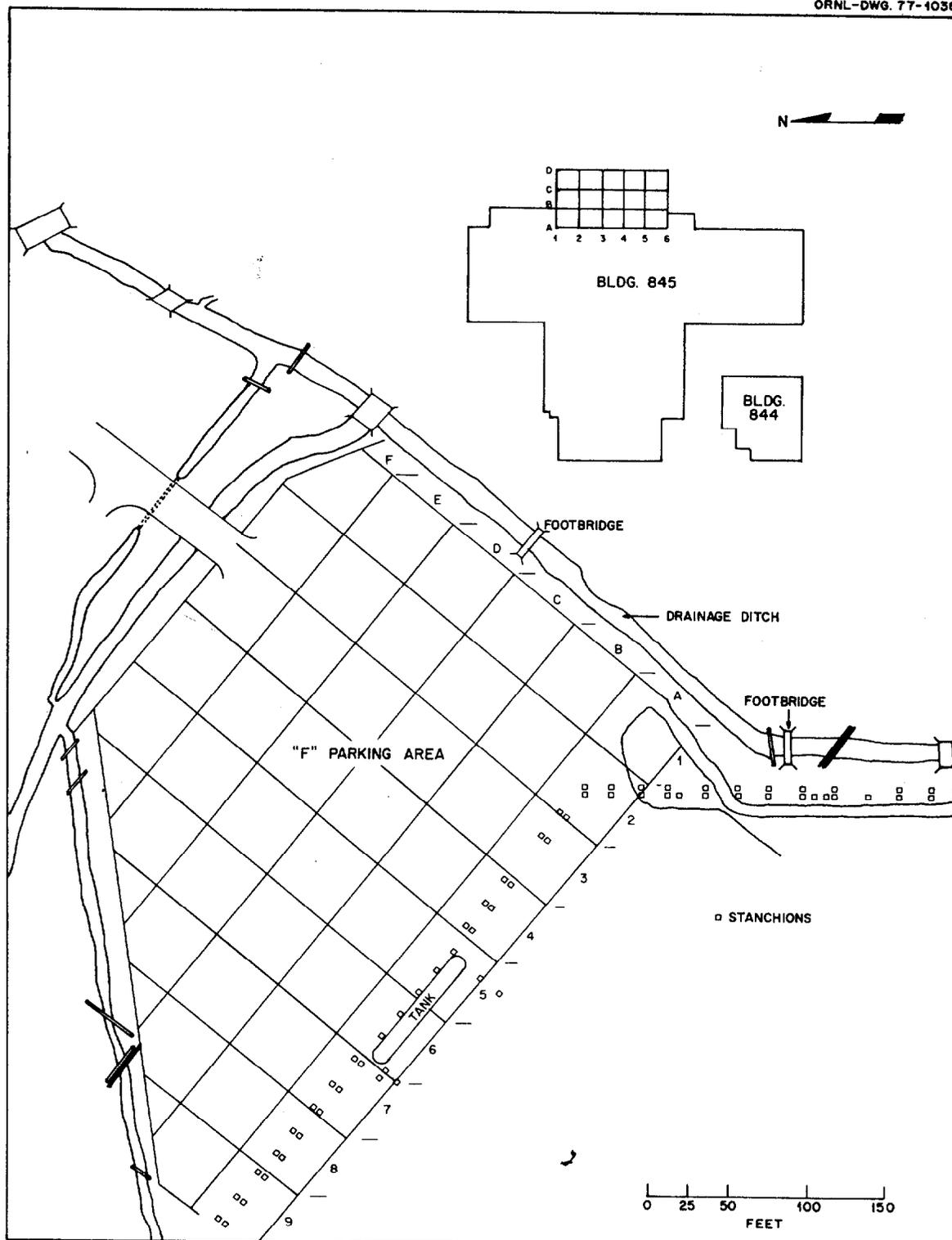


Fig. 12. Grid systems used for external gamma radiation level measurements in the "F" parking facility and in the area adjacent to the east wall of Building 845.

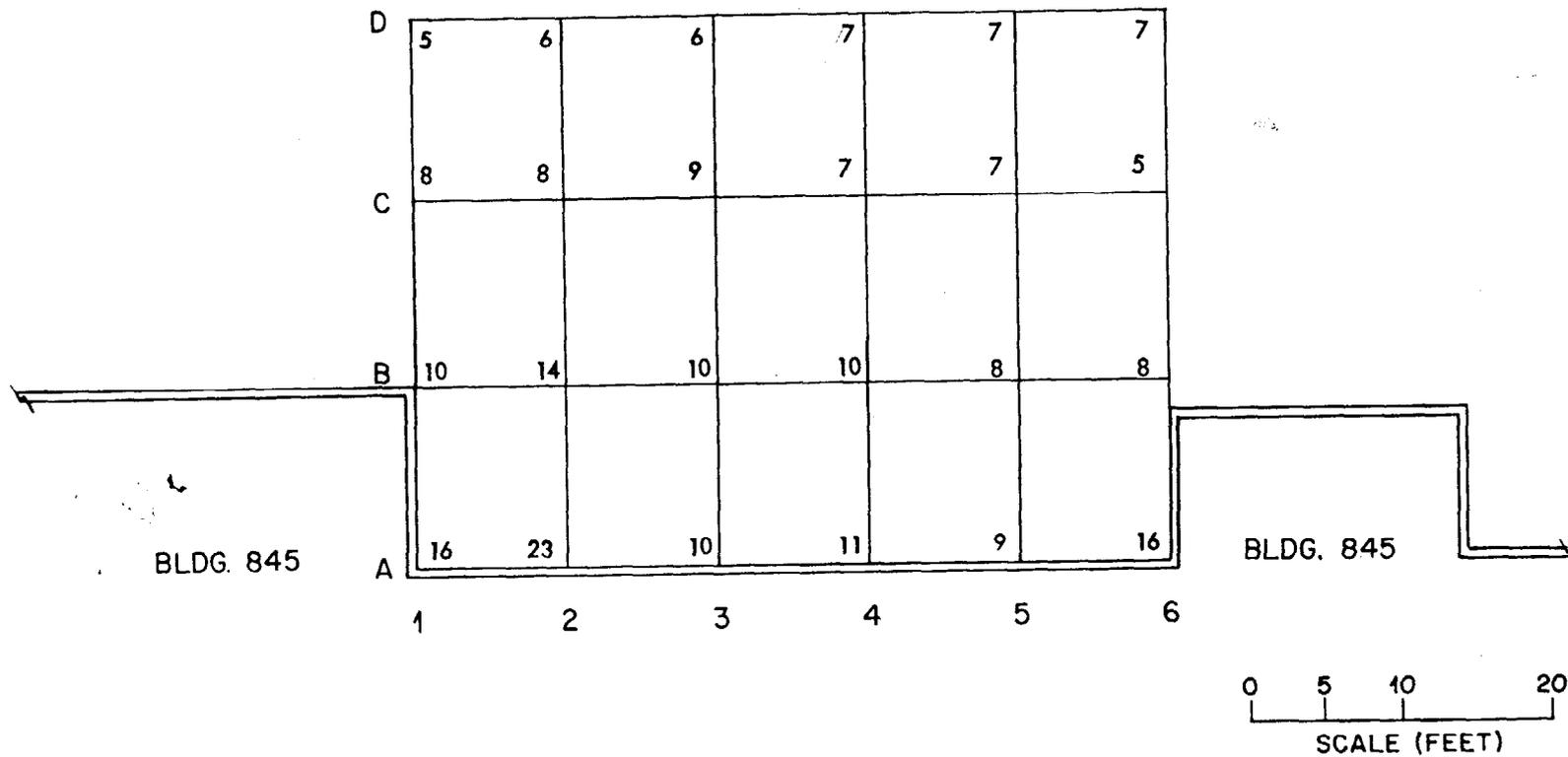


Fig. 13. External gamma radiation levels ( $\mu\text{R/hr}$ ) at 1 m above the surface at the grid points in an area adjacent to the east wall of Building 845.

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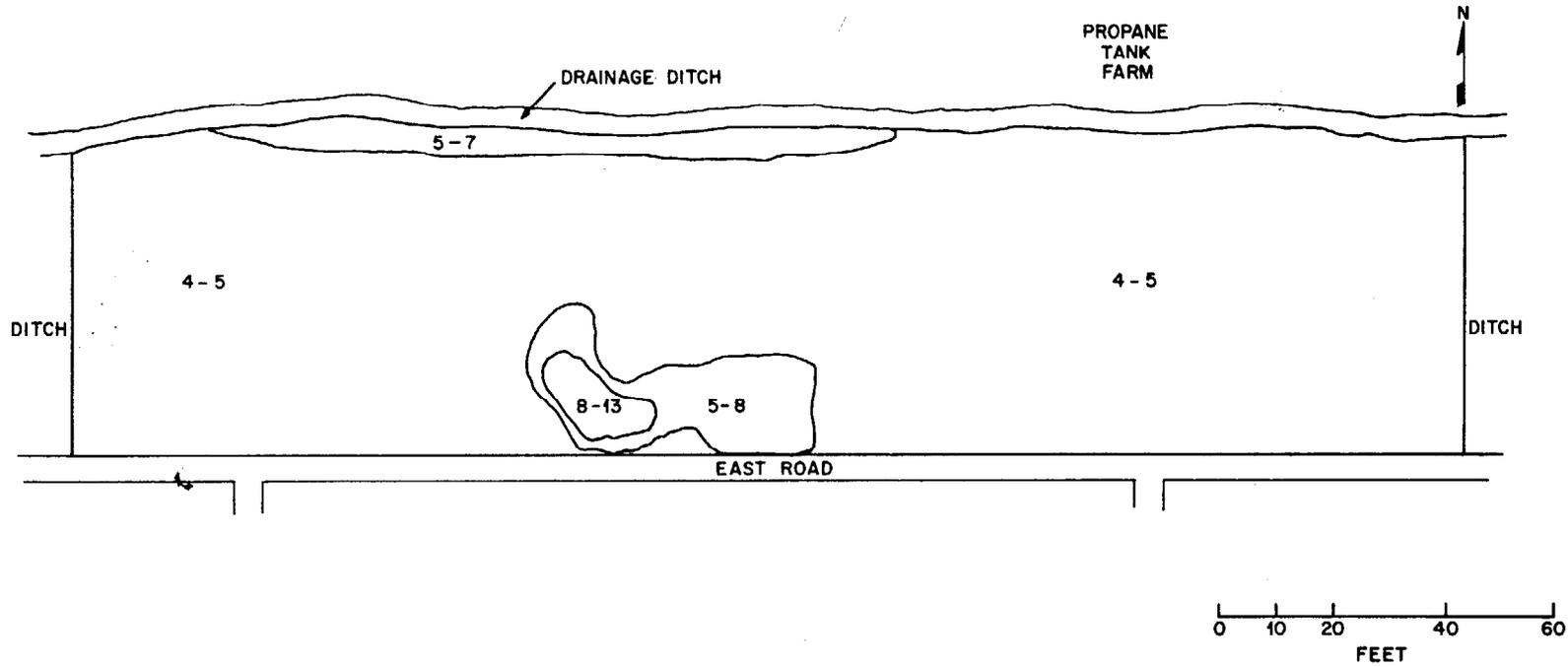


Fig. 14. External gamma radiation levels ( $\mu\text{R/hr}$ ) at 1 m above the surface in the east burial facility.

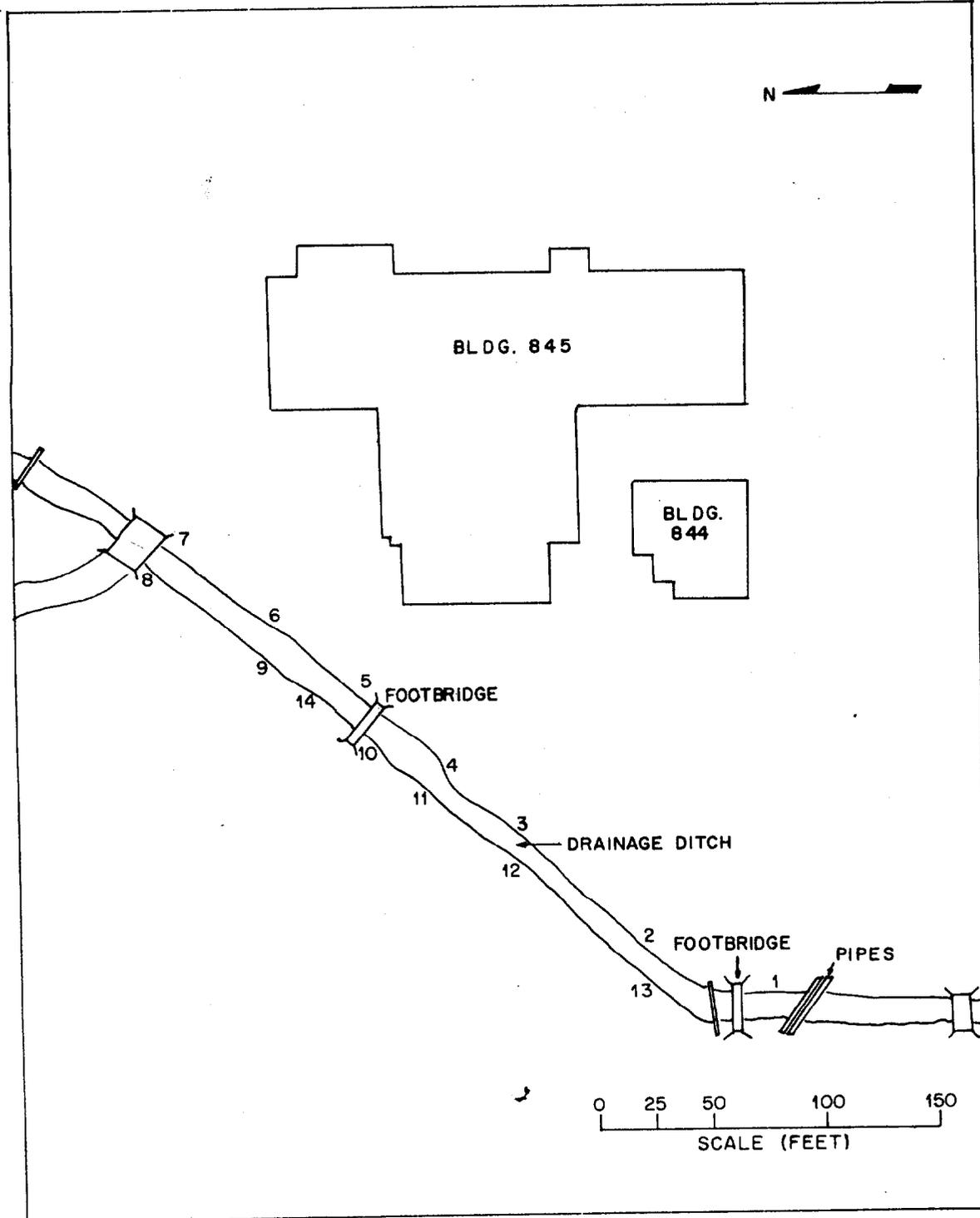


Fig. 15. Sampling points along the process waste drainage ditch.

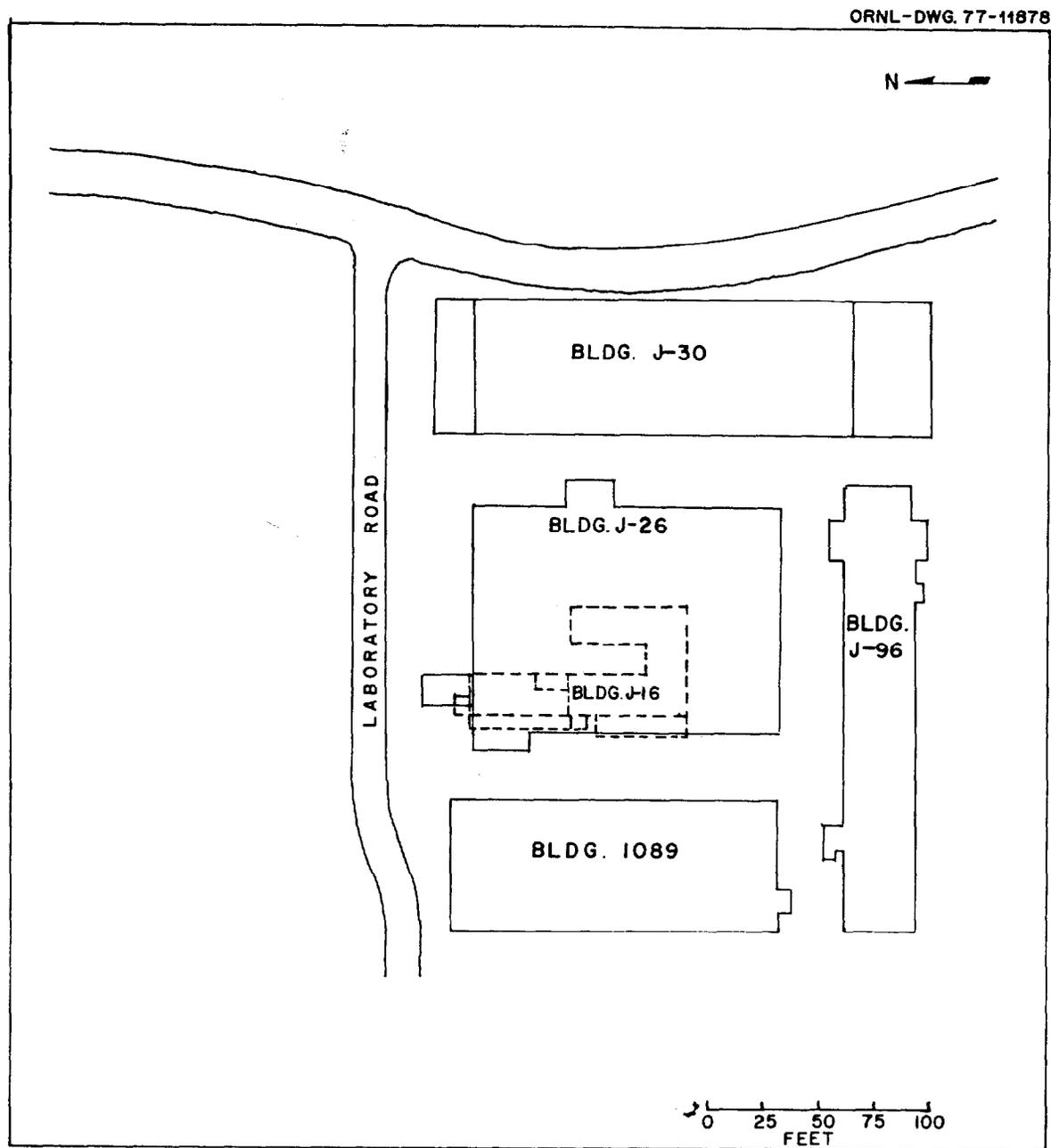


Fig. 16. Plan view of Building J-16 (demolished) and Building J-26.

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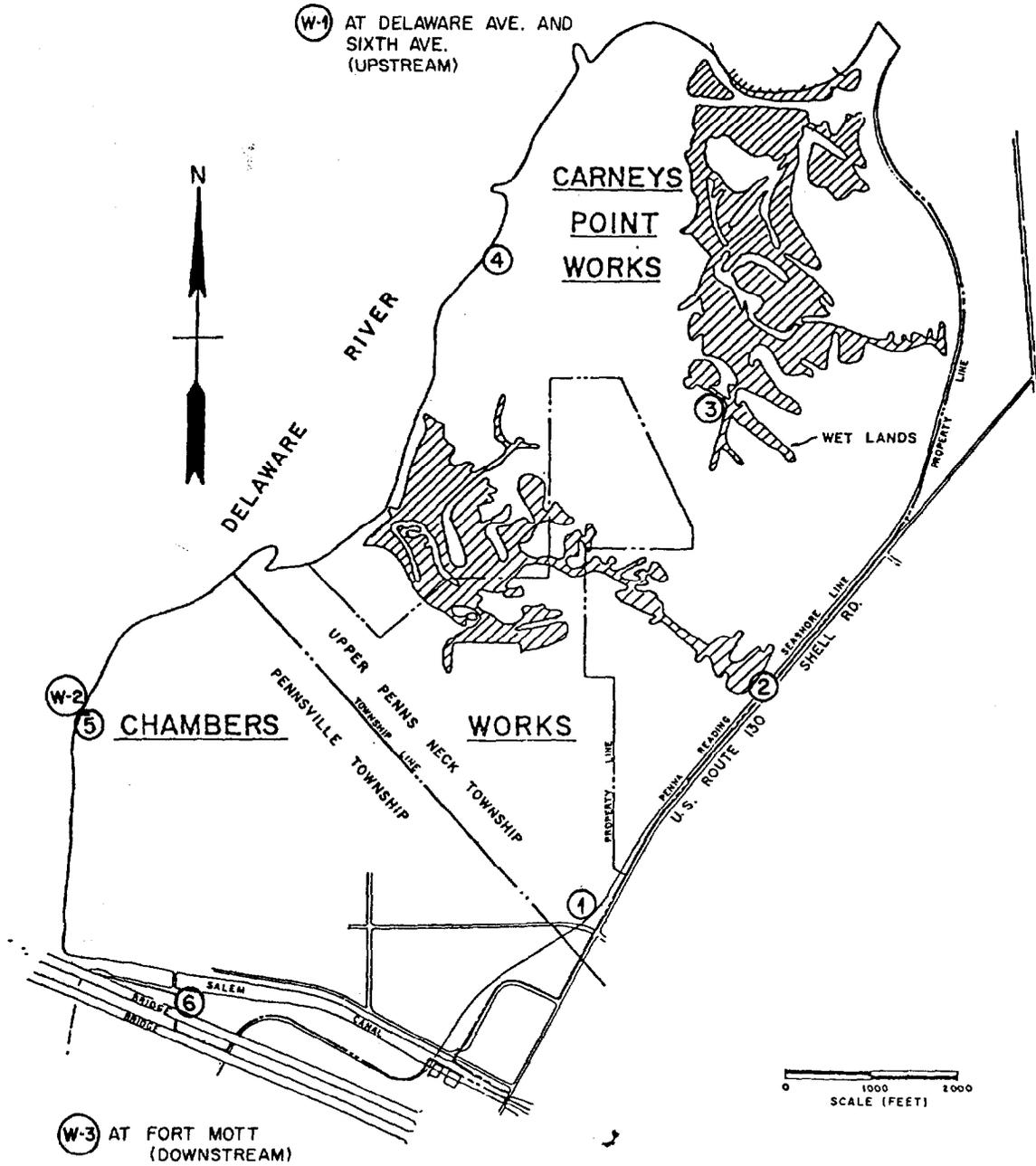


Fig. 17. Background sampling locations in the vicinity of the site.

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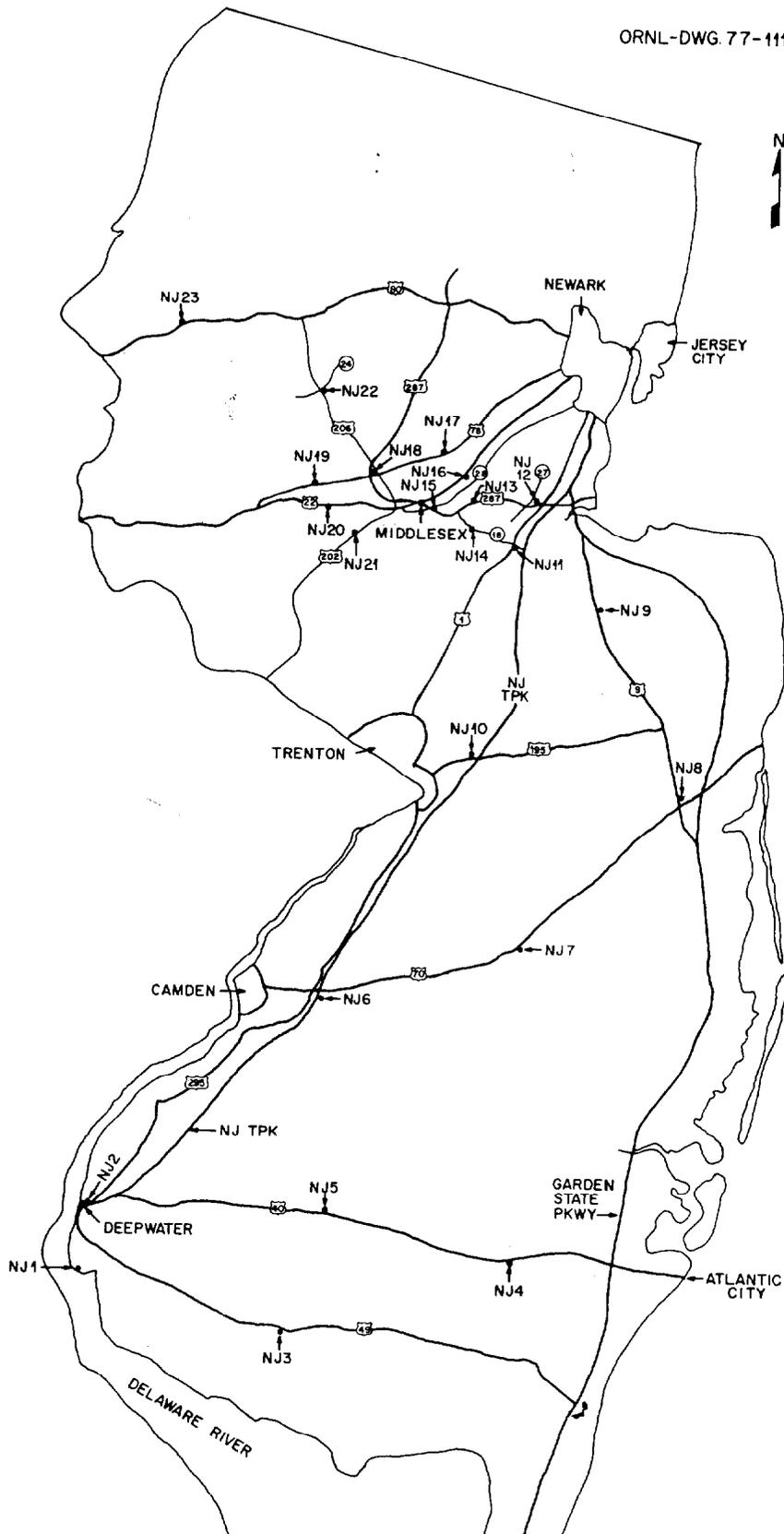


Fig. 18. Background sampling locations in the state of New Jersey.

Table 1. Direct readings<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
A- 1	900	0.40	B- 1	0.10
2		0.40	2	0.25
3	1500	0.50	3	0.10
4		0.50	4	0.15
5	1500	0.50	5	0.15
6		1.00	6	0.25
7	3000	0.75	7	0.15
8		0.75	8	0.25
9	1000	0.50	9	0.25
10		0.50	10	0.10
11	1000	0.75	11	0.15
12		0.75	12	0.15
13	1000	0.50	13	0.20
14		0.75	14	0.15
15	1000	1.00	15	0.15
16		0.50	16	0.15
17	1000	0.40	17	0.15
18		0.40	18	0.15
19	covered	0.50	19	0.15
20		0.50	20	0.30
21	1000	0.75	21	0.50
22		0.75	22	0.10
23	1000	0.50	23	0.10
24		0.50	24	0.10
25	1000	0.50	25	0.15
26		0.25	26	0.25
27	covered	0.25	27	0.50
28		0.25	28	0.25
29	covered	0.25	29	0.25

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
C- 1	covered with sealant	0.10	D- 1	0.10
2	covered with sealant	0.25	2	0.10
3	covered with sealant	0.05	3	0.05
4	covered with sealant	0.10	4	0.05
5	covered with sealant	0.20	5	0.10
6	covered with sealant	0.25	6	0.10
7	covered with sealant	0.10	7	0.25
8	covered with sealant	0.10	8	0.05
9	covered with sealant	0.10	9	0.05
10	covered with sealant	0.10	10	0.05
11	covered with sealant	0.10	11	0.05
12	covered with sealant	0.25	12	0.05
13	covered with sealant	0.25	13	< 0.05
14	covered with sealant	0.15	14	< 0.05
15	covered with sealant	0.25	15	0.25
16	covered with sealant	0.05	16	0.45
17	covered with sealant	0.05	17	0.10
18	covered with sealant	0.05	18	0.05
19	covered with sealant	0.05	19	0.20
20	covered with sealant	0.05	20	0.10
21	covered with sealant	0.05	21	0.35
22	covered with sealant	0.05	22	0.05
23	covered with sealant	0.10	23	0.05
24	covered with sealant	0.10	24	0.40
25	covered with sealant	0.50	25	0.30
26	covered with sealant	0.10	26	0.20
27	covered with sealant	0.10	27	0.05
28	covered with sealant	0.10	28	0.05
29	covered with sealant	covered	29	0.35

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
E- 1	300	0.10	F- 1	0.10
2		0.10	2	0.10
3	300	0.15	3	0.15
4		0.15	4	0.15
5	300	0.25	5	0.15
6		0.40	6	0.20
7	500	0.25	7	0.10
8		0.25	8	0.15
9	300	0.25	9	0.15
10		0.50	10	0.15
11	500	0.50	11	0.30
12		0.15	12	0.10
13	500	0.20	13	0.15
14		0.25	14	0.10
15	300	0.50	15	0.15
16		0.25	16	0.25
17	300	0.25	17	0.15
18		0.15	18	0.15
19	300	0.75	19	0.10
20		0.45	20	0.10
21	500	0.40	21	0.15
22		0.30	22	0.25
23	500	0.50	23	0.15
24		0.50	24	0.30
25	300	0.50	25	0.25
26		0.25	26	0.50
27	1000	0.25	27	0.50
28		0.25	28	0.50
29	covered with sealant	0.35	29	0.50

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
G- 1		0.10	H- 1	0.10
2	300	0.10	2	0.10
3		0.05	3	0.10
4	300	0.10	4	0.10
5		0.15	5	0.10
6	400	0.05	6	0.08
7		0.05	7	0.05
8	300	0.10	8	0.08
9		0.15	9	0.25
10	500	0.15	10	0.25
11		0.10	11	0.50
12	300	0.10	12	0.20
13		0.15	13	0.10
14	300	0.20	14	0.25
15		0.15	15	0.15
16	400	0.35	16	0.20
17		0.20	17	0.25
18	300	0.10	18	0.25
19		0.10	19	0.05
20	500	0.15	20	0.05
21		0.15	21	0.15
22	300	0.25	22	0.15
23		0.25	23	0.15
24	400	0.25	24	0.05
25		0.30	25	0.05
26	300	0.40	26	0.15
27		0.35	27	0.05
28	covered with sealant	0.35	28	0.05
29		0.75	29	0.25

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
I- 1	< 300	0.10	J- 1	0.10
2		0.10	2	0.10
3	< 300	0.10	3	0.10
4		0.10	4	0.10
5	< 300	0.10	5	0.10
6		0.10	6	0.10
7	< 300	0.05	7	0.10
8		0.05	8	0.15
9	< 300	0.10	9	0.10
10		0.20	10	0.25
11	< 300	0.15	11	0.05
12		0.25	12	0.05
13	< 300	0.10	13	0.05
14		0.10	14	0.20
15	< 300	0.25	15	0.25
16		0.15	16	0.20
17	< 300	0.25	17	0.18
18		0.30	18	0.20
19	< 300	0.15	19	0.30
20		0.10	20	0.50
21	< 300	0.05	21	0.25
22		0.05	22	0.05
23	< 300	0.05	23	0.25
24		0.20	24	0.40
25	< 300	0.15	25	0.50
26		0.05	26	0.25
27	< 300	0.05	27	0.25
28		0.05	28	0.25
29	< 300	0.10	29	0.25

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
K- 1		0.25	L- 1	0.10
2	300	0.20	2	0.10
3		0.15	3	0.10
4	300	0.10	4	0.10
5		0.15	5	0.10
6	300	0.10	6	0.40
7		0.10	7	0.15
8	300	0.15	8	0.10
9		0.10	9	0.15
10	500	0.50	10	0.15
11		0.35	11	0.50
12	400	0.15	12	0.30
13		0.15	13	0.20
14	400	0.15	14	0.15
15		0.50	15	0.15
16	300	0.30	16	0.25
17		0.15	17	0.15
18	300	0.15	18	0.15
19		0.20	19	0.15
20	300	0.15	20	0.15
21		0.10	21	0.15
22	300	0.10	22	0.15
23		0.10	23	0.15
24	300	0.35	24	0.15
25		0.50	25	0.15
26	200	0.10	26	0.15
27		0.35	27	0.30
28	200	0.20	28	0.15
29		0.15	29	0.15

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
M- 1	< 300	0.10	N- 1	0.15
2		0.10	2	0.10
3	< 300	0.10	3	0.10
4		0.10	4	0.10
5	< 300	0.10	5	0.10
6		0.15	6	0.15
7	< 300	0.10	7	0.10
8		0.10	8	0.10
9	500	0.15	9	0.10
10		0.20	10	0.20
11	500	0.25	11	0.15
12		0.50	12	0.15
13	300	0.50	13	0.15
14		0.25	14	0.20
15	300	0.25	15	0.20
16		0.15	16	0.15
17	100	0.20	17	0.15
18		0.25	18	0.15
19	200	0.15	19	0.15
20		0.15	20	0.15
21	300	0.15	21	0.15
22		0.15	22	0.30
23	300	0.15	23	0.15
24		0.15	24	0.15
25	300	0.15	25	0.15
26		0.15	26	0.15
27	300	0.15	27	0.15
28		0.15	28	0.15
29	300	0.15	29	0.15

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
0- 1		0.25	P- 1	0.25
2	< 300	0.10	2	0.50
3		0.15	3	0.25
4	< 300	0.15	4	0.25
5		0.30	5	0.50
6	300	0.20	6	0.40
7		0.10	7	0.40
8	300	0.10	8	0.40
9		0.10	9	0.25
10	300	0.15	10	0.25
11		0.15	11	0.25
12	500	0.15	12	0.30
13		0.15	13	0.45
14	500	0.30	14	0.35
15		0.20	15	0.50
16	500	0.20	16	0.50
17		0.15	17	0.45
18	500	0.25	18	0.50
19		0.15	19	0.50
20	300	0.15	20	0.50
21		0.25	21	0.50
22	300	0.40	22	0.25
23		0.15	23	0.10
24	300	0.05	24	0.10
25		0.05	25	0.05
26	300	0.05	26	0.10
27		0.03	27	0.10
28	300	0.05	28	0.10
29		0.05	29	0.10

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
Q-30				
31				
32	< 300	0.25		
33		0.25		
34	< 300			
35				
36	< 300	0.25		
37				
38	500	0.25		
39				
40	< 300			
R-30				
31				
32				
33	< 300			
34				
35	< 300			
36				
37	< 300			
38				
39	< 500			
40				
41				

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
S-30	< 300	0.25		
31		0.25		
32	< 300	0.25		
33		0.25		
34	< 300			
35				
36	< 300			
37				
38	< 500			
39				
40	floor covered			
41				
T-30				
31				
32				
33				
34				
35	< 300			
36				
37	1000			
38				
39				
40				
41				

Table 1. (cont'd.) Direct reading<sup>a</sup> of alpha contamination and beta-gamma dose rates on floor in first level of Building 845

Location <sup>b</sup>	Average direct reading $\alpha$ (dpm/100 cm <sup>2</sup> )	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)	Location <sup>b</sup>	Average direct reading $\beta\gamma$ (mrad/hr @ 1-cm)
U-30	covered with pipe		V-30	room covered with wood flooring
31			31	room covered with wood flooring
32	covered with pipe		32	room covered with wood flooring
33			33	room covered with wood flooring
34	< 200		34	room covered with wood flooring
35			35	room covered with wood flooring
36	< 200		36	room covered with wood flooring
37			37	room covered with wood flooring
38	covered with pipe		38	room covered with wood flooring
39			39	room covered with wood flooring
40	covered with pipe		40	room covered with wood flooring
41			41	room covered with wood flooring

<sup>a</sup>Direct alpha reading taken in alternate grid lines (A, C, E, etc).

<sup>b</sup>See Fig. 4.

Table 2. Directly measured beta-gamma dose rates exceeding 0.2 mrad/hr on walls in Building 845

Location <sup>a</sup>	Beta-gamma dose rate (mrad/hr)	Location <sup>a</sup>	Beta-gamma dose rate (mrad/hr)
<u>1st level</u>			
Walls in North section			
North (42, 0.5)	2.0	East, beam running from (0, 6.5) to (8, 6.5)	2.0
North (41, 3)	1.0	East, beam running from (8, 6.5) to (16, 6.5)	1.5
North (43, 7)	1.7	East, beam running from (0, 2.5) to (16, 2.5)	1.0
North (57, 0.5)	0.75	East, beam running from (16, 0.5) to (32, 0.5)	2.0
West (13, 0.5)	0.5	East, beam running from (16, 2.5) to (32, 2.5)	1.5
West (19, 0.5)	0.5	East, beam running from (16, 6.5) to (32, 6.5)	2.0
West (25, 0.5)	2.5	East, beam running from (32, 0.5) to (42, 0.5)	2.0
West (24, 3)	0.5	East (44, 0.5)	3.0
West (29, 0.5)	1.5	East (46, 0.5)	1.8
West (33, 0.5)	2.0	East, beam running from (32, 2.5) to (48, 2.5)	1.5
West (34, 2.5)	1.5	East, beam running from (32, 6.5) to (48, 6.5)	2.5
West (35, 5)	0.25	East (49, 0.5)	2.0
West (33, 7)	1.5	East (53, 0.5)	1.5
West (38, 0.5)	1.8	East (56, 0.5)	1.5
West (39, 3)	1.5	East (59, 0.5)	1.0
West (39, 7)	1.5	East, beam running from (48, 6.5) to (64, 6.5)	2.5
West (42, 0.5)	2.5	East (67, 0.5)	2.0
West (42, 7)	1.5	East (74, 0.5)	5.0
West (46, 0.5)	3.0	East (77, 0.5)	2.0
West (45, 2.5)	1.5	East (65, 2.5)	2.0
West (44, 5)	0.25	East (71, 2.5)	1.5
West (45, 7)	1.0		
West (50, 0.5)	3.0		
West (49, 2.5)	1.8		
West (49, 7)	1.5		
West (53, 0.5)	2.0		
West (56, 0.5)	0.5		
West (56, 2.5)	0.75		
West (55, 7)	1.3		
West (61, 0.5)	0.75		
West (63, 2.5)	0.75		
West (61, 7)	1.5		
West, beam running from (64, 0.5) to (80, 0.5)	1.3		
West, beam running from (64, 7) to (80, 7)	1.0		
East (2, 0.5)	1.0		
East (10, 0.5)	1.0		
East (14, 0.5)	1.5		

Table 2. (cont.) Directly measured beta-gamma dose rates exceeding 0.2 mrad/hr on walls in Building 845

Location <sup>a</sup>	Beta-gamma dose rate (mrad/hr)	Location <sup>a</sup>	Beta-gamma dose rate (mrad/hr)
East (74, 2.5)	2.8	West (46, 1.5)	2.5
East (76, 2.5)	2.0	West (46, 1)	1.5
East (78, 2.5)	1.0	West (46, 5)	1.5
East, beam running from (64, 6.5)		West (34, 7)	1.0
to (70, 6.5)	5.5	West (39, 7)	1.0
East (72, 6.5)	5.5	West (43, 7)	1.0
East (74, 6.5)	3.3	West (47, 7)	3.5
East (76, 6.5)	2.0	West (50, 1.5)	2.0
East (83, 0.5)	2.0	West (54, 2)	1.0
East (91, 0.5)	0.75	West (57, 2)	1.5
East (94, 0.5)	1.0	West (59, 2)	1.3
East (81, 2.5)	2.8	West (62, 1.5)	0.75
East (91, 2.5)	1.0	West (50, 7)	2.5
East (81, 6.5)	1.5	West (52, 7)	2.0
East (84, 6.5)	1.5	West (55, 7)	2.5
East (88, 6.5)	1.5	West (58, 7)	1.5
East (94, 6.5)	1.0	West (48, 1.5), behind vertical beam	4.0
		West (64, 1.5), behind vertical beam	2.0
<u>2nd level</u>		West (66, 1.5)	1.5
<u>Walls in North section</u>		West (66, 7)	1.5
North (3, 3)	0.35	East (38, 1.5)	1.0
North, beam running from (20, 1.5)		East (27, 7)	0.75
to (29, 1.5)	0.75	East (33, 7)	0.75
West (2, 2)	1.0	East (38, 7)	1.0
West (5, 2)	0.5	East (42, 1.5)	0.75
West (9, 2)	0.75	East (45, 1.5)	1.8
West (14, 1.5)	1.0	East (46, 1.5)	0.5
West (6, 7)	1.0	East (50, 1.5)	0.5
West (11, 7)	1.0	East (54, 1.5)	1.0
West (18, 1.5)	1.5	East (42, 7)	0.5
West (21, 2)	2.0	East (46, 7)	1.3
West (24, 2)	1.5	East (50, 7)	1.3
West (28, 2)	1.0	East (54, 7)	1.3
West (30, 1.5)	1.5	East (58, 1.5)	0.75
West (18, 7)	1.3	East (62, 1.5)	0.75
West (22, 7)	1.5	East (64, 1.5)	2.0
West (25, 7)	3.5	East (66, 1.5)	1.5
West (28, 7)	1.5	East (71, 1.5)	1.3
West (31, 7)	1.0	East (61, 7)	2.0
West (33, 1.5)	1.5	East (63, 7)	3.5
West (37, 2)	1.5	East (65, 7)	3.0
West (40, 2)	2.5	East (67, 7)	1.0
West (43, 2)	2.5	East (68, 7)	1.5
		East (71, 7)	0.5

Table 2. (cont.) Directly measured beta-gamma dose rates  
exceeding 0.2 mrad/hr on walls in Building 845

Location <sup>a</sup>	Beta-gamma dose rate (mrad/hr)	Location <sup>a</sup>	Beta-gamma dose rate (mrad/hr)
East (74, 1.5)	0.5	Walls in South section	
<u>3rd level</u>		South, average over area defined by (0, 0), (21, 0), (21, 8) and (0, 8)	0.5
Walls in North section		South, average over area defined by (21, 0), (41, 0), (41, 8) and (21, 8)	0.25
North (57, 2.5)	0.38	South, average over area defined by (41, 0), (60, 0), (60, 8) and (41, 8)	0.5
West (66, 2.5)	1.0	West, average over area defined by (33, 0), (82, 0), (82, 8), and (33, 8)	0.5
East (49, 3)	1.0		
East (66, 3)	1.0		
Walls in South section			
West (average over entire wall)	0.5		
East (average over entire wall)	0.3		
<u>4th level</u>			
Walls in North section			
East, average over area defined by (0, 3), (91, 0), (91, 8), and (0, 8)	0.5		

<sup>a</sup>The designation West (24, 3), for example, means the point is on the west wall, 24 ft to the right (facing the wall) of the lower left-hand corner of the wall, and 3 ft above the floor. See the example in Fig. 6.

Table 3. Results for smear samples taken in Building 845<sup>a</sup>

Location	Transferable alpha (dpm/100 cm <sup>2</sup> )	Transferable beta (dpm/100 cm <sup>2</sup> )
<u>1st Level</u>		
Floor		
Q32	< 10	120
S30	< 10	130
T41	< 10	130
U34	< 10	100
U36	< 10	170
U40	< 10	100
U35	< 10	220
Q34	< 10	180
Q36	< 10	230
Q40	< 10	120
A19	< 20	130
A23	< 20	130
E13	< 10	120
E23	< 10	120
E29	< 10	180
G26	< 10	100
I5	< 10	100
M7	< 10	120
O4	< 10	100
O16	< 10	120
O22	< 10	120
Lunchroom floor	< 10	150
Cold storage room floor	< 20	130
Overhead		
01	< 10	100
02	< 10	100
03	< 10	120
08	< 10	100
Walls in south section		
West (32,7)	15	320
West (14,3)	15	130
West (9,3)	25	250
West (9,7)	130	330
East (58,6)	< 10	100
South (8,6)	< 10	100

Table 3. (cont'd.) Results for smear samples taken in Building 845<sup>a</sup>

Location	Transferable alpha (dpm/100 cm <sup>2</sup> )	Transferable beta (dpm/100 cm <sup>2</sup> )
<u>1st Level</u>		
Walls in north section		
East (1,2)	< 10	100
East (12,7)	15	200
East (20,0)	190	170
East (30,7)	110	220
East (44,0)	210	300
East (45,5)	25	200
East (56,7)	120	10
East (77,7)	15	170
North (41,5)	20	150
North (9,3)	< 10	100
West (72,7)	60	120
West (56,0)	20	130
West (43,0)	50	120
West (48,7)	130	320
West (36,3)	60	200
West (34,7)	80	130
West (9,7)	180	320
West (11,3)	< 10	150
<u>2nd Level</u>		
Floor		
A6	< 10	130
B7	< 10	130
C12	< 10	130
Restroom	< 10	220
Walls		
West (66,3)	20	100
West (47,7)	80	120
West (50,3)	< 10	170
West (47,3)	80	500
West (41,7)	120	70
West (25,7)	130	120
West (19,3)	60	230
West (10,7)	60	300
East (71,3)	30	220
East (47,7)	180	270
East (39,3)	20	130
East (22,3)	< 10	130

Table 3. (cont'd.) Results for smear samples taken in Building 845<sup>a</sup>

Location	Transferable alpha (dpm/100 cm <sup>2</sup> )	Transferable beta (dpm/100 cm <sup>2</sup> )
<u>3rd Level</u>		
Floor		
A3	< 10	100
A1	< 10	120
C5	< 10	220
Walls in north section		
West (76,4)	< 10	170
West (25,2)	< 10	120
Walls in south section		
West (43,4)	< 10	100
West (27,4)	< 10	150
<u>4th Level</u>		
Floor		
B7	< 10	130
B3	< 10	100
A1	< 10	100
Overhead		
Ceiling beam over A4 rafter, ~8 ft above floor over B6	450 70	740 150
Walls in north section		
West (32,2)	< 10	150
Concrete floor of mezzanine	50	120
Restroom	< 10	250

<sup>a</sup>Note: Results are reported only for those smear samples showing transferable alpha or beta contamination levels of 10 dpm/100 cm<sup>2</sup> or more. Identifications of floor and ceiling locations refer to the grids shown in Fig. 4. Wall locations are given in Cartesian coordinates with the lower left hand corner of each wall used as an origin. For example, West (10,3) means the west wall, 10 ft out from the lower left hand corner (facing the wall), and 3 ft above the floor.

Table 4. Airborne  $^{222}\text{Rn}$  daughter concentrations in Building 845

Sample location	Number of working levels <sup>a</sup>
1st Floor north end	$5 \times 10^{-4}$
1st Floor center	$< \text{MDA}^b$
1st Floor south end	$6 \times 10^{-4}$
2nd Floor center	$< \text{MDA}^b$
3rd Floor center	$2 \times 10^{-4}$
4th Floor north end	$2 \times 10^{-4}$
4th Floor center	$1 \times 10^{-4}$

<sup>a</sup>Working level (WL) is defined as any combination of short lived radon daughters in one liter of air that will result in the ultimate emission of  $1.3 \times 10^5$  Mev of alpha particle energy.

<sup>b</sup>MDA is minimum detectable activity.

Table 5. Concentration of radionuclides found in residue and drain scale samples taken from the first level of Building 845.

Location <sup>a</sup>	Radionuclide concentrations (pCi/g)			
	$^{238}\text{U}$	$^{226}\text{Ra}$	$^{227}\text{Ac}$	$^{232}\text{Th}$
J-20 (drain)	1000	2.6	18.1	not found
K-1 (drain)	290	3.2	5.1	not found
A-15	51,460	not found	330	not found
E-25	26,960	16.1	not found	not found

<sup>a</sup>See Fig. 4.

Table 6. Results of high-volume air sampling in Building 845

Location	Radionuclide concentrations (pCi/cm <sup>3</sup> )		
	<sup>238</sup> U	<sup>226</sup> Ra	<sup>230</sup> Th
1st floor, north end, 1 m above floor	$4.7 \times 10^{-8}$	$6.9 \times 10^{-11}$	$6.3 \times 10^{-10}$
4th floor, north end, 1.5 m above floor	$9.7 \times 10^{-10}$	$1.7 \times 10^{-10}$	$5.1 \times 10^{-11}$
CG <sub>a</sub> <sup>*</sup>	$3 \times 10^{-6}$	$2 \times 10^{-6}$	$8 \times 10^{-8}$

\*The concentration guide in air (CG<sub>a</sub>) referred to here is the recommended concentration in uncontrolled areas on the basis of exposure for 168 hours per week.

Table 7. Measurements along the drainage ditch between Building 845 and the "F" parking facility

Location <sup>a</sup>	External $\lambda$ -radiation level at 1 m ( $\mu$ R/hr)	Radionuclide concentrations <sup>b</sup> (pCi/g)			
		<sup>238</sup> U	<sup>226</sup> Ra	<sup>232</sup> Th	<sup>227</sup> Ac
1	3	2.4	0.55	0.63	not found
2	4	1.4	0.69	0.75	1.7
3	4	1.2	0.64	0.60	not found
4	3	1.2	0.49	0.52	not found
5	6	0.8	0.34	0.38	not found
6	5	1.8	0.41	0.54	not found
7	3	8.5	0.49	0.50	not found
8	11	33.1	0.39	0.41	not found
9	9	63.5	0.38	0.41	not found
10	3	11.2	0.51	0.69	not found
11	4	1.37	0.54	0.72	not found
12	4	4.4	0.49	0.42	not found
13	4	0.91	0.39	0.49	not found
14	23	12,600	not found	not found	not found

<sup>a</sup>See Fig. 15.

<sup>b</sup>These radionuclide concentrations are for surface soil samples taken to a maximum depth of 5 cm.

Table 8. Concentration of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  in subsurface soil samples

Core hole number <sup>a</sup>	Depth (ft)	Radionuclide concentrations (pCi/g)			
		$^{238}\text{U}$	$^{226}\text{Ra}$	$^{227}\text{Ac}$	$^{232}\text{Th}$
1	1.0 to 2.0	144	0.7	not found	0.5
	2.0 to 3.0	83	0.9	not found	0.8
2	5.0 to 5.5	2.3	0.6	not found	0.7
	5.5 to 6.0	not found	0.7	not found	0.7
	6.0 to 6.5	2	1.0	not found	1.1
	6.5 to 7.0	0.1	1.0	not found	1.0
3	0.0 to 0.5	7050	15.0	19.0	not found
	0.5 to 1.0	1067	0.9	not found	0.8
	1.0 to 1.5	682	not found	not found	not found
	1.5 to 2.0	162	0.6	not found	0.7
	2.0 to 2.5	158	0.6	not found	0.7
	2.5 to 3.0	146	0.7	not found	0.6
	3.0 to 3.5	12.6	0.6	not found	0.7
	3.5 to 4.0	not found	0.7	not found	0.8
4	0.0 to 0.5	6390	18	38	not found
	0.5 to 1.0	11200	16	26	not found
	1.0 to 1.5	1750	not found	not found	not found
	1.5 to 2.0	777	not found	not found	0.8
	2.0 to 2.5	477	not found	not found	0.7
	2.5 to 3.0	260	not found	not found	0.5
	3.0 to 3.5	64	0.6	not found	0.7
	3.5 to 4.0	not found	0.7	not found	0.7
	4.0 to 4.5	367	1.1	not found	0.9
	4.5 to 5.0	3	0.9	not found	0.8
	5.0 to 5.5	1	0.7	0.4	0.8
	5.5 to 6.0	not found	0.9	not found	0.9

Table 8. (cont'd.) Concentration of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  in subsurface soil samples

Core hole number <sup>a</sup>	Depth (ft)	Radionuclide concentrations (pCi/g)			
		$^{238}\text{U}$	$^{226}\text{Ra}$	$^{227}\text{Ac}$	$^{232}\text{Th}$
5	6.0 to 6.5	1.1	0.5	not found	0.6
	6.5 to 7.0	not found	0.7	0.6*	0.7
	7.0 to 7.5	1.1	0.7	not found	0.8
	7.5 to 8.0	not found	1.2	0.8	1.3
	8.0 to 8.5	3.1	1.2	not found	1.4
	8.5 to 9.0	not found	1.4	not found	1.8
	9.0 to 9.5	2.5	1.4	not found	1.6
	9.5 to 10.0	not found	1.2	not found	1.4
6	1.0 to 1.5	not found	0.6	not found	0.7
	1.5 to 2.0	4.8	0.9	not found	1.0
	2.0 to 2.5	2.4	0.9	not found	1.0
	2.5 to 3.0	not found	1.1	not found	1.0
	3.0 to 3.5	not found	0.9	not found	1.1
	3.5 to 4.0	not found	0.7	not found	0.9
	4.0 to 4.5	2.6	1.4	not found	1.4
	4.5 to 5.0	9.5	1.3	not found	1.1
	5.0 to 7.0	1.5	0.9	not found	1.0
7	2.0 to 2.5	not found	1.3	1.0	1.2
	2.5 to 3.0	not found	1.8	not found	1.8
	3.0 to 3.5	not found	1.0	not found	1.1
	3.5 to 4.0	not found	1.1	not found	1.4

Table 8. (cont'd.) Concentration of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  in subsurface soil samples

Core hole number <sup>a</sup>	Depth (ft)	Radionuclide concentrations (pCi/g)			
		$^{238}\text{U}$	$^{226}\text{Ra}$	$^{227}\text{Ac}$	$^{232}\text{Th}$
8	0.0 to 0.5	70	0.8	not found	0.8
	0.5 to 1.0	17	0.9	not found	1.0
	1.0 to 1.5	9	1.0	not found	1.1
	1.5 to 2.0	not found	0.9	not found	0.8
	2.0 to 2.5	13	0.9	not found	1.0
	2.5 to 3.0	1.0	0.8	not found	0.9
	3.0 to 3.5	not found	1.1	0.8	1.2
	3.5 to 4.0	1.6	1.0	not found	1.3
	4.0 to 4.5	2.9	0.8	not found	1.0
	4.5 to 5.0	2.9	1.2	not found	1.4
	5.0 to 5.5	1.4	1.0	not found	1.3
	5.5 to 6.0	1.1	1.0	0.8	1.6
9	0.0 to 0.5	not found	0.8	not found	0.7
	0.5 to 1.0	not found	1.1	not found	0.7
	1.0 to 1.5	not found	0.4	not found	0.5
	1.5 to 2.0	not found	0.5	not found	0.6
	2.0 to 2.5	not found	0.6	not found	0.7
	2.5 to 3.0	not found	1.0	not found	1.2
	3.0 to 3.5	not found	1.1	0.7	0.9
	3.5 to 4.0	not found	1.4	not found	1.7
	4.0 to 4.5	not found	1.4	not found	1.6
	4.5 to 5.0	not found	1.2	not found	1.5
	5.0 to 5.5	not found	1.1	not found	1.3
	5.5 to 6.0	not found	1.2	1.0	1.3
10	0.0 to 2.0	7.8	1.0	0.8	1.0
	2.0 to 3.0	18	0.9	not found	1.1
	3.0 to 4.0	2.9	not found	not found	1.3

Table 8. (cont'd.) Concentration of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{227}\text{Ac}$ , and  $^{232}\text{Th}$  in subsurface soil samples

Core hole number <sup>a</sup>	Depth (ft)	Radionuclide concentrations (pCi/g)			
		$^{238}\text{U}$	$^{226}\text{Ra}$	$^{227}\text{Ac}$	$^{232}\text{Th}$
11	0.0 to 1.0	5190	not found	not found	not found
	1.0 to 2.0	751	0.6	not found	0.6
	2.0 to 2.5	320	not found	not found	0.6
	2.5 to 3.0	20	0.5	0.1	0.5
	3.0 to 3.5	274	0.8	not found	0.8
	3.5 to 4.0	64	0.8	not found	0.6
	4.0 to 4.5	671	0.9	not found	0.7
	4.5 to 5.0	35	0.7	not found	0.6
	5.0 to 5.5	not found	0.8	0.6	0.7
5.5 to 6.0	0.8	0.5	not found	0.7	
12	0.0 to 0.25	178	0.8	0.7	0.7
	0.25 to 0.5	1450	not found	not found	not found
	0.5 to 0.75	6920	not found	not found	not found
	0.75 to 1.0	2160	not found	not found	not found
	1.0 to 1.25	1620	2.3	not found	not found
	1.25 to 1.50	527	1.0	4.0	0.1
	1.50 to 1.75	171	0.5	not found	0.6
	1.75 to 2.0	92		not found	0.5
13	3.0 to 3.5	6.8	0.9	not found	0.5
	3.5 to 4.0	4.7	0.8	not found	0.8
14	0.0 to 0.5	3.5	0.2	not found	0.2
	0.5 to 1.0	not found	0.6	not found	0.7
	1.0 to 1.5	not found	1.0	0.7	0.8
	1.5 to 2.0	not found	0.6	not found	0.6
	2.0 to 2.5	not found	0.7	not found	not found
	2.5 to 3.0	2.0	1.0	not found	1.2

<sup>a</sup>See Figs. 2 and 3.

Table 9. Results of groundwater analyses

Core hole number <sup>a</sup>	Radionuclide concentrations (pCi/ml)			
	<sup>238</sup> U	<sup>226</sup> Ra	<sup>230</sup> Th	<sup>210</sup> Pb
9	$6.7 \times 10^{-4}$	$1.0 \times 10^{-3}$	$2.0 \times 10^{-4}$	$3.2 \times 10^{-3}$
11	$2.2 \times 10^{-1}$	$7.7 \times 10^{-4}$	$4.8 \times 10^{-4}$	$1.0 \times 10^{-2}$
12	$2.5 \times 10^{-1}$	$1.4 \times 10^{-4}$	$3.8 \times 10^{-3}$	---
13	$1.8 \times 10^{-3}$	$3.2 \times 10^{-4}$	$1.9 \times 10^{-4}$	$3.6 \times 10^{-3}$
CG <sub>w</sub> <sup>b</sup>	40	$3 \times 10^{-2}$	2	$1 \times 10^{-1}$

<sup>a</sup>See Fig. 3.

<sup>b</sup>The concentration guide for radioactivity in water (CG<sub>w</sub>) referred to here is the recommended concentration in uncontrolled areas on the basis of exposure for 168 hours per week.

Table 10. Background radiation levels and radionuclide concentrations

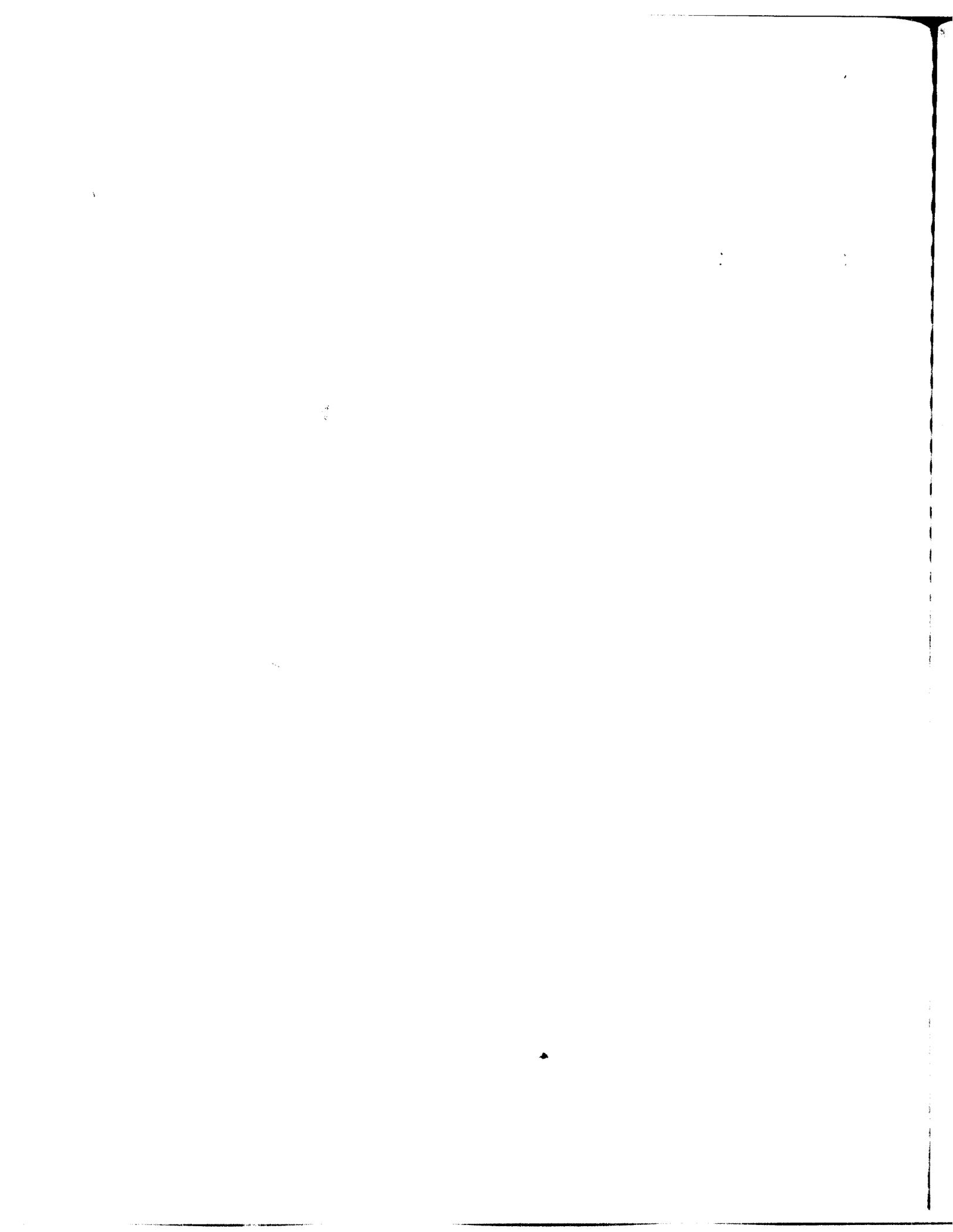
	$\gamma$ -Radiation level at 1 m ( $\mu$ R/hr)	Radionuclide concentrations (pCi/g)			
		$^{238}\text{U}$	$^{226}\text{Ra}$	$^{227}\text{Ac}$	$^{232}\text{Th}$
-	4	1.5	0.8	not found	0.7
-	4	1.9	0.5	0.3	0.6
-	6	4.0	0.6	2.24	0.7
-	6	1.6	0.9	not found	1.0
-	3	0.3	0.2	not found	0.3
-	4	1.8	0.8	not found	0.8

Fig. 17.

Table 11. Radionuclide concentrations in the Delaware River

Location <sup>a</sup>	Radionuclide concentrations (pCi/ml)			
	<sup>238</sup> U	<sup>226</sup> Ra	<sup>230</sup> Th	<sup>210</sup> Pb
W-1	$1.5 \times 10^{-3}$	$< 9 \times 10^{-6}$	$1.7 \times 10^{-5}$	$< 9 \times 10^{-4}$
W-2	$1.1 \times 10^{-3}$	$< 9 \times 10^{-6}$	$1.5 \times 10^{-5}$	$< 9 \times 10^{-4}$
W-3	$4.3 \times 10^{-4}$	$2.3 \times 10^{-5}$	$3.2 \times 10^{-5}$	$< 4.5 \times 10^{-4}$

<sup>a</sup>See Fig. 17.



APPENDIX I

DESCRIPTION OF RADIATION SURVEY

METERS AND SMEAR COUNTERS

## RADIATION SURVEY METERS

## Alpha Survey Meters

Two types of alpha survey meters are used to measure alpha radioactivity on surfaces. One type of instrument uses a ZnS scintillator and the other uses a gas-flow proportional counter to detect the alpha radiation.

The alpha scintillation survey meter consists of a large area (50-60 cm<sup>2</sup>) ZnS detector with a photomultiplier tube in the probe which is coupled to a portable scaler/ratemeter (see Fig. I-A). The ZnS detector is covered with a 5-mil aluminized mylar sheet in order to make the instrument light-tight. The mylar, in turn, is covered with a grid to prevent puncturing the detector when surveying over rough surfaces. This instrument is capable of measuring alpha surface contamination levels of a few dpm/100 cm<sup>2</sup> but must be used in the scaler mode for this purpose. It is highly selective for densely ionizing radiation such as alpha particles; the instrument is relatively insensitive to beta and gamma radiation.

The gas-flow proportional counter uses propane gas as the detection medium. Through front panel meter readings it can be used to measure alpha contamination levels from a few hundred dpm/100 cm<sup>2</sup> to several hundred thousand dpm/100 cm<sup>2</sup>. If individual pulses are counted, this instrument can also be used for measurements down to a few dpm/100 cm<sup>2</sup>. The probe has a surface area of approximately 61 cm<sup>2</sup> and has a 2.5-mil aluminized mylar covering with a protective grid. Due to the protective grid, the active area of the probe is 50 cm<sup>2</sup>. It is relatively insensi-

tive to other than alpha radiation. This instrument, shown in Fig. I-B, is manufactured by the Eberline Instrument Company as their model PAC-4G meter with a probe.

Both of these instruments are calibrated at ORNL using  $^{239}\text{Pu}$  alpha sources. While each instrument is individually calibrated, the calibration factors are typically 5 to 6 dpm/cpm.

#### Beta Survey Meter

A portable Geiger-Muller (G-M) survey meter is the primary instrument for measuring beta-gamma radioactivity. The G-M tube is a halogen-quenched stainless steel tube having a  $30 \text{ mg/cm}^2$  wall thickness and presenting a cross-sectional area of approximately  $10 \text{ cm}^2$ . Since the G-M tube is sensitive to both beta and gamma radiation, measurements are taken in both an open window and a closed-window configuration. Beta radiation cannot penetrate the closed window, and, thus, the beta reading can be determined by taking the difference between the open and closed window readings. This meter is shown in Fig. I-C.

The G-M survey meter was calibrated at ORNL for gamma radiation using an NBS standard Ra source. The gamma calibration factor is typically of the order of 2600 cpm/mR per hr.

In order to assess beta-gamma surface dose rates from uranium contaminated surfaces using this instrument, a field calibration was performed. The G-M survey meter was compared with a Victoreen Model 440 ionization chamber (see Fig. I-D) and was found to produce 1750 cpm/mrad/hr with a 25% standard deviation for a wide variety of surfaces, including concrete, wood, pavement, bricks, and steel beams.

### Gamma Scintillation Survey Meter

A portable survey meter using a NaI scintillation probe is used to measure low-level gamma radiation exposure. The scintillation probe is a 3.2 x 3.8-cm NaI crystal coupled to a photomultiplier tube. This probe is connected to a Victoreen Model Thyac III ratemeter (see Fig. I-E). This unit is capable of measuring radiation levels from a few  $\mu\text{R/hr}$  to several hundred  $\mu\text{R/hr}$ . This instrument is calibrated at ORNL with an NBS standard  $^{226}\text{Ra}$  source. Typical calibration factors are of the order of 300 cpm/ $\mu\text{R}$  per hr.

### SMEAR COUNTERS

#### Alpha Smear Counter

This detector assembly, used for the assay of alpha emitters on smear paper samples, consists of a light-tight sample holder, a zinc sulfide phosphor and a photomultiplier tube. This detector assembly was used with electronic components housed in a portable NIM bin (see Fig. I-F). The electronics package consisted of a preamplifier, a ORTEC 456 high voltage power supply, a Tennelec TC 211 linear amplifier and a Tennelec TC 545 counter-timer.

The alpha smear counter was used in the field and was calibrated daily using an alpha source with a known disintegration rate.

#### Beta Smear Counter

The beta smear counter consisted of a thin mica window ( $\sim 2 \text{ mg/cm}^2$ ) G-M tube mounted on a sample holder and housed in a 23-cm diam x 35-cm high lead shield. Located under the counter window is a slotted sample holder, accessible through a hinged door on the shield. An absorber can

be interposed in the slot between the sample and the counter window to determine relative beta and gamma contributions to the observed sample counting rate. The electronics for this counter were housed in a portable NIM bin and consisted of a Tennelec TC 148 preamplifier, an ORTEC 456 high voltage power supply and a Tennelec TC 545 counter-timer.

This unit, shown in Fig. I-F, was used in the field to measure beta activity on smear papers and was calibrated daily using a beta standard of known activity.

The instruments described above are maintained in good condition and are transported from ORNL to each radiological survey site in one of two mobile laboratory vehicles as shown in Fig. 1-G. This motor coach serves as a base of operations at each survey site. It is used as a temporary office for data reporting and storage, and general purpose laboratory for handling and packaging environmental samples.

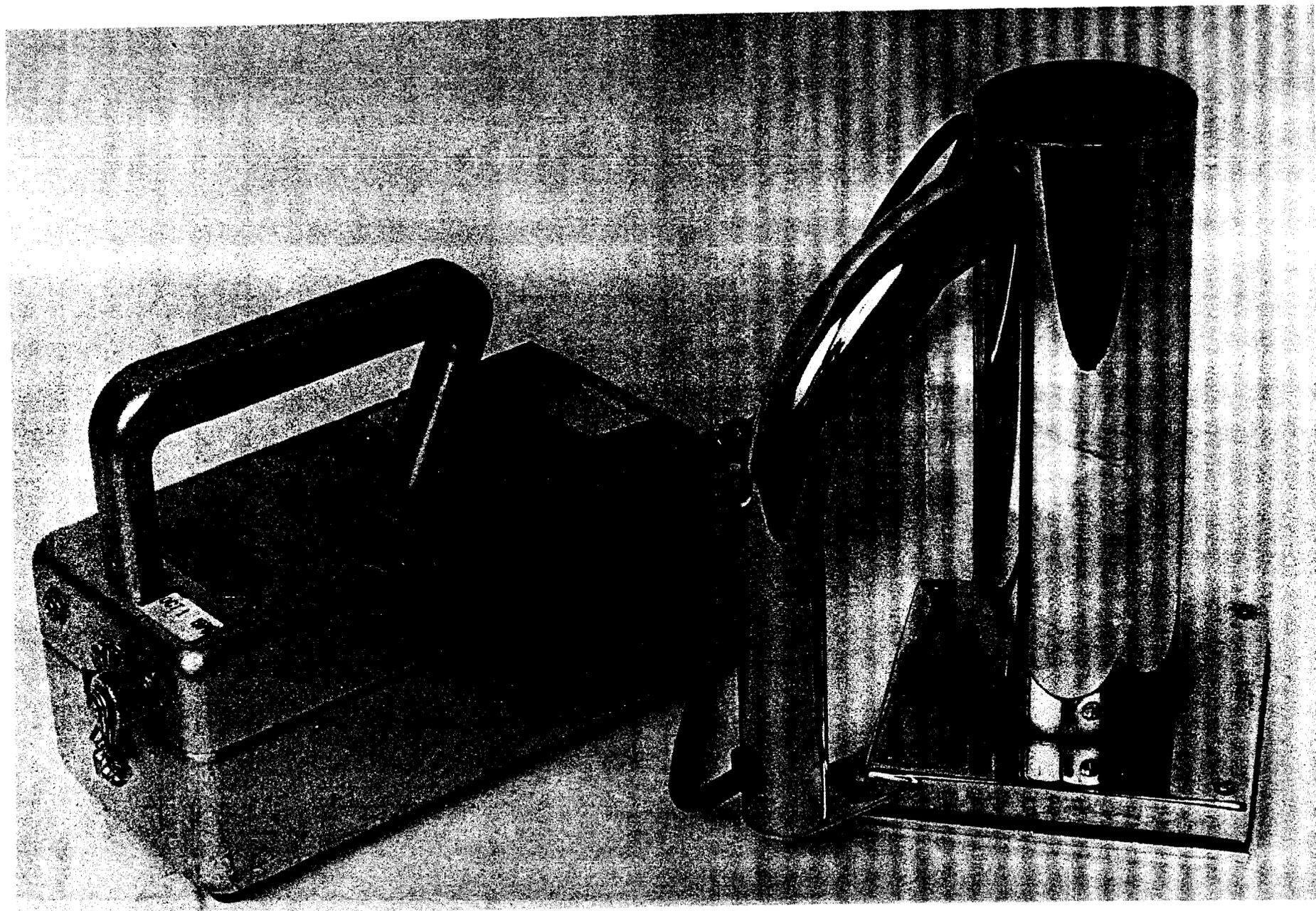


Fig. I-A. Alpha scintillation survey meter.

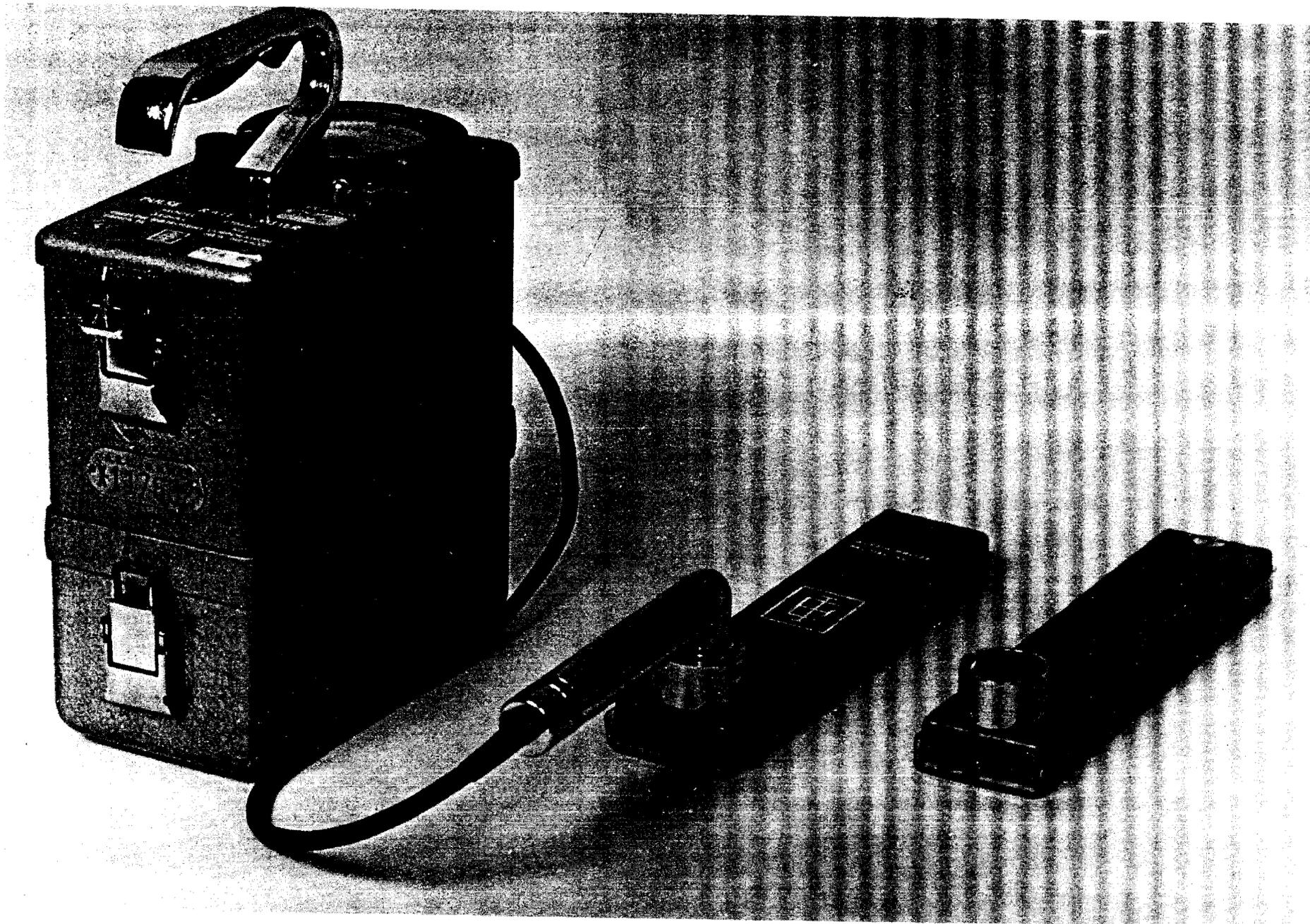


Fig. I-B. Gas-flow proportional alpha survey meter.



Fig. I-C. Geiger-Mueller survey meter.

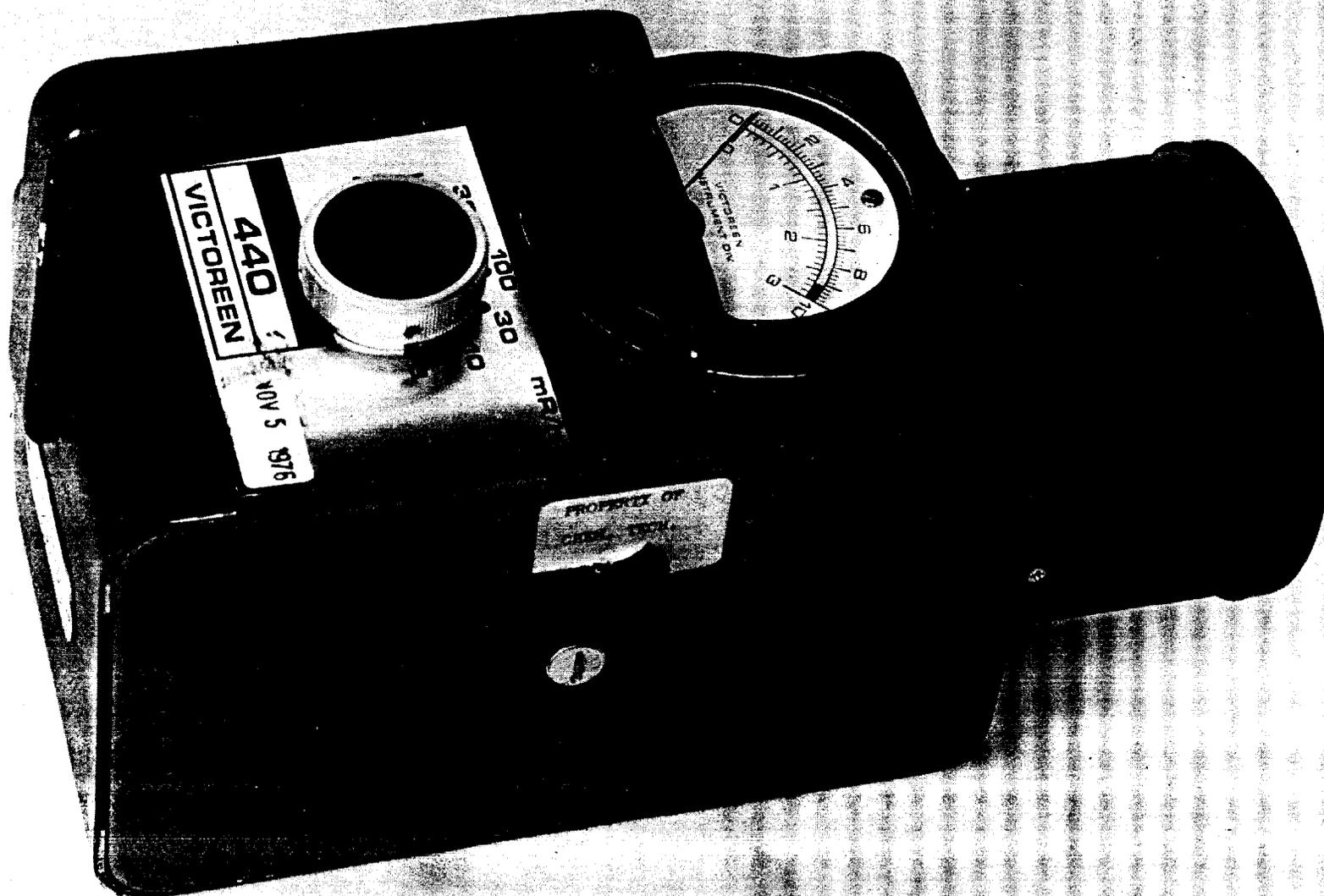


Fig. I-D. Victoreen Model 440 ionization chamber.



Fig. I-E. Victoreen Model Thyac III ratemeter.

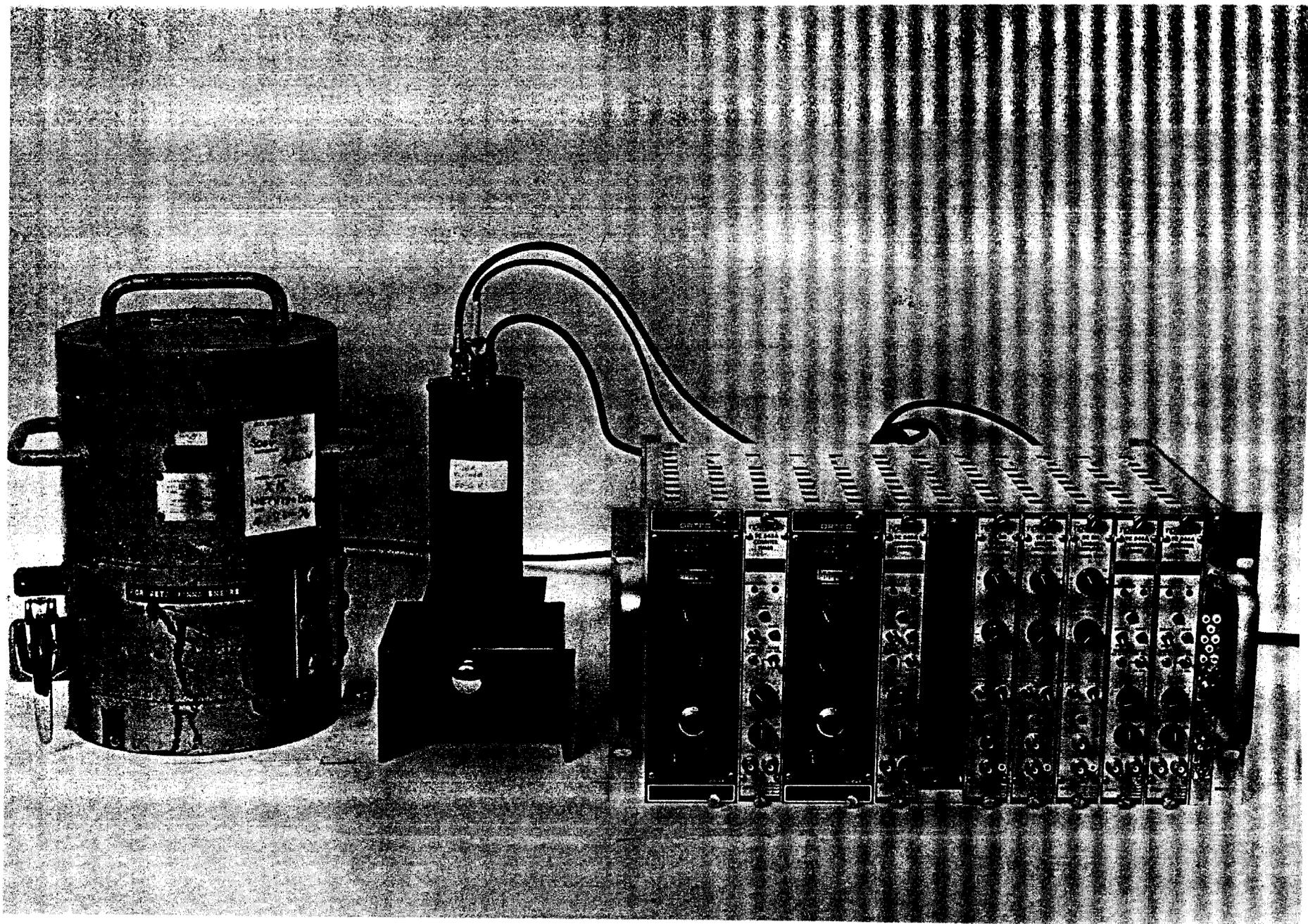


Fig. I-F. Alpha and beta smear counters.



Fig. I-G. Mobile lab used on survey.

APPENDIX II

DESCRIPTION OF THE TECHNIQUES FOR THE MEASUREMENT  
OF RADON AND RADON DAUGHTER CONCENTRATIONS IN AIR

TECHNIQUE FOR THE MEASUREMENT OF  $^{222}\text{Rn}$  PROGENY CONCENTRATIONS IN AIR

An alpha spectrometry technique has been refined by Kerr<sup>1,2</sup> for the measurement of  $^{222}\text{Rn}$  progeny concentrations in air. From one integral count of the  $^{218}\text{Po}$  alpha activity and two integral counts of the  $^{214}\text{Po}$  alpha activity, the concentrations in air of  $^{218}\text{Po}$ ,  $^{214}\text{Bi}$  and  $^{214}\text{Pb}$  may be calculated.

Particulate  $^{222}\text{Rn}$  daughters attached to airborne dust are collected on a membrane filter with a pore size of 0.4 microns. A sampling time of 5 minutes and a flow rate of 10 to 20 LPM are used. This filter sample is then placed under a silicon surface barrier detector and counted. The detector and counting system used for radon daughter measurements are shown in Fig. II-A. Usually, counting of this kind is performed with a vacuum between the sample and the detector which requires a complicated sample holder and time-consuming sample changing methods. Experiments at this laboratory have shown that ease in sample handling is obtained with little loss in resolution when helium is used as a chamber fill gas.<sup>3</sup> In this counter, helium is flowed between the diode and the filter sample, which are separated by a distance of 0.5 cm. One integral count of the  $^{218}\text{Po}$  alpha activity is obtained from 2 to 12 minutes, and two integral counts of the  $^{214}\text{Po}$  activity are obtained from 2 to 12 minutes and 15 to 30 minutes, respectively. All counting intervals are referenced to  $t = 0$  at the end of sampling.

The equations describing the  $^{222}\text{Rn}$  progeny atoms collection rates on the filter are of the form

$$\frac{dn_i(t)}{dt} = C_i v + \lambda_{i-1} n_{i-1}(t) - \lambda_i n_i(t) \quad , \quad (1)$$

where

$n_i$  = number of the  $i^{\text{th}}$  species of atom on the filter as a function of time,

$\lambda_i$  = radioactive decay constant of the  $i^{\text{th}}$  species ( $\text{min}^{-1}$ ),

$C_i$  = concentration of the  $i^{\text{th}}$  species ( $\text{atoms l}^{-1}$ ), and

$v$  = air sampling flow rate ( $\text{liters min}^{-1}$ ).

The solution of Eq. (1) is of the form

$$y = e^{-ax} [y_0 + \int F(x) e^{ax} dx].$$

From the general form of the solution, specific equations can be obtained describing the number of each  $^{222}\text{Rn}$  decay product collected on the filter as a function of time. Also by letting  $v = 0$  in Eq. (1), a set of equations describing the decay on the filter of each  $^{222}\text{Rn}$  progeny can be obtained. The equations describing the decay of  $^{222}\text{Rn}$  progeny on the filter can be integrated and related to the integral counts obtained experimentally. Values for the total activities of  $^{218}\text{Po}$ ,  $^{214}\text{Pb}$ , and  $^{214}\text{Bi}$  on the filter at the end of sampling are obtained by applying matrix techniques. The airborne concentrations are obtained by solving the equations describing the atom collection rates on the filter. A computer program has been written to perform these matrix operations, to calculate the air concentrations of the radon progeny, and to estimate the accuracy of the calculated concentrations.

## TECHNIQUE FOR THE MEASUREMENT OF RADON CONCENTRATIONS IN THE AIR

A Lucas Chamber (Fig. II-B) consists of a 95-ml glass flask, coated inside with a uniform layer of zinc sulfide. For measurements of radon concentration in the air, the flask is evacuated to a pressure of 50 microns of Hg. The flask is then taken to a location where a sample is desired and the collection valve is opened. After collection of air in the flask, sample counting is delayed 3 to 4 hr to allow the radon daughters to attain equilibrium. Alpha particles from the radon daughters produce scintillations in the zinc sulfide. The sample is normally counted for 1000 seconds with a photomultiplier tube assembly. A calibration performed at ORNL using a known radon concentration indicated that the conversion factor is 2.02 pCi/liter per cpm. After the sample has been counted, the flask is again evacuated to 50  $\mu$  of Hg to prevent contamination.

References

- II-1. G. D. Kerr, Measurement of Radon Progeny Concentrations in Air by Alpha-Particle Spectrometry, ORNL/TM-4924 (July 1975).
- II-2. G. D. Kerr, "Measurement of Radon Progeny Concentrations in Air," Trans. Am. Nuc. Soc. 17, 541 (1973).
- II-3. P. T. Perdue, W. H. Shinpaugh, J. H. Thorngate and J. A. Auxier, "A Convenient Counter for Measuring Alpha Activity of Smear and Air Samples," Health Phys. 26, 114 (1974).

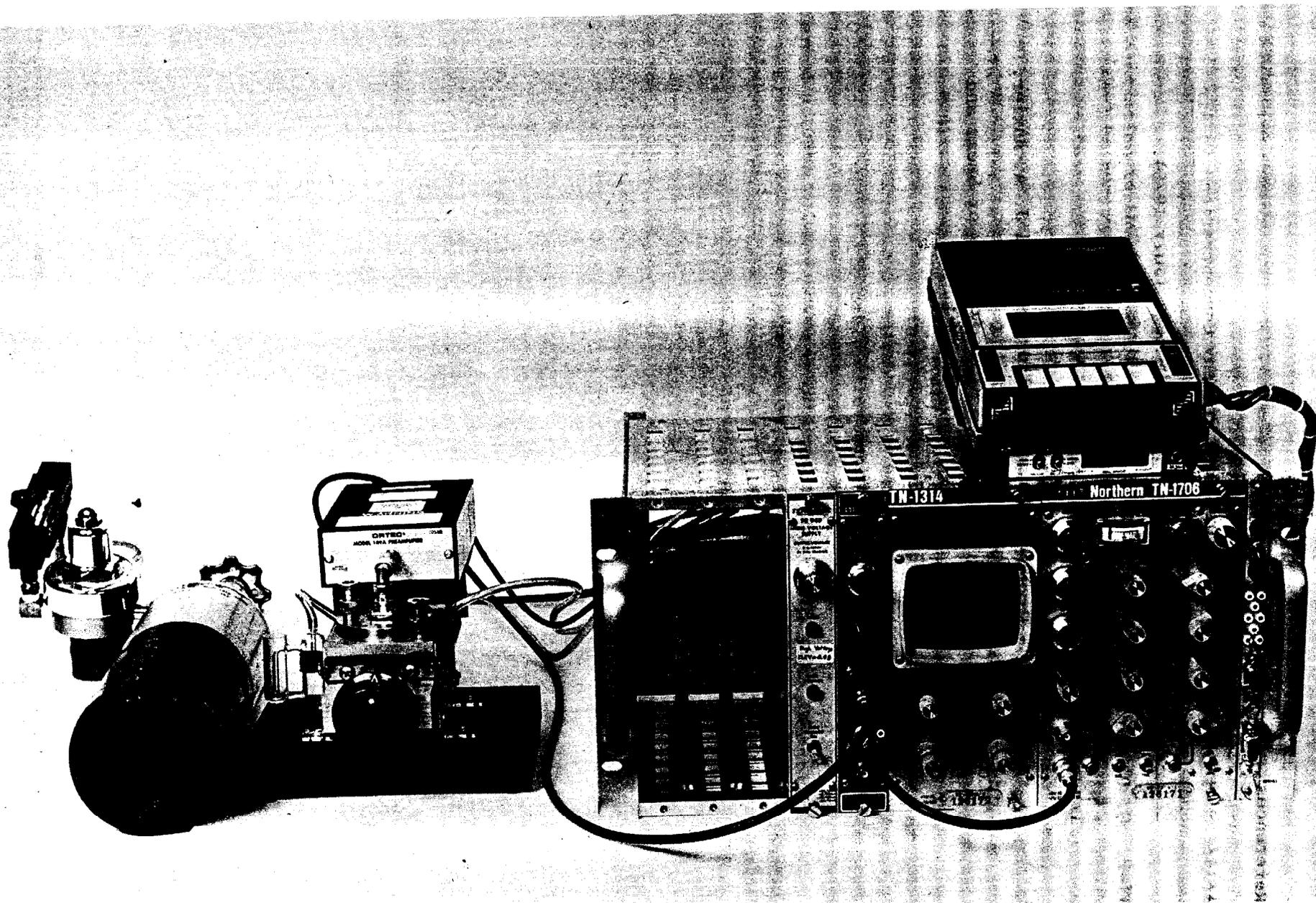


Fig. II-A. System used for measurement of radon daughter concentrations.

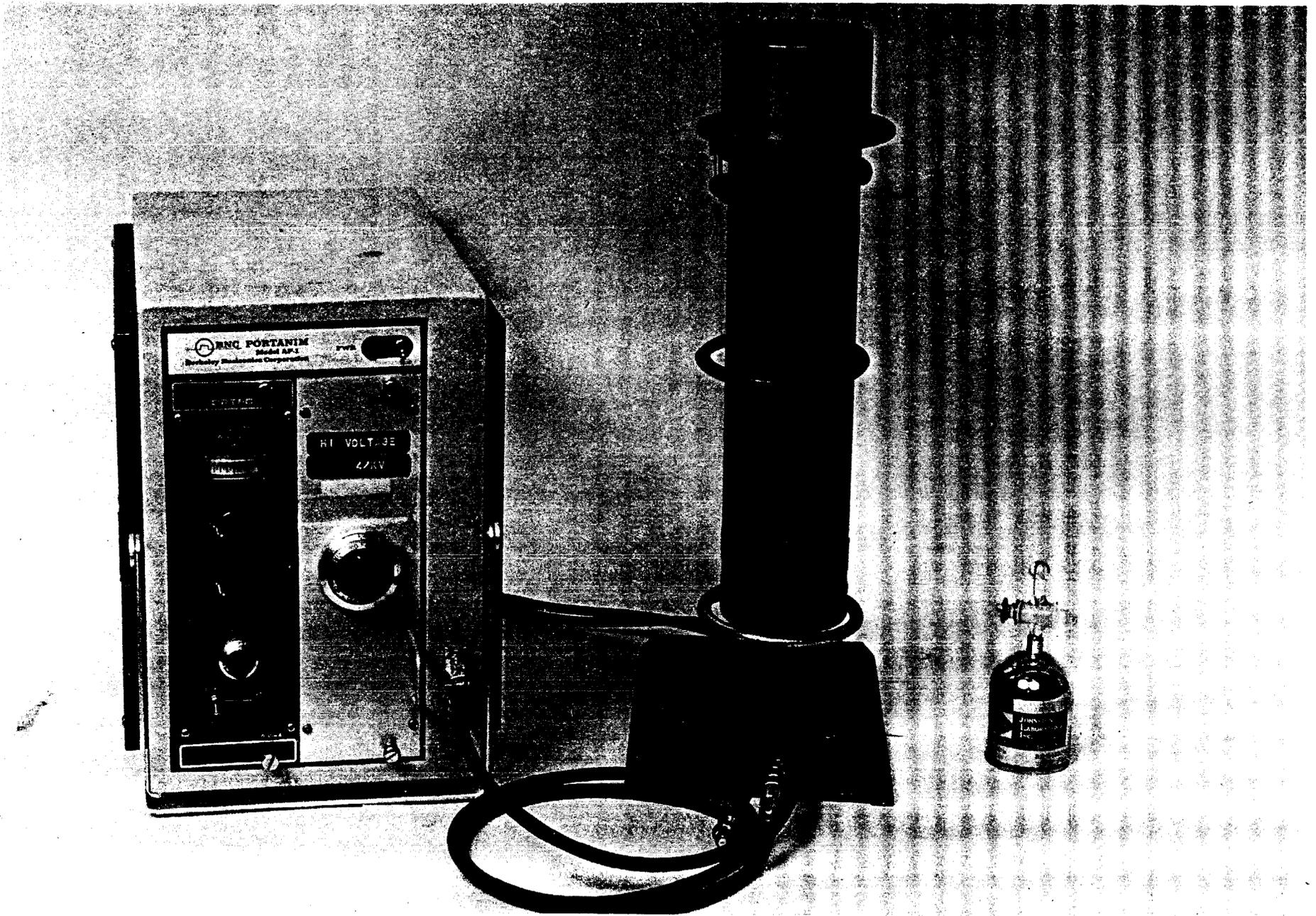
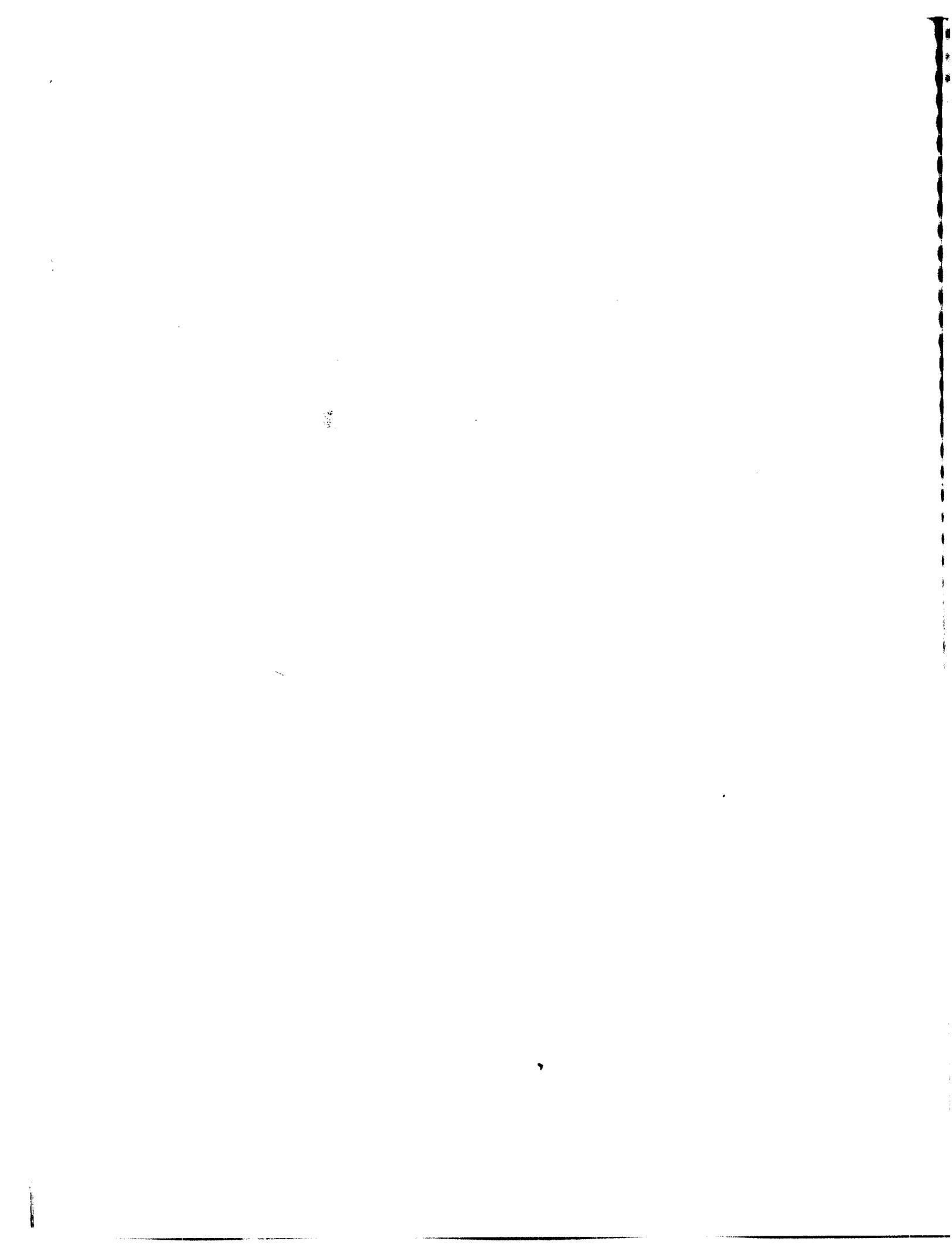


Fig. II-B. Lucas Chamber.



APPENDIX III

DESCRIPTION OF Ge(Li) DETECTOR AND  
SOIL COUNTING PROCEDURES

## DESCRIPTION OF Ge(Li) DETECTOR SYSTEM

A holder for twelve 30-cc polyethylene bottles (standard containers for liquid scintillation samples) and a background shield have been designed for use with a 50-cc Ge(Li) detector system in laboratory counting of radioactivity in environmental samples (see Figs. III-A, III-B). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300-cc sample and a graded shield developed for use with the system, it is possible to measure 1 pCi/g of  $^{232}\text{Th}$  or  $^{226}\text{Ra}$  with an error of  $\pm 10\%$  or less.

Pulses are sorted by a 4096-channel analyzer (see Fig. III-C), stored on magnetic tape, and subsequently entered into a computer program which uses an iterative least squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. The program relies on a library of radioisotopes which contains approximately 700 isotopes and 2500 gamma-rays and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying  $^{226}\text{Ra}$ , six principal gamma-ray lines are analyzed. Most of these are from  $^{214}\text{Bi}$  and correspond to 295, 352, 609, 1120, 1765, and 2204 KeV. An estimate of the concentration of  $^{238}\text{U}$  is obtained from an analysis of the 93 KeV line from its daughter  $^{234}\text{Th}$ .

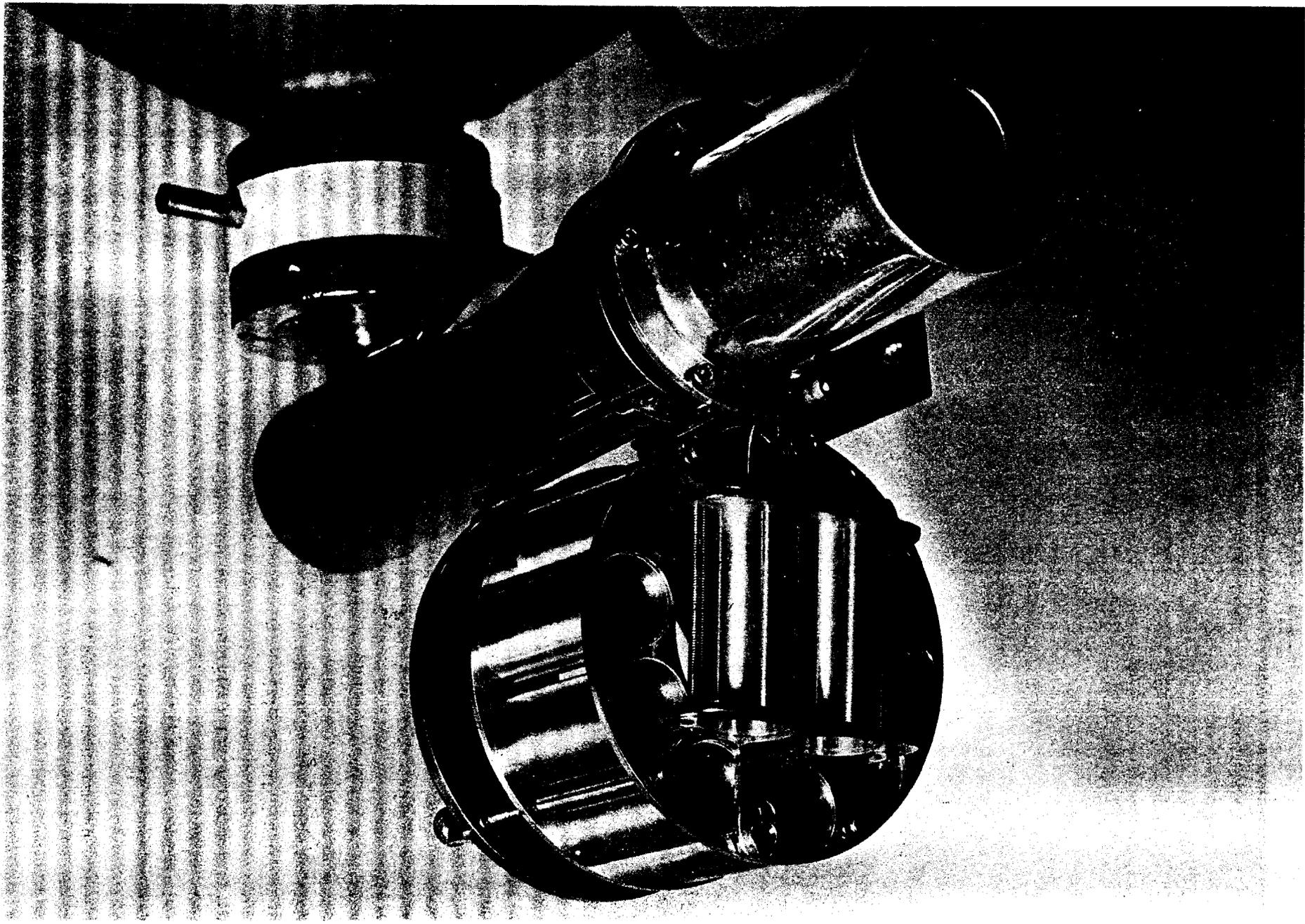


Fig. III-A. Holder for Ge(Li) detector system samples.

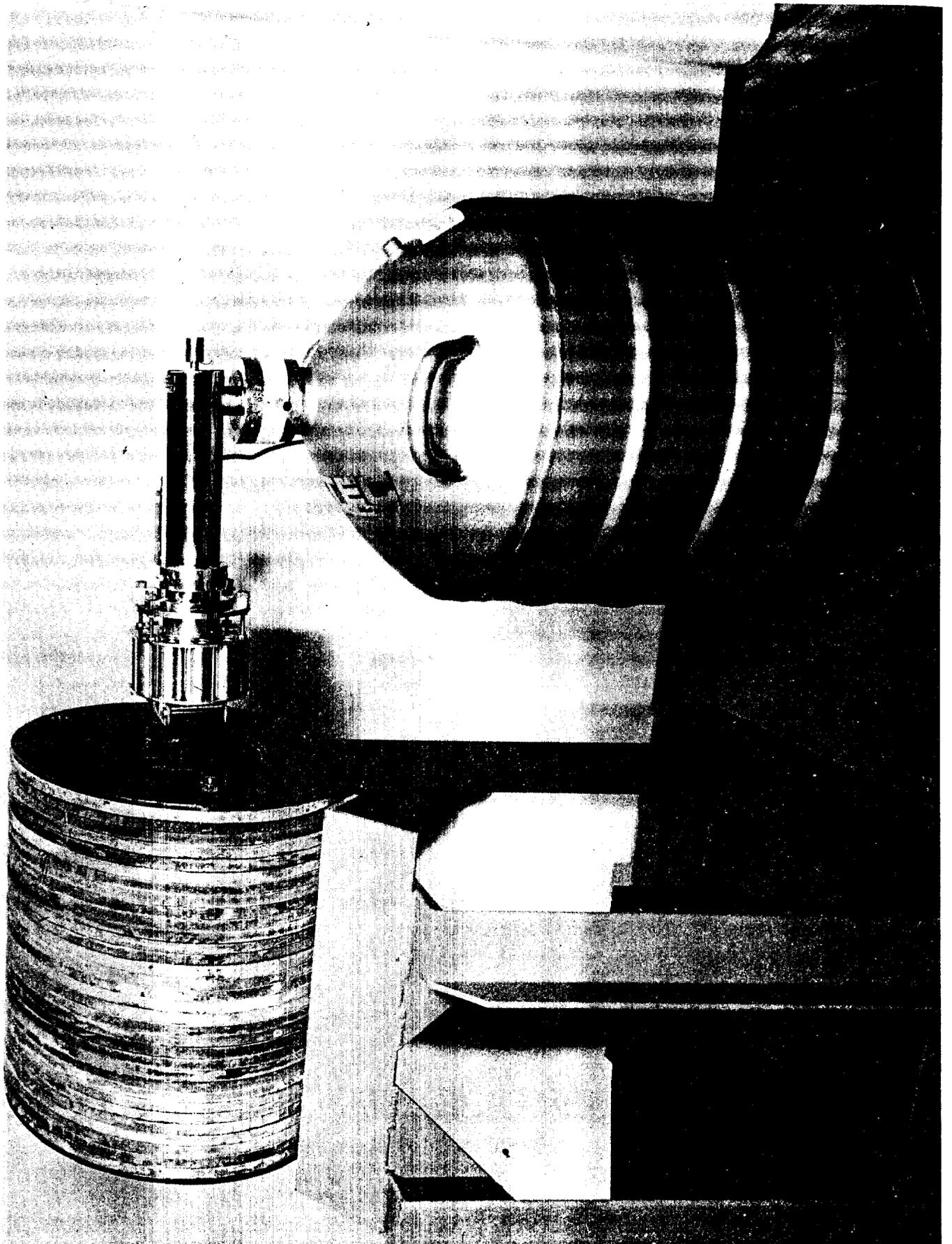
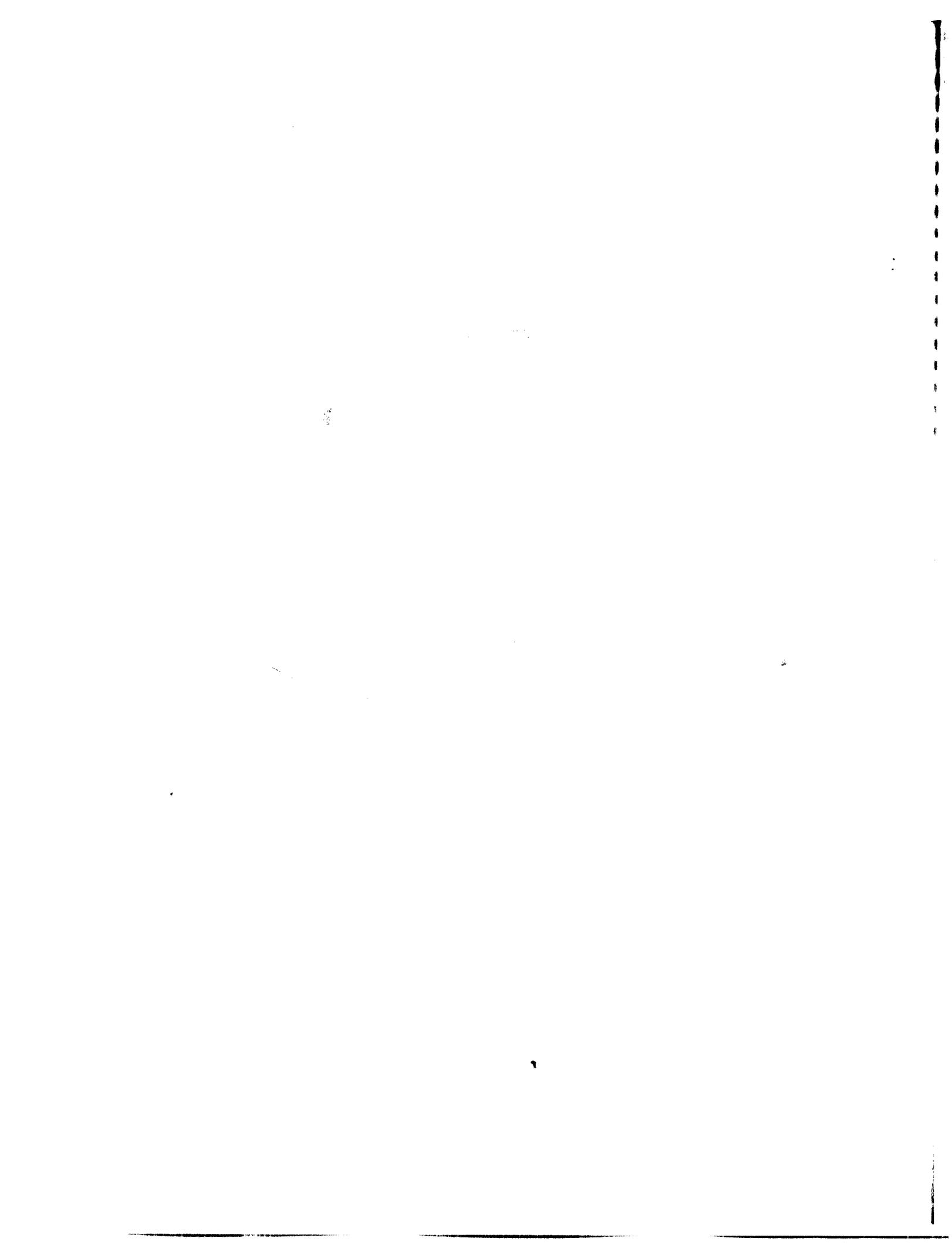


Fig. III-B. Ge(Li) detector system.



Fig. III-C. 4096-channel analyzer.



APPENDIX IV

PERTINENT RADIOLOGICAL REGULATIONS,  
STANDARDS AND GUIDELINES

GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT  
PRIOR TO RELEASE FOR UNRESTRICTED USE  
OR TERMINATION OF LICENSES FOR BYPRODUCT, SOURCE,  
OR SPECIAL NUCLEAR MATERIAL

U. S. Nuclear Regulatory Commission  
Division of Fuel Cycle and  
Material Safety  
Washington, D.C. 20555

November 1976

The instructions in this guide in conjunction with Table IV-1 specify the radioactivity and radiation exposure rate limits which should be used in accomplishing the decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table IV-1 do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control will be considered on a case-by-case basis.

1. The licensee shall make a reasonable effort to eliminate residual contamination.
2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table I prior to applying the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.
3. The radioactivity on the interior surfaces of pipes, drain lines, or ductwork shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces of premises, equipment, or scrap which are likely to be contaminated but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement shall be presumed to be contaminated in excess of the limits.
4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with materials in excess of the limits specified. This may include, but would not be limited to, special circumstances such as razing of buildings, transfer of premises to another organization continuing work with radioactive materials, or conversion of facilities to a long-term storage or standby status. Such request must:
  - a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.
  - b. Provide a detailed health and safety analysis which reflects that the residual amounts of materials on surface areas, together with other considerations such as prospective use of the premises, equipment or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table I. A copy of the survey report shall be filed with the Division of Fuel Cycle and Material Safety, USNRC, Washington, D.C. 20555, and also the Director of the Regional Office of the Office of Inspection and Enforcement, USNRC, having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:
  - a. Identify the premises.
  - b. Show that reasonable effort has been made to eliminate residual contamination.
  - c. Describe the scope of the survey and general procedures followed.
  - d. State the findings of the survey in units specified in the instruction.

Following review of the report, the NRC will consider visiting the facilities to confirm the survey.

TABLE IV-1

## ACCEPTABLE SURFACE CONTAMINATION LEVELS

NUCLIDES <sup>a</sup>	AVERAGE <sup>b c f</sup>	MAXIMUM <sup>b d f</sup>	REMOVABLE <sup>b e f</sup>
U-nat, U-235, U-238, and associated decay products	5,000 dpm $\alpha$ /100 cm <sup>2</sup>	15,000 dpm $\alpha$ /100 cm <sup>2</sup>	1,000 dpm $\alpha$ /100 cm <sup>2</sup>
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm <sup>2</sup>	300 dpm/100 cm <sup>2</sup>	20 dpm/100 cm <sup>2</sup>
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm <sup>2</sup>	3,000 dpm/100 cm <sup>2</sup>	200 dpm/100 cm <sup>2</sup>
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except SR-90 and other noted above.	5,000 dpm $\beta\gamma$ /100 cm <sup>2</sup>	15,000 dpm $\beta\gamma$ /100 cm <sup>2</sup>	1,000 dpm $\beta\gamma$ /100 cm <sup>2</sup>

<sup>a</sup>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.

<sup>b</sup>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.

<sup>c</sup>Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

<sup>d</sup>The maximum contamination level applies to an area of not more than 100 cm<sup>2</sup>.

<sup>e</sup>The amount of removable radioactive material per 100 cm<sup>2</sup> of surface area should be determined by wiping that area with dry filter or soft absorbent 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.

<sup>f</sup>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 milligrams per square centimeter of total absorber.

Excerpts from

Proposed

ANSI N328-197

Proposed American National Standard

Control of Radioactive Surface Contamination  
on Materials, Equipment, and Facilities to be  
Released for Uncontrolled Use

~~Secretariat~~

~~Health Physics Society~~

Property shall not be released for uncontrolled use unless documented measurements show the total and removable contamination levels to be no greater than the values in Table IV-2 or Table IV-3. (Table IV-3 is easier to apply when the contaminants cannot be individually identified.)

Where potentially contaminated surfaces are not accessible for measurement (as in some pipes, drains, and ductwork), such property shall not be released pursuant to this standard, but made the subject of case-by-case evaluation. Credit shall not be taken for coatings over contamination.

TABLE IV-2

## SURFACE CONTAMINATION LIMITS

The levels may be averaged\* over the 1 m<sup>2</sup> provided the maximum activity in any area of 100 cm<sup>2</sup> is less than 3 times the limit value.

	Limit (Activity)	
	dpm/100 cm <sup>2</sup>	
<u>Nuclide</u>	Total	Removable
Group 1: Nuclides for which the nonoccupational MPC <sup>†</sup> is 2 x 10 <sup>-13</sup> Ci/m <sup>3</sup> or less, or for which the nonoccupational MPC <sup>‡</sup> is 2 x 10 <sup>-7</sup> Ci/m <sup>3</sup> or less; includes Ac-227; Am <sup>W</sup> -241; -242m, -243; Cf-249; -250, -251, -252; Cm-243, -244, -245, -246, -247, -248; I-125, -129; Np-237; Pa-231; Pb-210; Pu-238, -239 -240, -242, -244; Ra-226, -228; Th-228, -230. <sup>§</sup>	100	20
Group 2: Those nuclides not in Group 1 for which the nonoccupational MPC <sup>†</sup> is 1 x 10 <sup>-12</sup> Ci/m <sup>3</sup> or less or for which the nonoccupational MPC <sup>‡</sup> is 1 x 10 <sup>-6</sup> Ci/m <sup>3</sup> or less; includes Es-254; Fm-256; I-126, -131, -133; Po-210; Ra-223; Sr-90; Th-232; U-232. <sup>§</sup>	1,000	200
Group 3: Those nuclides not in Group 1 or Group 2.	5,000	1000

\*See note following Table III-3 on application of limits.

<sup>†</sup>MPC<sup>a</sup>: Maximum Permissible Concentration in Air applicable to continuous exposure of members of the public as published by or derived from an authoritative source such as NCRP, ICRP or NRC (10 CFR Part 20 Appendix B Table 2, Column 1.)

<sup>‡</sup>MPC<sup>w</sup>: Maximum Permissible Concentration in Water applicable to members of the public.

<sup>§</sup>Values presented here are obtained from 10 CFR Part 20. The most limiting of all given MPC values (e.g. soluble vs. insoluble) are to be used. In the event of the occurrence of mixture of radionuclides, the fraction contributed by each constituent of its own limit shall be determined and the sum of the fractions must be less than 1.

TABLE IV-3

## ALTERNATE SURFACE CONTAMINATION LIMITS

(All alpha emitters, except U-nat and Th-nat are considered as a group)

The levels may be averaged over  $1 \text{ m}^2$ \* provided the maximum activity in any area of  $100 \text{ cm}^2$  is less than 3 times the limit value.

<u>Nuclide</u>	Limit (Activity)	
	<u>dpm/100 cm<sup>2</sup></u>	
	Total	Removable
If the contaminant cannot be identified; or if alpha emitters other than U-nat and Th-nat are present; or if the beta emitters comprise Ac-227, Ra-226, Ra-228, I-125 and I-129.	100	20
If it is known that all alpha emitters are generated from U-nat and Th-nat; and beta emitters are present which, while not identified, do not include Ac-227, I-125, I-129, Ra-226 and Ra-228.	1,000	200
If it is known that alpha emitters are generated only from U-nat and Th-nat; and the beta emitters, while not identified, do not include Ac-227, I-125, I-129, Sr-90, Ra-223, Ra-228, I-126, I-131 and I-133.	5,000	1,000

## \*NOTE ON APPLICATION OF TABLES 1 AND 2 TO ISOLATED SPOTS OR ACTIVITY:

For purposes of averaging, any  $\text{m}^2$  of surface shall be considered to be contaminated above the limit, L, applicable to  $100 \text{ cm}^2$  if:

a. From measurements of a representative number, n, of sections, it is determined that  $1/n \sum_{i=1}^n S_i \geq L$ , where  $S_i$  is the dpm/100  $\text{cm}^2$  determined from measurement of section i; or

b. On surfaces less than  $1 \text{ m}^2$ , it is determined that  $1/n \sum_{i=1}^n S_i \geq AL$ , where A is the area of the surface in units of  $\text{m}^2$ ; or

c. It is determined that the activity of all isolated spots or particles in any area less than  $100 \text{ cm}^2$  exceeds 3L.

SURGEON GENERAL'S GUIDELINES  
Part 712  
Grand Junction Remedial Action Criteria

Federal Register, Vol. 41, No. 253, pp. 56777-8, Thursday, December 30, 1976

PART 712 - GRAND JUNCTION  
REMEDIAL ACTION CRITERIA

712.1 Purpose

(a) The regulations in this part establish the criteria for determination by ERDA of the need for, priority of and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colo., to radiation emanating from uranium mill tailing which have been used as construction-related material.

(b) The regulations in this part are issued pursuant to Publ. L. 92-314 (86 Stat. 222) of June 16, 1972.

713.2 Scope

The regulations in this part apply to all structures in the area of Grand Junction, Colo., under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

712.3 Definitions

As used in this part:

(a) "Administrator" means the Administrator of Energy Research and Development or his duly authorized representative.

(b) "Area of Grand Junction, Colo.," means Mesa County, Colo.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "ERDA" means the U.S. Energy Research and Development Administration or any duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) Averaging the results of 6 air samples, each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure approved by the Commission.

(h) "Milliroentgen (mR) means a unit equal to one-thousandth (1/1000) of a roentgen which roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive decay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally, these include Radium A (polonium-218), Radium B (lead-218), Radium C (bismuth-214), and Radium C (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colo.

(l) "Surgeon General's guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium mill operation involved in the Federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of  $1.3 \times 10^5$  MeV of potential alpha energy.

#### 712.4 Interpretations

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of ERDA other than a written interpretation by the General Counsel will be recognized to be binding upon ERDA.

#### 712.5 Communications

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards, and Compliance, U.S. Energy Research and Development Administration, Washington, D.C. 20545.

#### 712.6 General radiation exposure level criteria for remedial action

The basis for undertaking remedial action shall be the applicable

guidelines published by the Surgeon General of the United States. These guidelines recommend the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings:

EGR	RDC	Recommendation
Greater than 0.1 mR/hr.	Greater than 0.05 WL.	Remedial action indicated
From 0.05 to 0.1 mR/hr.	From 0.01 to 0.05 WL.	Remedial action may be suggested.
Less than 0.05 mR/hr.	Less than 0.01 WL.	No remedial action in- dicated.

712.7 Criteria for determination of possible need for remedial action

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under or adjacent to the structure, one of the following criteria is met:

(a) Where ERDA approved data on indoor radon daughter concentration levels are available:

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

(b) Where ERDA approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/hr. or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceeds 0.02 mR/hr. above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/hr. above background, the indoor radon daughter concentration level is less than 0.01 WL above background and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/hr. above background but is less than 0.02 mR/hr. above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures: (i) An external gamma radiation level of 0.15 mR/hr. above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

712.8 Determination of possible need for remedial action where criteria have not been met

The possible need for remedial action may be determined where the criteria in 712.7 have not been met if various other factors are present. Such factors include, but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occupying affected area, occupancy time, and use of the affected area.

712.9 Factors to be considered in determination of order or priority for remedial action

In determining the order or priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

(a) Classification of structure. Dwellings and schools shall be considered first.

(b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in 712.7 will be considered first.

(c) Order of application. Insofar as feasible remedial action will be taken in the order which the application is received.

(d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.

(e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.

(f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.

(g) Climatic conditions. Climatic conditions or other reasonable considerations may affect the scheduling of certain remedial measures.

#### 712.10 Selection of appropriate remedial action

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/hr. above background in the case of dwellings and schools and 0.15 mR/hr. above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding may be considered in addition to that of tailings removal. ERDA shall select the remedial action technique or combination of techniques, which it determines to be the most appropriate under the circumstances.

ENVIRONMENTAL PROTECTION AGENCY  
Title 40-Part 141  
Drinking Water Regulations-Radionuclides

Interim Primary Drinking Water Regulations  
Promulgation of Regulations on Radionuclides  
Federal Register, Vol. 41, No. 133, pp. 28402-9 Friday, July 9, 1976

Part 141.15 Federal Register  
Vol 41, No. 133, p 28404, Friday, July 9, 1976

Maximum contaminant levels for  $^{226}\text{Ra}$ ,  $^{228}\text{Ra}$ , and gross alpha particle radioactivity.

- (a) Combined  $^{226}\text{Ra}$  and  $^{228}\text{Ra}$  - 5 pCi/liter.
- (b) Gross alpha particle activity (including  $^{226}\text{Ra}$  but excluding radon and uranium) - 15 pCi/liter.

EVALUATION OF RADIATION EXPOSURES  
AT THE E. I. DUPONT COMPANY,  
DEEPWATER, NEW JERSEY\*

The U. S. Department of Energy has determined that the Chambers Works of the E. I. DuPont Company in Deepwater, New Jersey, is presently contaminated with radioactive residues from previous uses of this property. Under current conditions of use, this contamination does not cause employees working at the site to receive radiation exposures appreciably different from those due to naturally occurring environmental radioactivity. However, under different conditions of use (i.e. use of the contaminated soils for growing crops, actions which involve agitation or abrasion of dry contaminated surfaces, or extended maintenance activities involving contaminated portions of existing property), there could be a potential for radiation exposure to people. For that reason, the DOE will conduct further evaluations to enable appropriate actions to be identified that will preclude any concerns for radioactivity at this site.

DuPont performed chemical conversion of uranium for the Manhattan Engineer District (MED) during the 1940's. Operations included the development of a process for converting uranium oxide to uranium tetrafluoride, production of uranium tetrafluoride, research into the conversion of the uranium oxide to uranium metal, and some production of uranium metal. A waste burial area, due north of East Road, served as a disposal site for some contaminated material which was removed from the two process buildings. This area currently serves as a radioactive materials burial facility approved by the State of New Jersey under an agreement with the Nuclear Regulatory Commission (NRC). The entire Chambers Works complex, consisting of approximately 700 acres, is located near the residential communities of Deepwater, Pennsville, and Penns Grove. At present, one building remains at the location of the old uranium processing facilities and is designated Building 845. A second building, J-16, was demolished in the period 1943 to 1945 and several feet of earth was removed. A new building, designated J-26, now stands at this location.

Most of the contamination at the Deepwater site is due to natural uranium. Employees at this site receive slight radiation exposures from this contamination. Exposures come from beta and gamma radiations emitted by contamination on building surfaces or in the ground. Additional exposures received by ingestion (i.e., eating or drinking in one of the contaminated areas) are relatively small compared with direct beta and gamma radiation. At present, exposures received by inhalation--that is, by breathing air contaminated with radioactive materials--are also small compared with direct beta and gamma radiation. A summary of radiation exposures at the DuPont site is provided in Table 1 along with appropriate guidelines and generally accepted background values.

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\*This evaluation is based upon data contained in a Department of Energy Report, DOE/EV-0005/8, entitled "Radiological Survey of the E. I. DuPont Company, Chambers Works, Deepwater, New Jersey, December 1978.

The naturally-occurring radionuclides present at the E. I. DuPont site are also present in minute quantities throughout our environment. Concentrations of these radionuclides in normal soils, air, water, food, etc., are referred to as background concentrations. Radiation exposures resulting from this environmental radioactivity are referred to as background exposures. These background exposures are not caused by any human activity and, to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry and, to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

Uranium-238 is believed to have been created when the earth was formed. It is still present today because it takes a very long time to decay. The half-life is a measure of the time required for radioactive decay; for uranium-238 it is 4.5 billion years. For example, consider an initial inventory of one curie<sup>a</sup> of uranium-238, one-half curie will remain in existence at the end of 4.5 billion years, with one-quarter curie surviving to 9 billion years. As the uranium-238 decays, it changes into another substance- thorium-234. Thorium-234 is called the "daughter" of uranium-238. In turn, thorium-234 is the "parent" of protactinium-234. Radioactive decay started by uranium-238 continues as shown in Table 2 until stable lead is formed. The "decay product" listed in Table 2 is the radiation produced as the parent decays.

#### Uranium Contamination of Soils

Elevated concentrations of uranium-238 were found in soils in the vicinity of Building 845 and in the waste burial area. Normal soils contain a background concentration of about one picocurie<sup>b</sup> per gram (pCi/g) of uranium-238. Concentrations of uranium-238 as high as 12,600 pCi/g were found in surface soils at the DuPont site. Subsurface soils are contaminated to a depth of about 3 feet; subsurface contamination ranged from 17 to 3475 pCi of uranium-238 per gram of soil.

<sup>a</sup>A curie is a unit defined for expressing the amount of radioactivity present in a substance; one curie of uranium-238 represents  $3.7 \times 10^{10}$  disintegrations per second. Because of the long half-life of uranium-238, a curie is represented by 6600 pounds of that material. On the other hand, a curie of thorium-234, the daughter of uranium-238, is represented by only four one-hundred-thousandths of one gram due to its short half-life of 24 days.

<sup>b</sup>One picocurie is one million-millionth of a curie, previously defined.

### Direct Beta and Gamma Radiation Exposures

As may be seen in Table 2, uranium-238 decays into thorium-234, which decays into protactinium-234. The half-lives of these latter two radionuclides are very short compared to uranium-238. Consequently, the concentrations of these two radionuclides are today the same as the concentration of uranium-238. Thorium-234 and protactinium-234 emit beta and gamma radiation. Hence, surfaces contaminated with uranium-238 can produce beta- and gamma-radiation exposures.

Surfaces in Building 845 are contaminated with uranium-238. The Nuclear Regulatory Commission (NRC) requires applicable to its licensees state that the average beta and gamma exposure rate measured at a distance of one centimeter above surfaces should not exceed 0.2 millirad<sup>c</sup> per hour. Uranium contamination on large portions of the floor, wall, and ceiling surfaces in Building 845, particularly on the first level, results in beta- and gamma-exposure rates in excess of 0.2 millirad per hour, with a maximum value of 15 millirad per hour. For comparison, the skin dose which would be expected from a normal year's watching of color television by an adult is 1.6 millirads<sup>d</sup> for a child less than 15 years of age, the comparable dose is 3.6 millirads per year (according to the United Nations Scientific Committee on the Effects of Atomic Radiation).

The primary concern of the NRC guideline is exposure of skin surfaces. The thickness of ordinary shoe soles is adequate to protect the skin of feet from beta radiation. Other areas of body skin are adequately protected from these exposures if they remain away from these surfaces. In most cases, exposures are negligible at a distance of one foot away from these surfaces. Although potential exists for exposures far in excess of the guidelines, beta and gamma surface exposures are believed to be inconsequential to employees at this site due principally to a low frequency of occupancy. For example, during a normal month, there is total of approximately 5000 man-hours spent in Building 845.

As may be seen in Table 2, several of the daughters of uranium-238 emit gamma radiation (gamma-rays are penetrating radiation like X-rays). Hence, the contamination on this site is a potential source of external gamma radiation exposure. External gamma exposures measured at one meter<sup>d</sup> above the ground or floor of buildings ranged from 3 to 23 micro-Roentgens per hour. Exposure to this upper level for 2000 hours per year, a typical

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<sup>c</sup>A millirad is a unit used to measure the amount of radiation energy absorbed by human tissues.

<sup>d</sup>The Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A micro-Roentgen is one-millionth of a Roentgen.

work year, would lead to an exposure of 46,000 micro-Roentgens. For comparison, a typical chest X-ray (according to Department of Health, Education, and Welfare data) might yield an exposure of 27,000 micro-Roentgens. Background levels in the Deepwater area averaged 11 microRoentgens per hour.

The National Council on Radiation Protection and Measurement (NCRP) has recommended a maximum annual whole-body exposure rate of 500,000 microRoentgens per year to an individual continually exposed in the general public. This value corresponds to 250 microRoentgens per hour for 2000 exposure hours (40 hours per week and 50 weeks per year). Thus, all whole-body gamma radiation exposures at this site are well within guideline values.

#### Other Considerations of Exposure

Radon-222, one of the members of the uranium-238 family shown in Table 2, is an inert gas which may leave the soil and enter the atmosphere. Radioactive decay of radon-222 is rapid (days) and its decay gives rise to short-lived daughters as shown in Table 2. Background concentrations of radon daughters both inside and outside structures are typically less than 0.01 working level (WL).<sup>e</sup> All radon daughter product concentrations measured in buildings at the DuPont site were far below the guide value of 0.03 WL given in Federal Regulation 10 CFR 712.<sup>f</sup>

Health studies of uranium and other hard rock miners have established that inhalation of large quantities of daughters of radon-222 over long periods of time increases an individual's risk of contracting lung cancer. The present federal guide value for uranium mine workers (given by the Environmental Protection Agency), when translated to the units discussed here, would limit mine workers to an exposure of 0.33 working level, assuming exposure for 2000 hours per year, a typical work year. This level is significantly lower than the exposures received by most of the miners included in the health studies referred to above.

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<sup>e</sup>The working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

<sup>f</sup>Title 10, Code of Federal Regulations, Part 712, is a document published by the Energy Research and Development Administration (now Department of Energy) and may be found in the Federal Register).

Concentrations of long-lived radionuclides in air in Building 845 are far below the guidelines applicable to licensees which are set forth in 10 CFR 20<sup>g</sup> for the general public. Concentrations of radionuclides in groundwater and surface water are well below guidelines given in 10 CFR 20 for the general public.

Use of contaminated soil for growing crops could produce appreciable human exposures through consumption of these crops. Actions which involve agitation or abrasion of dry, contaminated surfaces could create airborne radioactive dust which, when inhaled, would also produce internal human exposures. For example, about a pound of solid material was removed from the first floor of Building 845; this material contained 51,000 pCi/g of uranium-238 (15% by weight). Another sample removed from this floor contained 27,000 pCi/g of uranium-238 (8% by weight). Floor drains also contained uranium-238 residues with concentrations as high as 1000 pCi/g (0.3% by weight).

#### Risk and Radiation Exposures

Risks resulting from radiation exposures should be considered within the context of other risks incurred in normal living. For simplicity, risks to health may be classified in four categories:

1. Unacceptable--problems with risk so high as to require immediate action, such as severe diseases where medical treatment is required to save a life.
2. Concerned--problems where people are willing to spend time and money to reduce potential hazards. Examples of this include the maintenance of public highways and signs, signals, fire departments, and rescue squads.
3. Recognized--problems where people may accept some inconvenience to avoid certain activities such as flying in airplanes, swimming alone, etc.
4. No great concern--problems with a low frequency of occurrence. There is an awareness of potential hazard, but an accompanying feeling that these problems occur only to other people.

An individual may be exposed to risks over which he can exercise some control (voluntary), and risks over which he feels he has no personal control or choice (involuntary).

Daily, an individual is confronted with decisions about risk which have an associated benefit--for example, driving a car. This can serve as an illustration that a voluntary, concerned risk may be deemed appropriate due to the desirable perceived benefit. As another example, an individual who smokes cigarettes has subjected himself to a risk of lung cancer which is about ten times higher than that for a non-smoker.

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<sup>g</sup>Title 10, Code of Federal Regulations, Part 20, is a document published by the Nuclear Regulatory Commission and may be found in the Federal Register.

For purposes of radiation protection, all radiation exposures are assumed to be capable of increasing an individual's risk of contracting cancer. A precise numerical value cannot be assigned with any certainty to a given individual's increase in risk attributable to radiation exposure. The reasons for this are numerous; they include the individual's age of onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other cancer-causing agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimates of the number of increased cancers in the relatively small working population at the Deepwater site.

The normal annual death rate from lung cancer for all population groups in Salem County (as of 1970) was 23.1 deaths per 100,000 population. At the same time, the annual death rates from lung cancer for all population groups in the United States and the State of New Jersey were 21.1 and 25.7 deaths per 100,000 population, respectively. A one-year exposure to the guideline value for uranium miners (0.33 working level for 2000 hours) might increase the risk of death due to lung cancer by approximately four percent.

The annual death rate from all types of cancer among all population groups in Salem County (as of 1970) was 169 deaths per 100,000 population. At the same time, the death rates from all types of cancer for all population groups in the United States and in the State of New Jersey were 151 and 175 per 100,000 population, respectively. A one-year exposure to penetrating gamma radiation of 500,000 microRoentgens might increase the risk of death due to all types of cancer by about one-tenth of a percent. Exposures in excess of these guideline values would be expected to result in proportionately higher increases in risk. Consequently, any action taken to reduce either the rate or the duration of radiation exposures would also reduce the risk attendant to that exposure.

There are no data at present which give evidence of a relationship between low-level exposure of the skin and the development of skin cancers. This does not mean that skin cancer cannot be produced by low-level exposures. This does mean that the risk associated with guideline level exposures of the skin is so small that it cannot be quantified.

#### Remedial Measures

Employees working in Building 845 at the DuPont site are currently receiving small radiation exposures to the skin. The risk associated with these exposures is imperceptibly small. However, the potential exists for more serious exposures by inhalation of radioactive dusts. Decontamination of the uranium-238 residues on building surfaces would remove the source of actual and potential exposures associated with Building 845.

The uranium-238 contamination in soils surrounding Building 845 is a source of potential human exposure as is that in the waste burial area. However, exposures from the latter source can be controlled by provisions of the license issued by the State of New Jersey. Thus, removal of the contaminated soils around Building 845 and proper disposal of these soils in the licensed waste burial area would improve the protection to persons on the site. The next stage of the Department of Energy's Remedial Action Program is to identify and evaluate various alternatives to assure adequate protection against current and potential radiation exposures at this location.

#### Summary

In summary, the DuPont site is contaminated with residues containing naturally occurring uranium. Under current conditions of site use, this contamination does not cause employees working at the site to receive radiation exposures appreciably different from those due to background radiation. However, under different conditions of use (i.e., use of contaminated soils for growing crops or actions which involve agitation or abrasion of dry contaminated surfaces), potential radiation exposures to employees and the public could result. For that reason, the DOE will conduct further evaluations to enable the identification of appropriate actions which will preclude any concerns for radioactivity at this site.

Table 1

SUMMARY OF EXPOSURE DATA AT E. I. DUPONT COMPANY  
DEEPWATER, NEW JERSEY

Exposure Source	Background Levels	Guideline Value for General Public	Guideline Value for Radiation Workers	Average Levels at DuPont Site
Radon daughters in air	Less than 0.01 "working-level" <sup>a</sup>	0.01 working level for residences and school rooms, and 0.03 working level for other structures	0.33 working level for uranium miners exposed for 40 hours per week and 50 weeks per year	Average daytime concentration ranged from 0.0001 to 0.0006 working level
Gamma radiation from decay products of uranium contamination	11 micro-Roentgens <sup>b</sup> per hour in the Deepwater area	250 microRoentgens per hour above natural background for 40 hours per week and 50 weeks per year for an individual in the general public. This is equivalent to 0.5 Roentgens per year	5 Roentgens per year	Average gamma radiation levels 1 meter above the floor or ground ranged from 3 to 23 microRoentgens per hour

<sup>a</sup>The working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

<sup>b</sup>The Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microRoentgen is one millionth of a Roentgen.

Table 2

## Uranium-238 decay series

Parent	Half-life	Decay products	Daughter
uranium-238	4.5 billion years	alpha	thorium-234
thorium-234	24 days	beta, gamma	protactinium-234
protactinium-234	1.2 minutes	beta, gamma	uranium-234
uranium-234	250 thousand years	alpha	thorium-230
thorium-230	80 thousand years	alpha	radium-226
radium-226	1600 years	alpha	radon-222
radon-222	3.8 days	alpha	polonium-218
polonium-218*	3 minutes	alpha	lead-214
lead-214*	27 minutes	beta, gamma	bismuth-214
bismuth-214*	20 minutes	beta, gamma	polonium-214
polonium-214*	<u>2</u> second 10,000	alpha	lead-210
lead-210	22 years	beta	bismuth-210
bismuth-210	5 days	beta	polonium-210
polonium-210	140 days	alpha	lead-206
lead-206	stable	none	none

\*Short-lived radon daughters.