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**RESULTS OF THE INDOOR
RADIOLOGICAL SURVEY**

AT

**THE W. R. GRACE CO.
CURTIS BAY SITE
BALTIMORE, MARYLAND**

W. D. Cottrell
R. D. Foley
C. A. Johnson

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DEPARTMENT OF ENERGY

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HEALTH AND SAFETY RESEARCH DIVISION

Nuclear and Chemical Waste Programs
(Activity No. AH 10 05 00 0; ONLWCO1)

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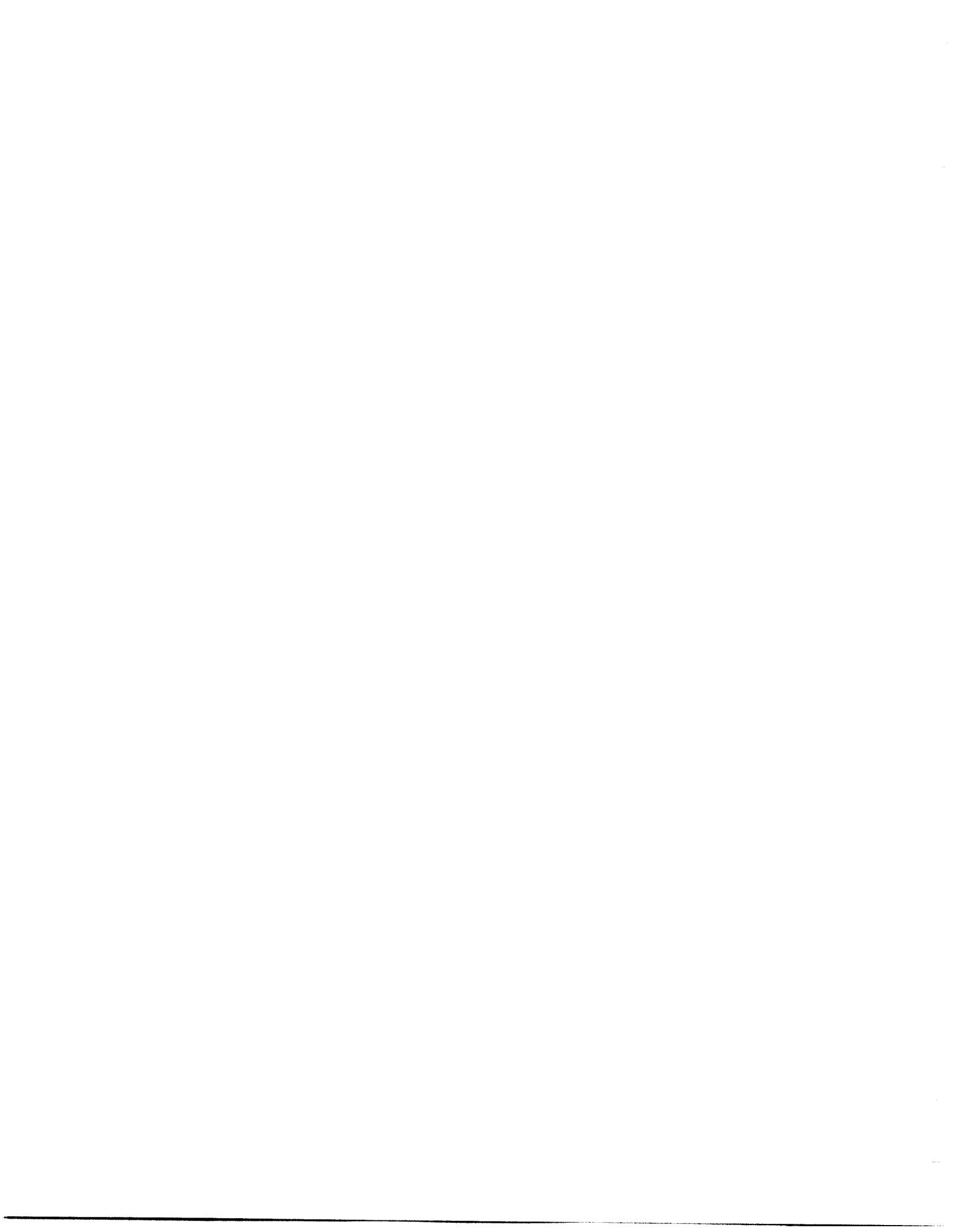
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ABSTRACT

The W. R. Grace Company, Davison Chemical Division, conducted developmental research and extraction of thorium from monazite ore at its Curtis Bay facility in Baltimore, Maryland, during the 1950s under contract to the Atomic Energy Commission (AEC). Only one of the numerous buildings on the site was used for these operations that were limited to a period of approximately one year ending in 1957. A 1979 aerial survey of the site for the Department of Energy (DOE) indicated that a comprehensive ground survey was required to determine whether or not any contamination remained from the AEC activities in that building. A radiological scoping survey performed later that year for DOE by a team from the Measurement Applications and Development Group of the Health and Safety Research Division, Oak Ridge National Laboratory (ORNL), disclosed surface contamination (alpha) levels in excess of DOE criteria on all five levels of the building. As a result of this finding, two additional surveys were performed in 1986 by ORNL at the request of DOE to evaluate any present or potential health risk. They are detailed in this report.

The results of the 1986 surveys revealed several areas having elevated levels of radiation as a result of significant quantities of thorium on some building surfaces such as floors and ceiling beams. Most areas were small spots and in locations of low occupancy; thus, the possibility for significant exposure to workers was judged to be low. To confirm this evaluation, annual radiation exposure estimates for workers frequenting the few, larger contaminated areas on the site were derived using ORNL survey data and occupancy factors provided by the W. R. Grace Company. Estimates ranged from 27 to 41 mrem/yr or a maximum of 41% of the basic dose limit of 100 mrem/yr for members of the general public. Following removal of a contaminated duct from the fourth level of the building, concentrations of radon and radon decay products were well below guideline values. This fact, the spotty nature of much of the contamination on the lower floors, and current work and use conditions render it highly unlikely that personnel may receive any radiation exposure exceeding guidelines. However, further evaluation and review may be necessary if conditions or operations conducted in this building were to change.

**RESULTS OF THE INDOOR RADIOLOGICAL SURVEY
AT THE W. R. GRACE AND COMPANY,
CURTIS BAY SITE, BALTIMORE, MARYLAND**

INTRODUCTION

During the mid-1950s, developmental research and extraction of thorium from monazite ore was carried out by the W. R. Grace Company, Davison Chemical Division, at its Curtis Bay facility in Baltimore. The facility, comprising approximately 260 acres, including a 40-acre waste disposal area (all but four acres are used for nonradioactive materials and debris), is located approximately eight miles south of the city of Baltimore. The original contract to process and handle the monazite sand was made in 1955 between the Atomic Energy Commission (AEC) and Rare Earths, Inc., and subsequently transferred to the W. R. Grace Company in 1956. The operation carried out by the W. R. Grace Company covered a period of approximately one year and resulted in the burial of radioactive materials, residues, and contaminated equipment on plant property.¹

The Curtis Bay facility includes numerous buildings; however, AEC activities were limited to Building 23, which housed the monazite process during the W. R. Grace contract period which was concluded in 1957. Although some structures and most process equipment were removed, the building shell and some interior structures and tankage still exist and are currently being used in processes involving the production of nonradioactive molecular sieves. The surrounding areas are industrial, and the nearest residence is about a half-mile away.

In 1978, the W. R. Grace Company contracted Radiation Management Corp. to perform a radiological survey of the site. This survey indicated that there was no detectable contamination resulting from the AEC activities in the buildings. However, based on a review of the survey, additional survey work was recommended to characterize the radiological condition of the site. An aerial survey of the site was conducted in July 1979 for the U.S. Department of Energy (DOE). Results indicated that a comprehensive ground survey of the area was required, and the assignment was given to Oak Ridge National Laboratory (ORNL).

Visits to the chemical plant and disposal area were made in April and October 1979 by members of a radiological survey team from ORNL to perform a radiological scoping survey of the facility and to gather sufficient information to allow site preparation subcontracts to be put in place. At this time, surface contamination and surface radiation measurements were made at random locations in Building 23 (the former process building).

Building surfaces in some areas, especially around vats and hoppers, showed radiation levels of approximately 3 mrad/h. Such levels are in excess of criteria. Surface contamination (alpha) levels in excess of criteria were measured on all five levels of this building.

A radiological survey plan for the W. R. Grace Company property was developed by ORNL and presented to DOE in October 1979; however, due to changes in DOE priorities the survey was not carried out at that time.

Subsequently, ORNL was requested by DOE to conduct a limited radiological survey of the site to evaluate any present or potential health risk. Surveys were made at the Curtis Bay site on two different occasions during 1986. The first survey, which was the most extensive, was performed in October 1986, when members of the Health and Safety Research Division (HASRD) of ORNL conducted a limited radiological characterization survey of the portion of Building 23 that had been involved with the thorium operation. The second survey, conducted during December after removal of the contaminated duct, consisted of radon sampling only.

This report describes in detail the results of the radiological survey. A drawing showing the general area and location of the Curtis Bay site is presented in Fig. 1. A photograph showing an aerial view of the property and general location of Building 23 is given in Fig. 2. Detailed drawings of each floor are shown in Figs. 3-14. Background radiation levels and DOE guidelines are indicated in Tables 1 and 2, and all radiological measurements are listed by floor in Tables 3-7.

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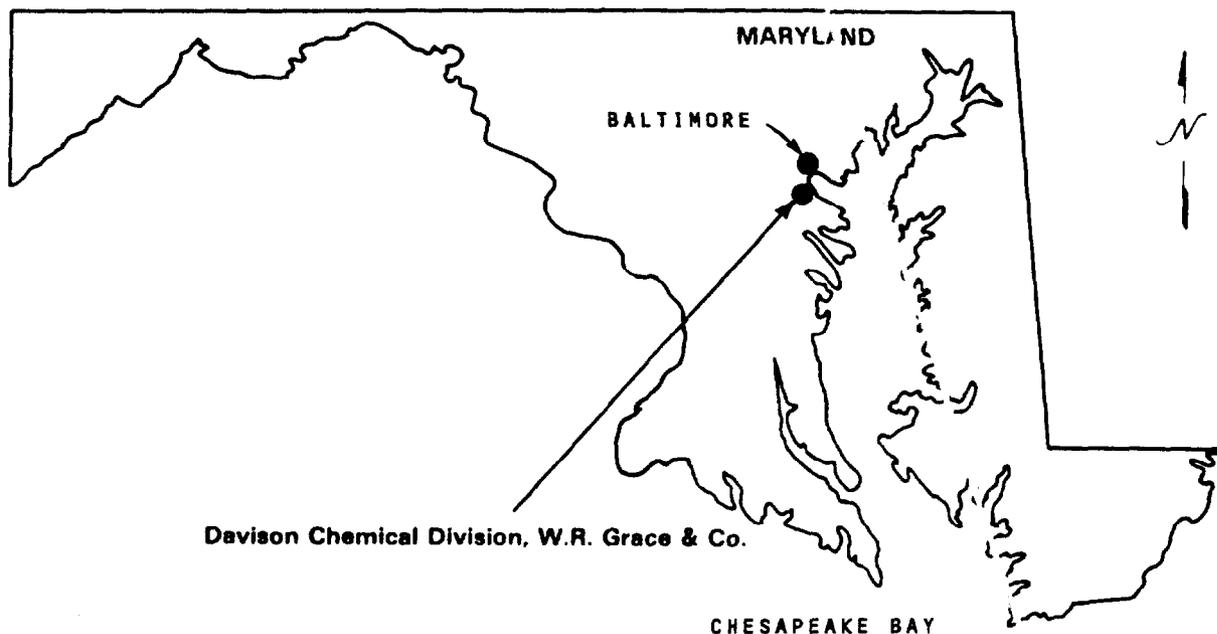


Fig. 1. Location of the W. R. Grace site in the Baltimore, Maryland, area.



AERIAL VIEW APPROACHING FROM THE NORTHEAST

Aerial view of Grace plant in center. Licensed dump area in left foreground. Curtis Bay in right foreground. Fertilizer plants of U.S. Steel and Southern States Coop. in left background. Hess and Amoco petroleum terminals in right background.

Fig. 2. Aerial view of the W. R. Grace site, Baltimore, Maryland.

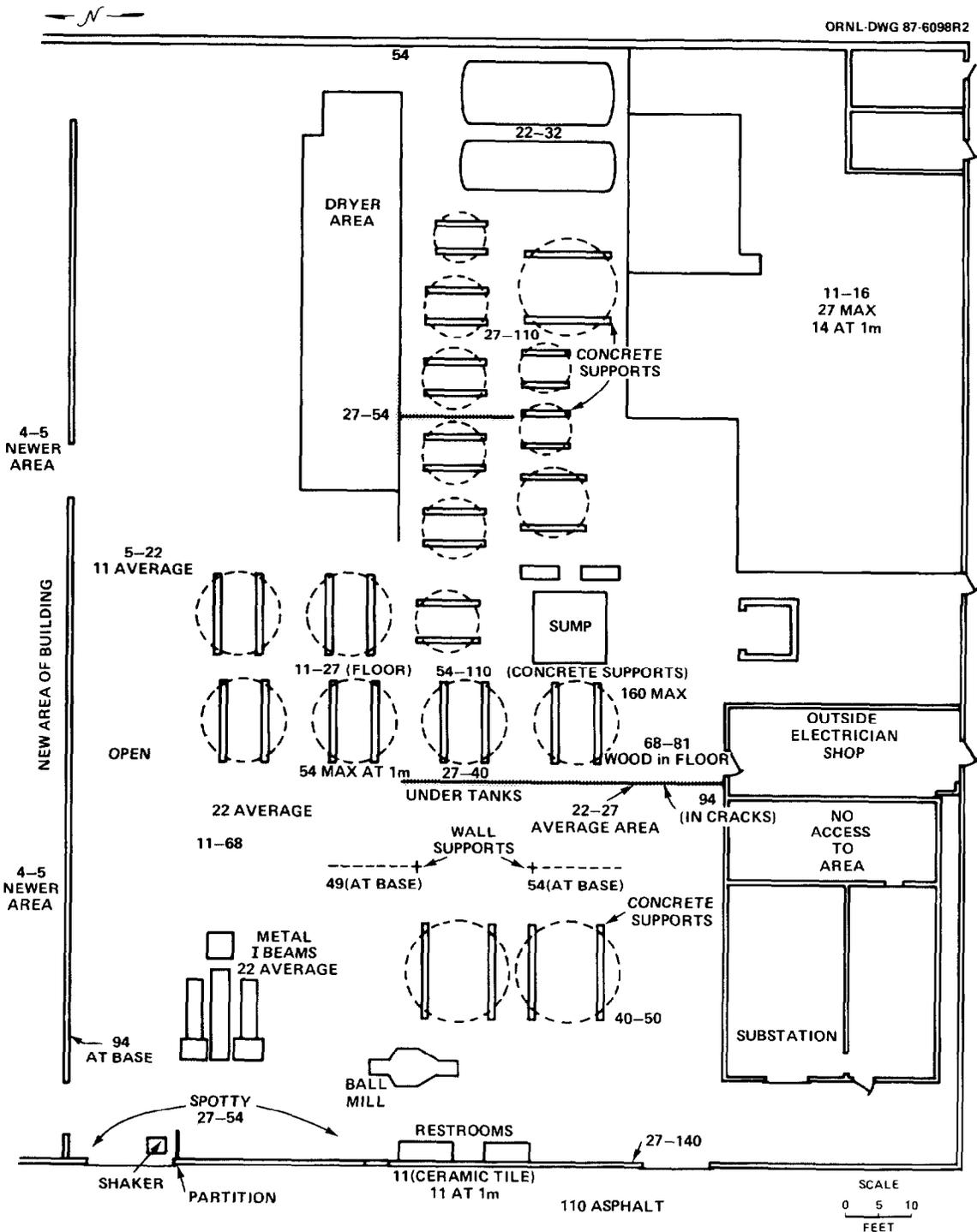


Fig. 3. Gamma exposure rates ($\mu\text{R/h}$), first floor (level 100.5 ft), Building 23, W. R. Grace site.

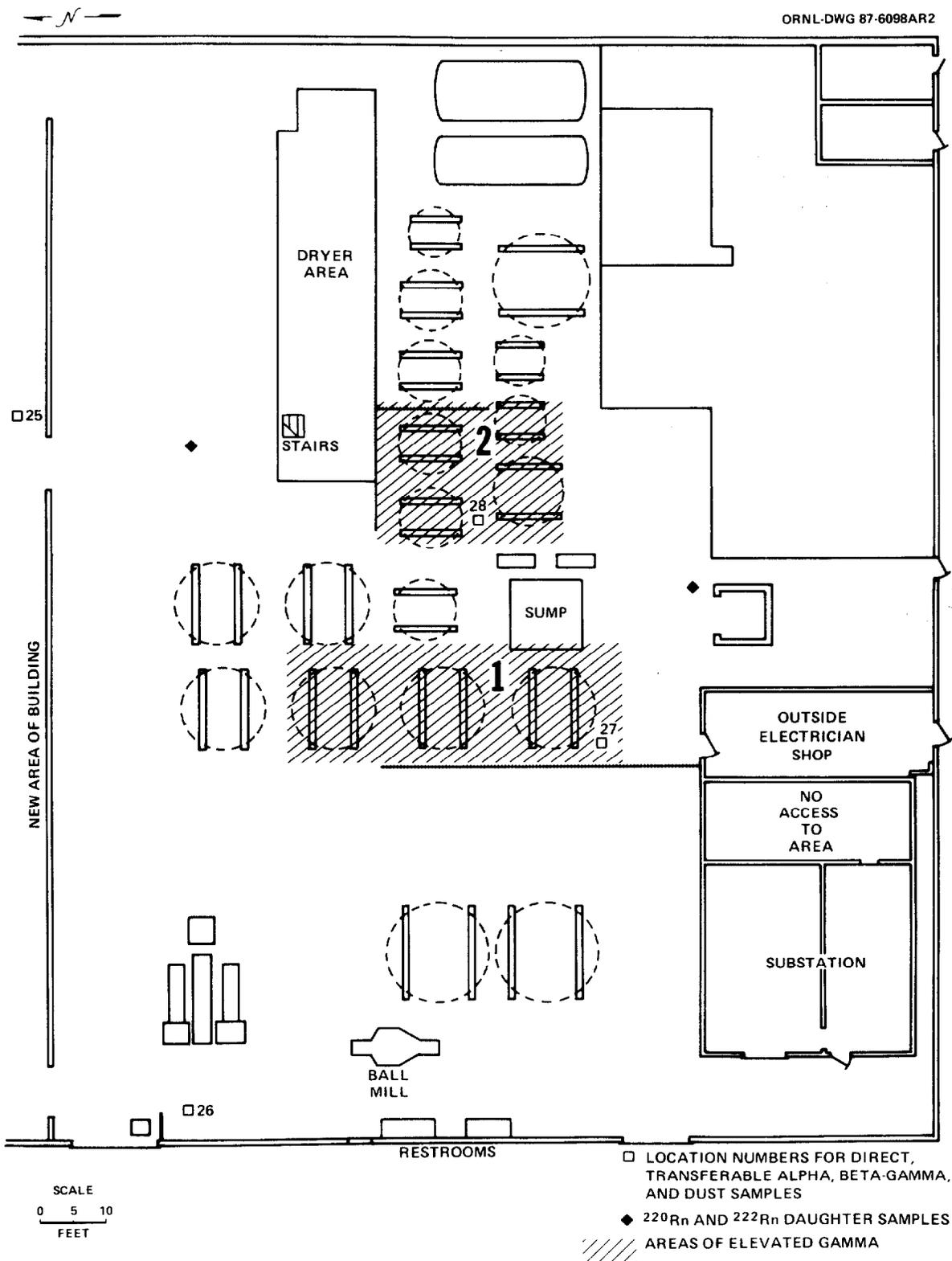


Fig. 4. Sampling and measurement locations, first floor (level 100.5 ft), Building 23, W. R. Grace site.

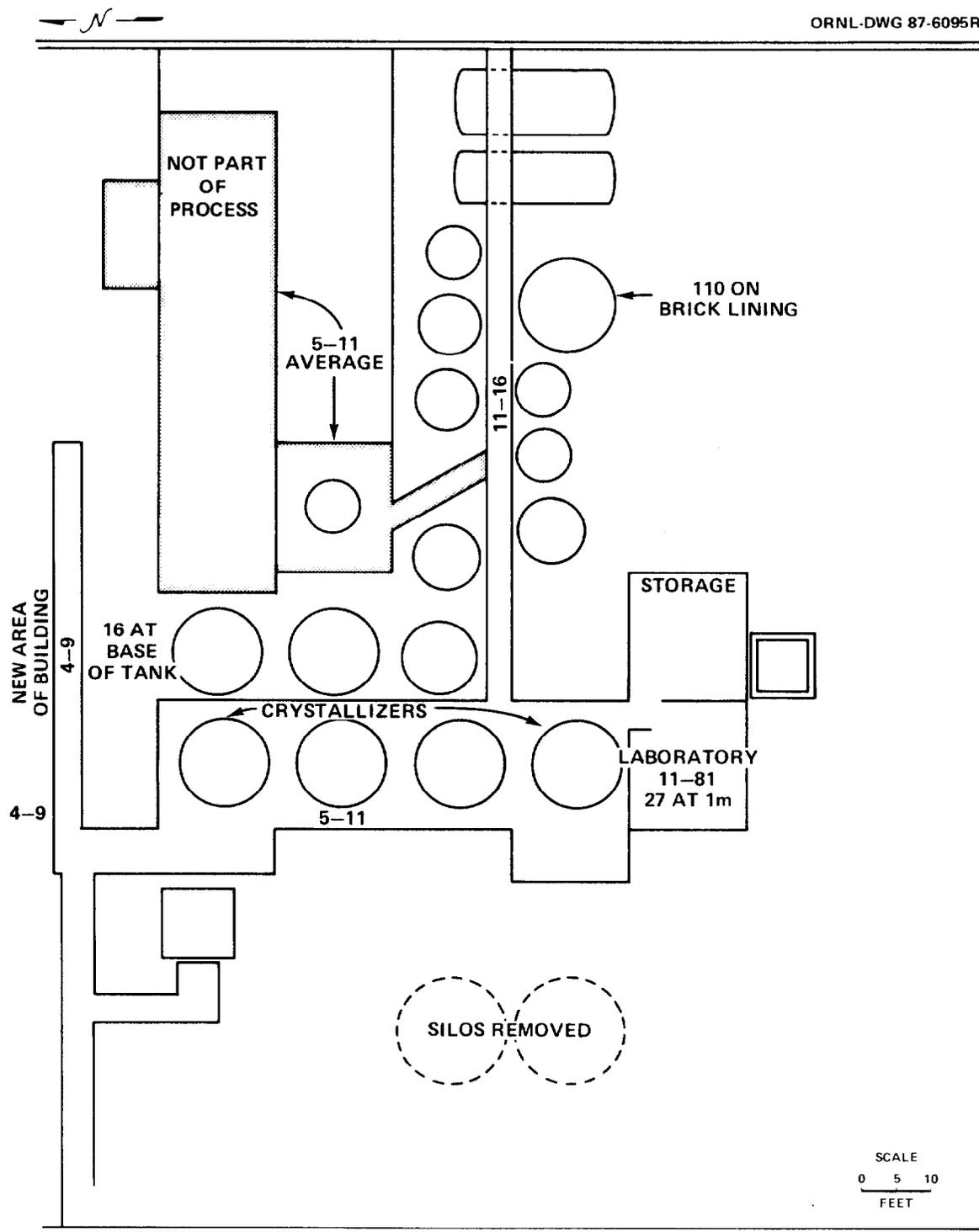


Fig. 5. Gamma exposure rates ($\mu\text{R/h}$), second floor (level 114.5 ft), Building 23, W. R. Grace site.

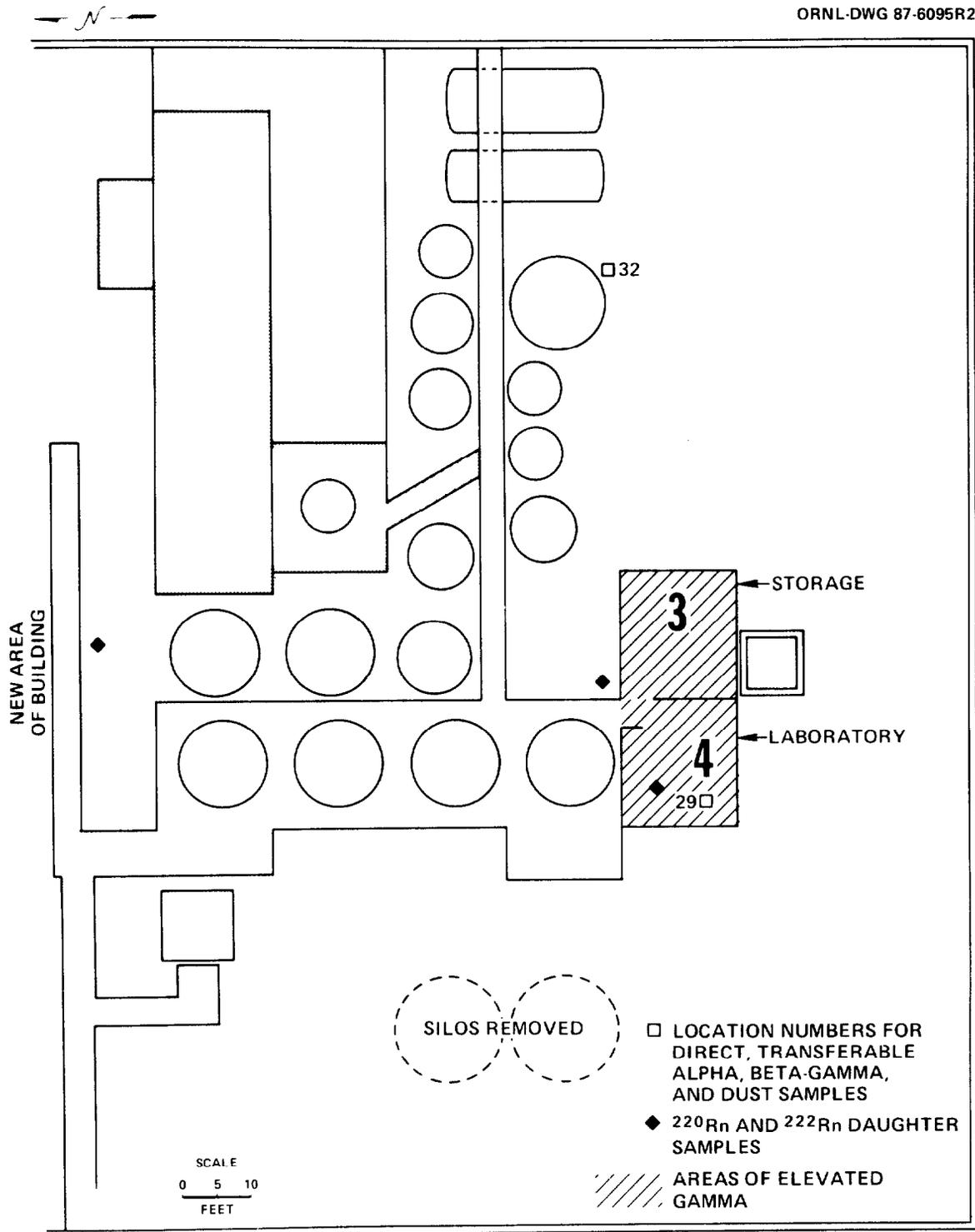


Fig. 6. Sampling and measurement locations, second floor (level 114.5 ft), Building 23, W. R. Grace site.

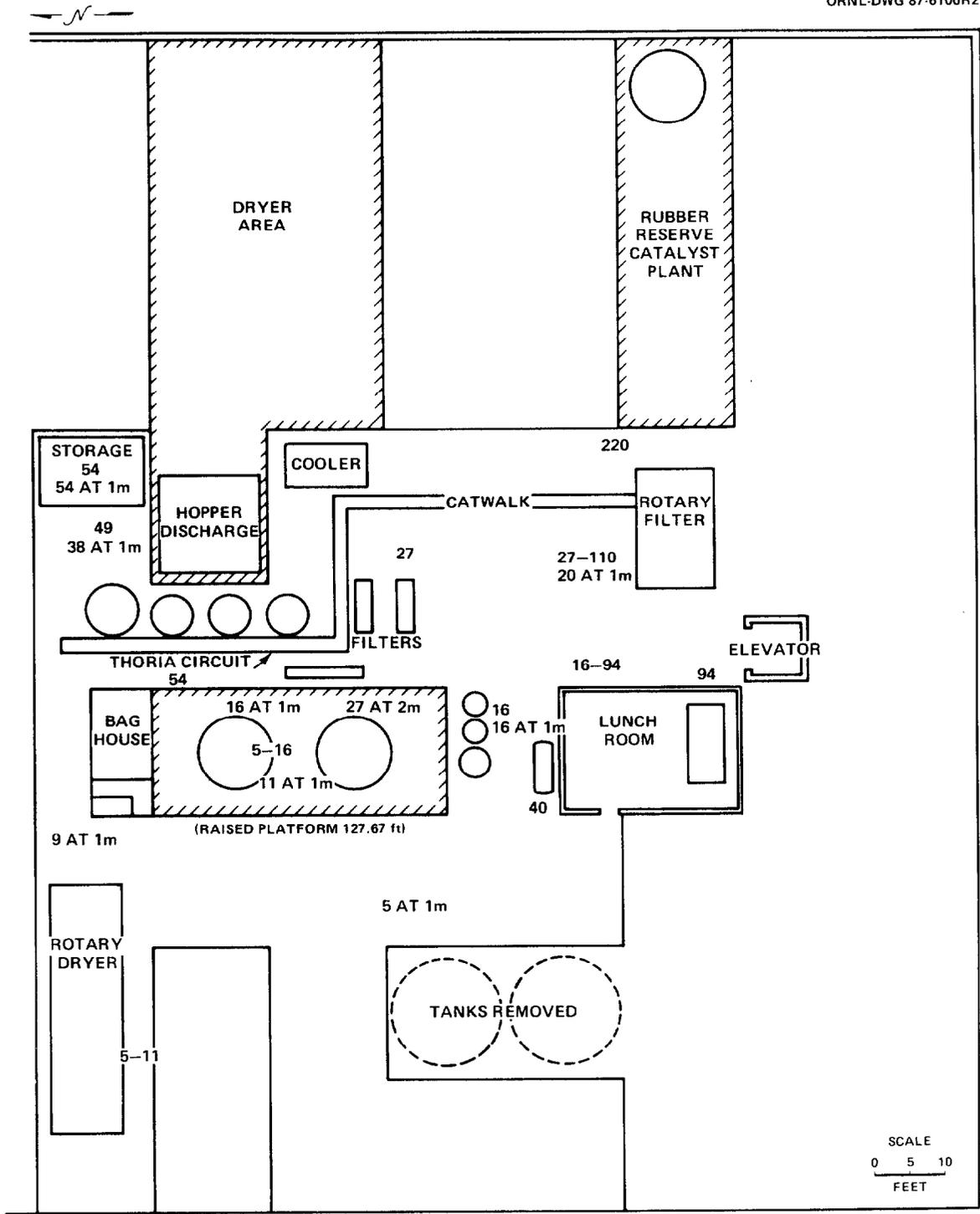


Fig. 7. Gamma exposure rates ($\mu\text{R/h}$), third floor (levels 124 ft and 127.67 ft), Building 23, W. R. Grace site.

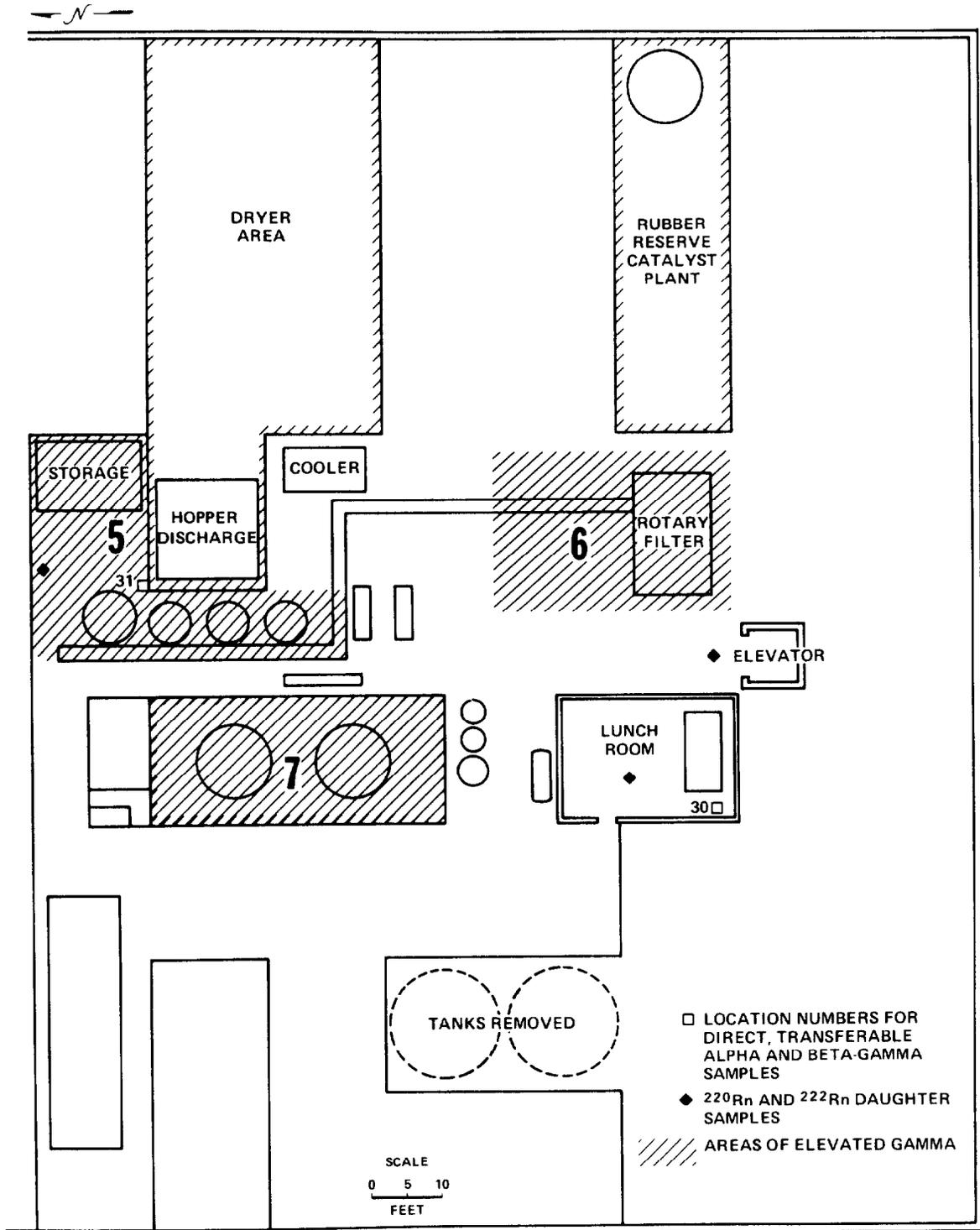


Fig. 8. Sampling and measurement locations, third floor (levels 124 ft and 127.67 ft), Building 23, W. R. Grace site.

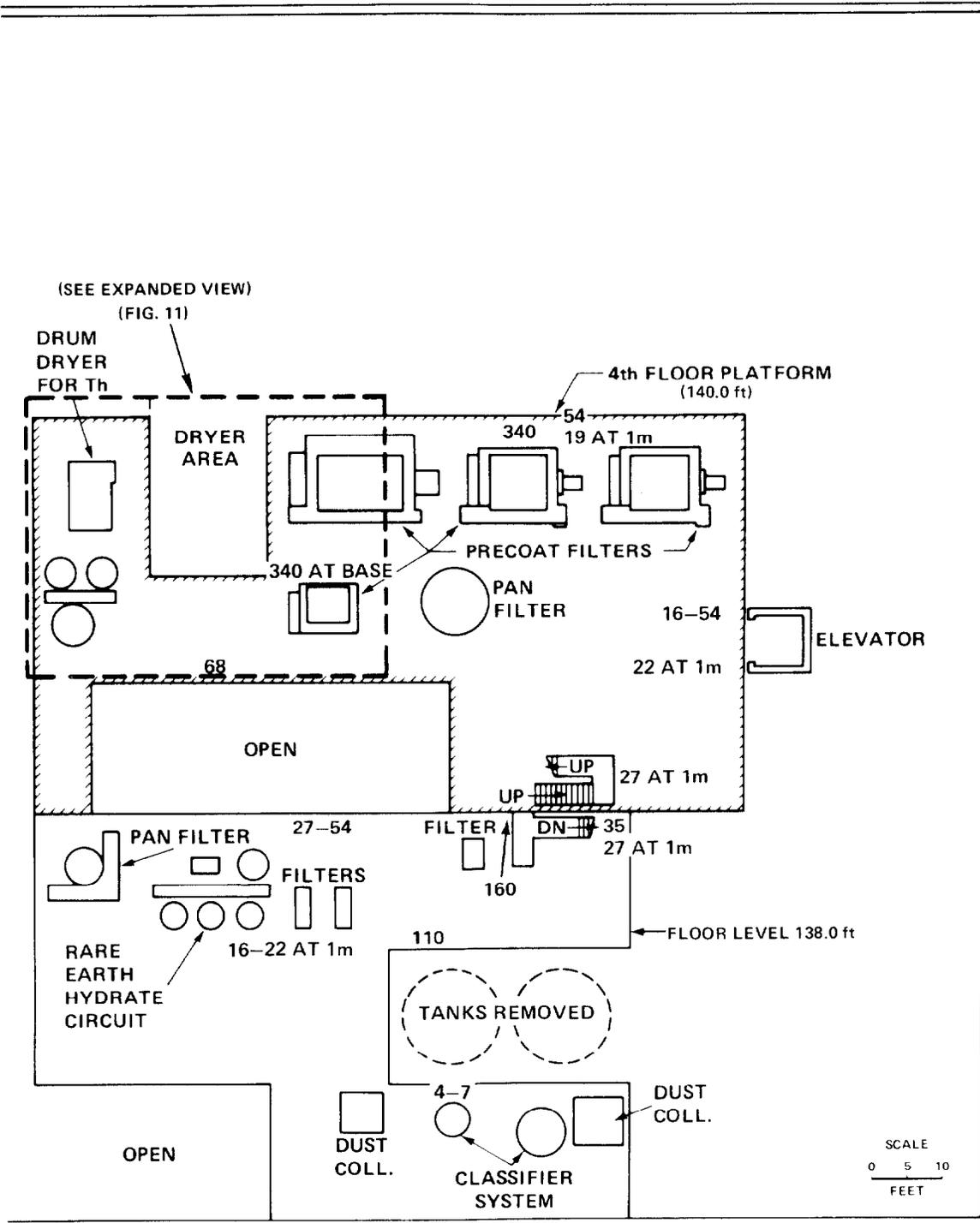


Fig. 9. Gamma exposure rates ($\mu\text{R}/\text{h}$), fourth floor (levels 138 ft and 140 ft), Building 23, W. R. Grace site.

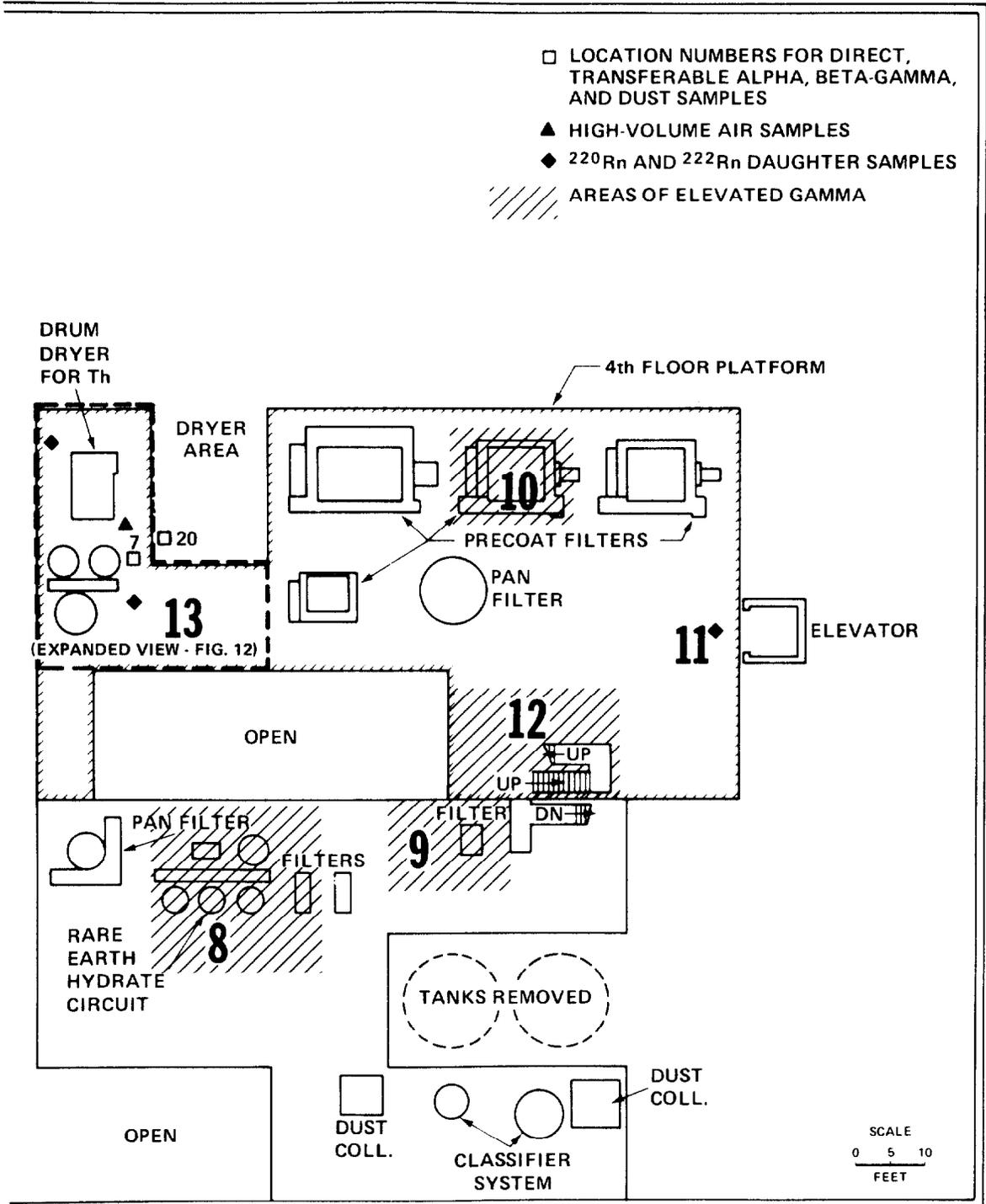


Fig. 10. Sampling and measurement locations, fourth floor (levels 138 ft and 140 ft), Building 23, W. R. Grace site.

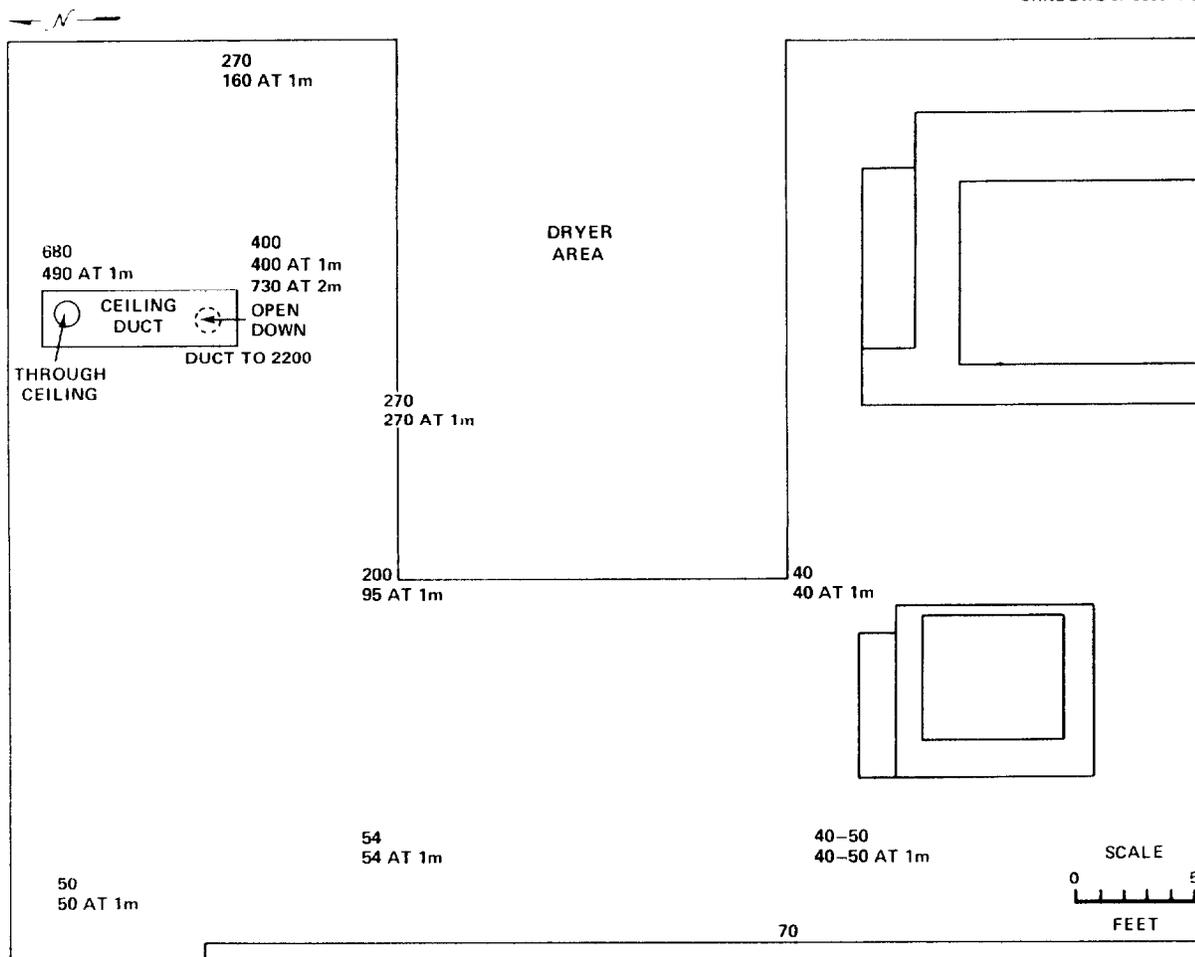


Fig. 11. Gamma exposure rates ($\mu\text{R/h}$), fourth floor (level 140 ft), Building 23, W. R. Grace site.

SURVEY METHODS

The radiological survey of this property included the following measurements made inside the building: (1) gamma scanning of all levels, (2) gamma exposure rates at 1 m above the floor surface and at the floor surface, (3) radionuclide analysis of solid material samples, (4) direct and transferable alpha and beta-gamma activity, (5) gross alpha concentrations in air, and (6) radon daughter concentrations in air. A comprehensive description of the survey methods and instrumentation has been presented in another report.²

Unless otherwise stated, each floor was surveyed in the following manner: accessible areas were scanned with a gamma scintillation detector, and the range and average gamma radiation levels were recorded at 1 m and at the surface. Alpha and beta-gamma dose rate measurements were made at selected points, generally where elevated gamma radiation levels were found on each level. Smear samples were taken in areas having elevated beta-gamma dose rates for the determination of transferable alpha and beta contamination levels.

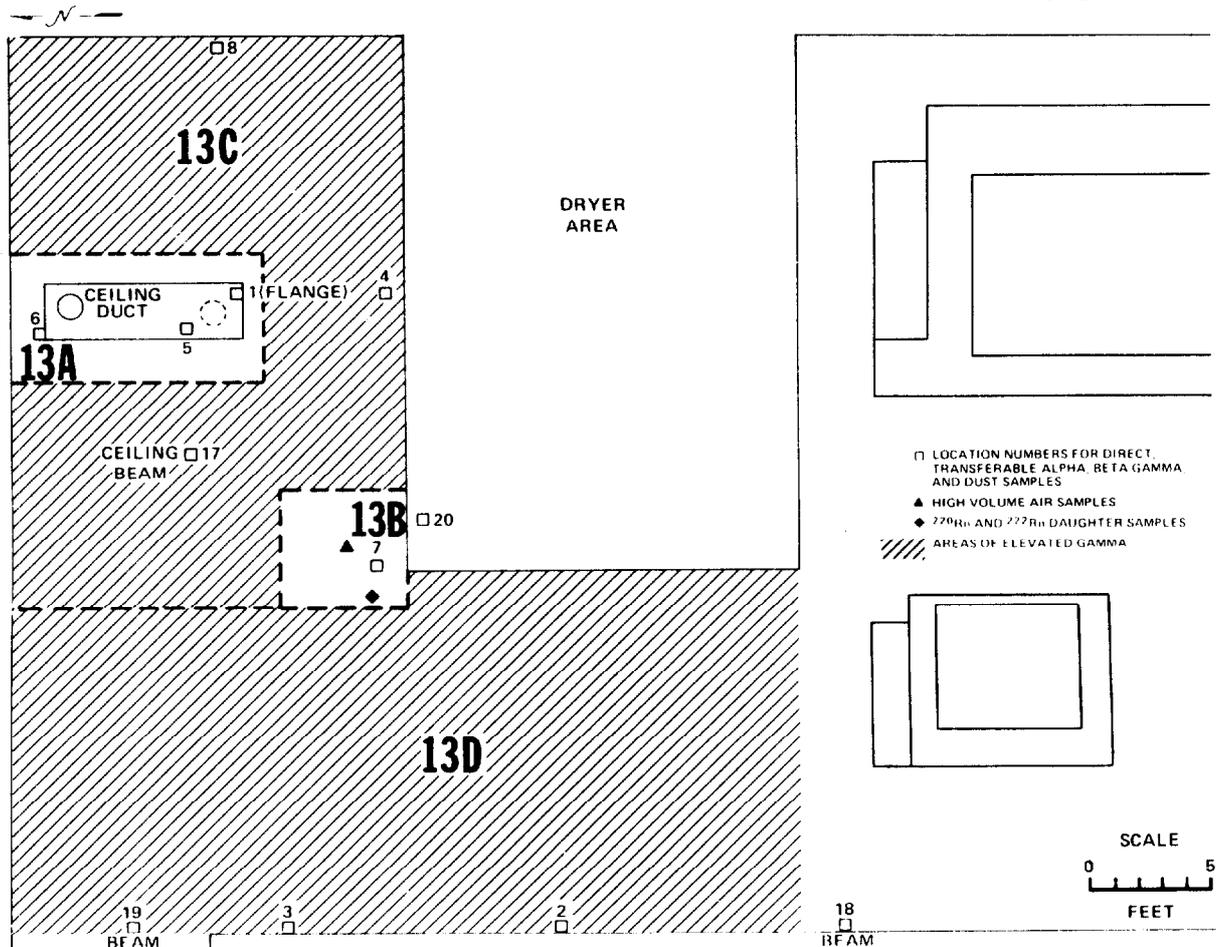


Fig. 12. Sampling and measurement locations, fourth floor (level 140 ft), Building 23, W. R. Grace site.

Representative areas of overhead surfaces (i.e., ceilings, structural members, and ducts) were scanned in the same manner; direct alpha and beta contamination levels were measured at elevated gamma points. On some floors and ceiling beams a thick layer of fine, powderlike "dust," generated from current operations, made it impossible to take direct alpha measurements. Samples of this dustlike solid material were collected from floors and beams and returned to ORNL for analysis of ^{226}Ra , ^{232}Th , and ^{238}U . These results are reported in Table 6.

At one time a large part of the building was used in the thorium process, and it was assumed that all levels may have been contaminated. Sampling for gross alpha and beta concentrations in air was done to determine if residual contamination was being resuspended to present an air contamination problem. High-volume and low-volume air samples were taken throughout the building. The low-volume samples were taken and counted on site to determine if there was gross air contamination present. The high-volume samples were taken concurrently with some of the low-volume samples and were returned

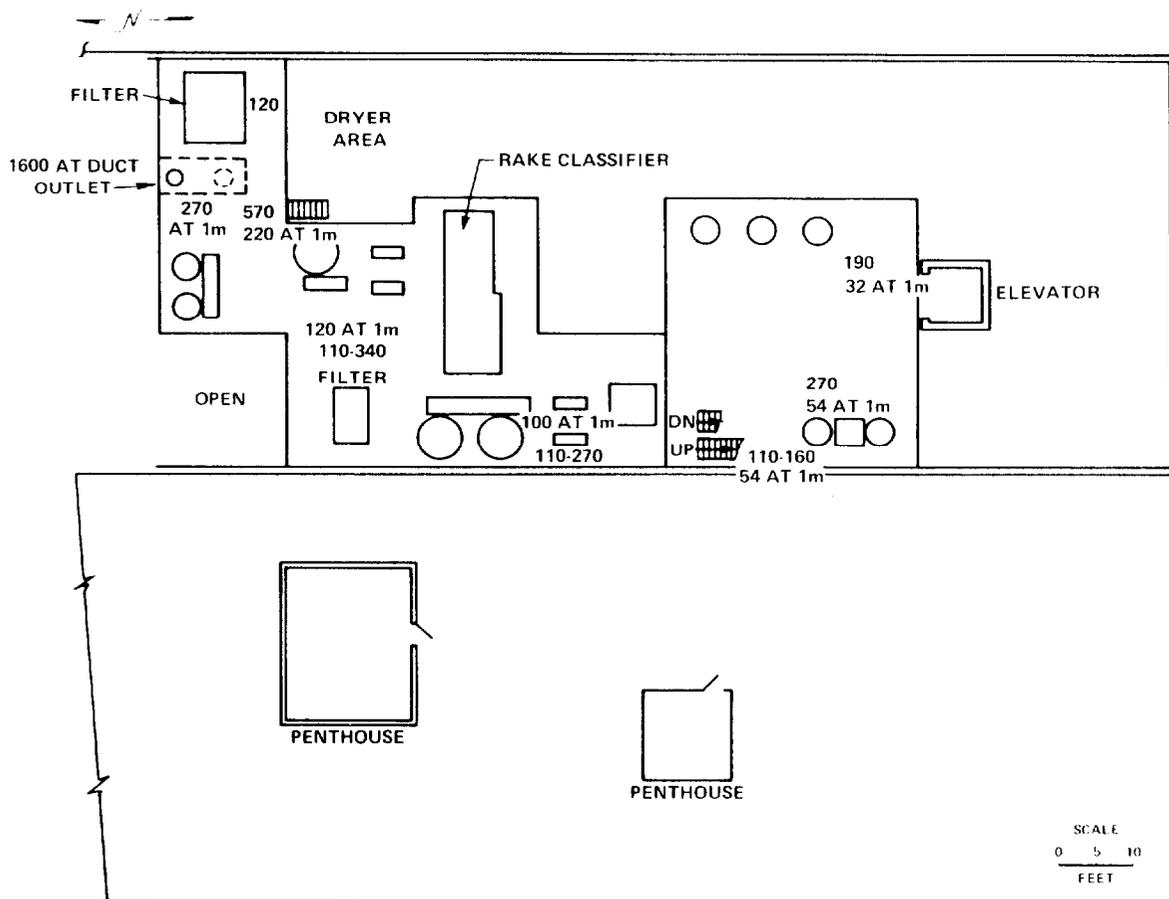


Fig. 13. Gamma exposure rates ($\mu\text{R}/\text{h}$), fifth floor (level 149 ft), Building 23, W. R. Grace site.

to the lab for a more in-depth analysis. The high-volume sample results are reported in Table 5. In addition to these measurements, radon (^{222}Rn and ^{220}Rn) daughter concentrations in air were taken at different times and in several locations on each level as shown in Table 4.

SURVEY RESULTS

Typical radiation background levels for the Curtis Bay processing site were obtained by measuring gamma radiation and radionuclide concentration levels at several points in the building's newer portion that was never involved in the thorium process. These are presented in Table 1. The data are provided for comparison with the survey results presented in this section. A summary of DOE radiation guidelines applicable to the Curtis Bay site is shown in Table 2.

With the exception of transferable activity measurements that are reported as net disintegration rates, all direct measurements presented in this report are gross readings; background radiation levels have not been subtracted. For the measurement of transferable alpha and beta contamination levels, average instrument background counts were deter-

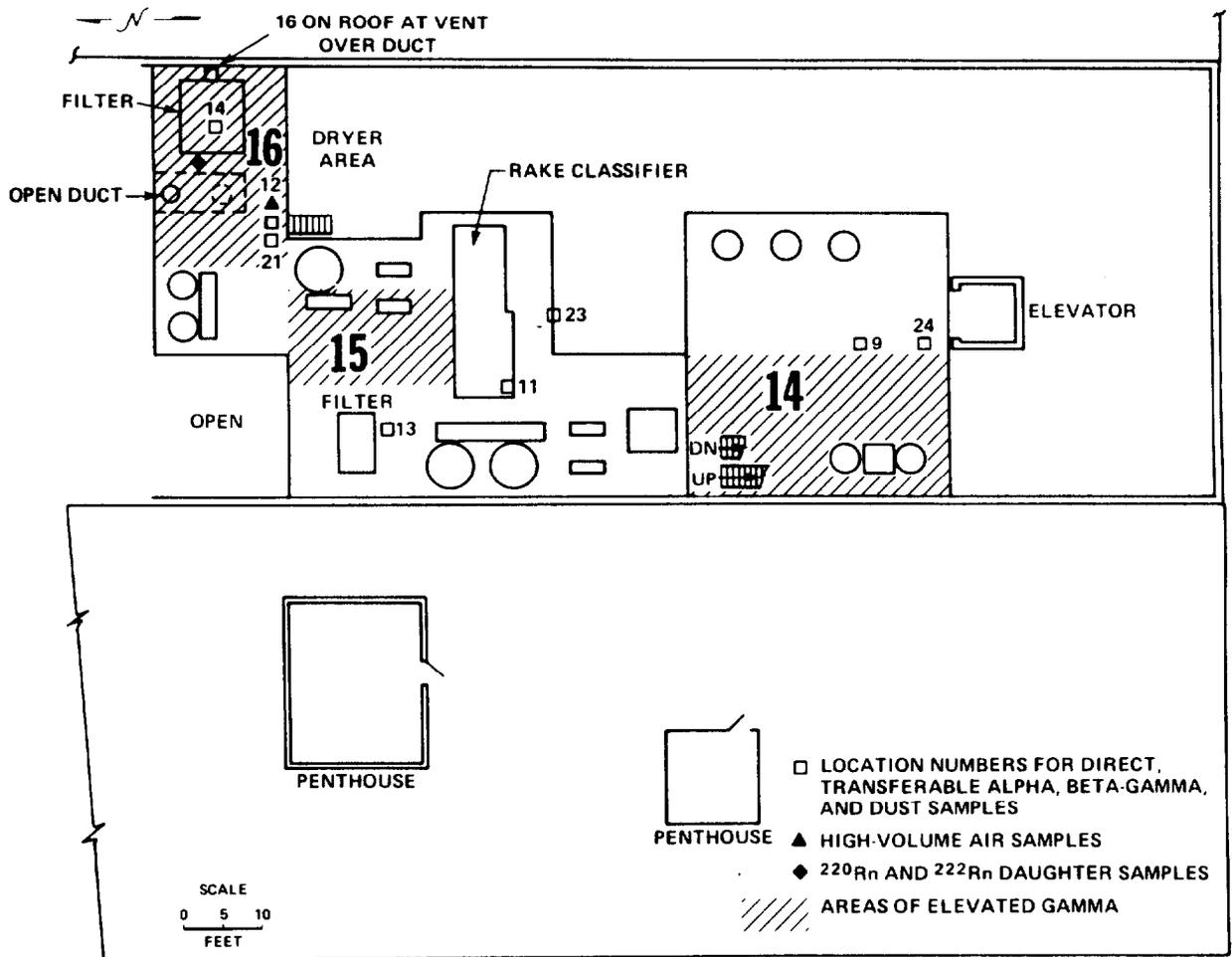


Fig. 14. Sampling and measurement locations, fifth floor (level 149 ft), Building 23, W. R. Grace site.

mined and subtracted from gross counts. All measurements in the tables and text are given to two significant figures.

Although the W. R. Grace Company occupies numerous buildings on the property at the Curtis Bay site, AEC activities were limited to Building 23. This building is now being used for chemical processes involving nonradioactive materials. Surface contamination levels measured on the site are compared in this report with DOE guidelines for residual radioactive material.

The major radiological contaminant at the Curtis Bay site is ^{232}Th . According to DOE guidelines for alpha emitters, the average and maximum limits for direct measurements of alpha contamination levels on surfaces contaminated with ^{232}Th are 1000 dpm/100 cm² and 3000 dpm/100 cm², respectively. Transferable alpha contamination should not exceed 200 dpm/100 cm².

**Table 1. Background radiation levels
at the W. R. Grace site**

| Type of radiation measurement or sample | Radiation level or radionuclide concentration | |
|--|--|----------------|
| | Range | Average |
| Gamma exposure rate at 1 m above floor ($\mu\text{R/h}$) ^a | 4-5 | 5 |
| Concentration of radionuclides in solid material (pCi/g) ^a | | |
| ²³⁸ U ^b | | 0.39 |
| ²²⁶ Ra | | 0.42 \pm 0.1 |
| ²³² Th | | 0.50 \pm 0.2 |

^aValues obtained from the building's newer area, which was not used in the thorium process.

^bTotal analytical error of measurement results is less than $\pm 5\%$ (95% confidence level).

Regardless of the contaminant, average and maximum beta-gamma dose rates should not exceed 0.20 mrad/h and 1.0 mrad/h, respectively. Unless otherwise stated, beta-gamma dose rates between 0.20 mrad/h and 1.0 mrad/h reported in this document are average measurements over an area of not more than 1 m².

Guidelines for ²²²Rn concentrations in buildings state that the average radon decay product concentration (including background) due to uranium by-products shall not exceed 0.02 WL* (2 pCi/L) (picocuries† per liter).‡ These same standards may be applied for ²²⁰Rn and its decay products in air due to thorium by-products. Remedial action shall be undertaken for any building that exceeds an annual average radon decay product concentration (including background) of 0.03 WL (3 pCi/L). For thorium, concentrations in air shall not exceed 1×10^{-12} $\mu\text{Ci/mL}$ in uncontrolled areas.

As an aid in surveying and data management, survey blocks on each floor are defined by natural boundaries (i.e., walls and structures or equipment remaining in the building).

*A working level (WL) is defined as any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 meV of alpha particle energy.

†The curie is a unit used to define the radioactivity in a substance and equals that quantity of any radioactive isotope undergoing 2.2×10^{12} disintegrations per minute. The picocurie is one million-millionth of a curie or that amount yielding 2.2 disintegrations per minute.

‡Conversion from WLs to pCi/L assumes the radon products are in equilibrium with the radon. Practical experience suggests that decay products are usually only a fraction of the radon concentration (e.g., at 50% equilibrium 0.02 WL = 4 pCi/L radon; therefore, the 100% equilibrium assumption represents a very conservative conversion).

Table 2. Summary of radiation guidelines applicable to the W. R. Grace site^a

| Mode of exposure | Exposure conditions | Guideline value |
|--|--|--|
| External gamma radiation | Indoor gamma radiation (above background) | 20 $\mu\text{R}/\text{h}$ |
| Surface contamination ^b | Th-NAT contamination fixed on surfaces | 1000 dpm/100 cm^2 (average) 3000 dpm/100 cm^2 (maximum) |
| | Removable Th-NAT | 200 dpm/100 cm^2 |
| Beta-gamma dose rate | Average dose rate in an area no greater than 1 m^2 | 0.20 mrad/h |
| | Maximum dose rate in any 100- cm^2 area | 1.0 mrad/h |
| Radionuclides in air ^c | Th-NAT in air (uncontrolled area) | 1×10^{-12} $\mu\text{Ci}/\text{mL}$ |
| ²²⁰ Rn, ²²² Rn daughters | Average annual radon daughter concentration (including background) | 0.02 WL |

^aU.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites (April 1987).

^bApplicable to building and equipment surfaces only.

^cU.S. Department of Energy 5480.1A, "Subject: Environmental Protection, Safety, and Health Protection Program for DOE Operations," XI-1 (August 31, 1981).

Gamma measurements made during the general scan of the building are shown for each floor in Figs. 3, 5, 7, 9, 11, and 13. The absence of data for a particular type of measurement in a survey block on any figure should be interpreted as meaning that this particular measurement was at the background level or below.

Areas that were completely inaccessible are labeled as such. Regions showing elevated gamma radiation levels are numbered (bold type) and the approximate areas are indicated by shading in Figs. 4, 6, 8, 12, and 14. Nomenclature used to describe equipment and/or structures remaining in the building is based on the drawings provided by the W. R. Grace Company.

**Table 3. Alpha, beta-gamma, and gamma measurements
in selected locations of Building 23**

| Location No. ^a | Directly measured contamination (single points) | | Transferable contamination (dpm/100 cm ²) | | Gamma exposure rate at the surface (μ R/h) | Gamma exposure rate at 1 m (μ R/h) |
|------------------------------|--|---|---|--------------------------------------|---|--|
| | Alpha (dpm/100 cm ²) | Beta-gamma dose rate at 1 cm (mrad/h) | Alpha | Beta | | |
| <i>First level</i> | | | | | | |
| 25 | 16 | 0.006 | <i>b</i> | <i>b</i> | 4.9 | <i>c</i> |
| 26 | 7 | 0.032 | <i>b</i> | <i>b</i> | 32 | 9.4 |
| 27 ^d | 56 | 0.043 | <i>b</i> | 29 | 74 | 19 |
| 28 ^d | 120 | 0.045 | <7 | 86 | 54 | <i>c</i> |
| <i>Second level</i> | | | | | | |
| 29 ^d | 840 | 0.060 | <i>c</i> | <i>c</i> | 81 | 27 |
| 32 | 140 | 0.058 | 3 | 57 | 120 | <i>c</i> |
| <i>Third level</i> | | | | | | |
| 30 | 42 | 0.024 | 7 | <i>b</i> | 26 | 11 |
| 31 ^d | 690 | 0.062 | <i>c</i> | <i>c</i> | 49 | 38 |
| <i>Fourth level</i> | | | | | | |
| 1 ^d | 200,000 ^e | 15 ^e | 170 ^e 320 ^f | 340 ^e 560 ^f | <i>c</i> | <i>c</i> |
| 2 ^d | 55 | 0.019 | <i>b</i> | <i>b</i> | 68 | <i>c</i> |
| 3 ^d | 86 | 0.034 | <i>b</i> | <i>b</i> | 68 | <i>c</i> |
| 4 ^d | 290 | 0.076 | <i>b</i> | 57 | 270 | 270 |
| 5 ^d | 63 | 0.086 | <i>b</i> | 14 | <i>c</i> | <i>c</i> |
| 6 ^d | 550 | 1.6 | <i>b</i> | 43 | <i>c</i> | <i>c</i> |
| 7 ^d | 55 | 0.036 | <i>b</i> | 100 | <i>c</i> | <i>c</i> |
| 8 ^d | 120 | 0.037 | 10 | 14 | 270 | 160 |
| 17 ^d | 7,800 | 0.11 | <i>b</i> | <i>b</i> | <i>c</i> | <i>c</i> |
| 18 | 39 | 0.014 | <i>b</i> | <i>b</i> | <i>c</i> | <i>c</i> |
| 19 | 55 | 0.01 | <i>b</i> | <i>b</i> | <i>c</i> | <i>c</i> |
| 20 ^d | 180 | 0.022 | <i>b</i> | 43 | 81 | <i>c</i> |
| <i>Fifth level</i> | | | | | | |
| 9 ^d | 20,000 | 1.9 | 7 | 43 | <i>c</i> | <i>c</i> |
| 11 ^d | 6,200 | 0.48 | 3 | <i>b</i> | 270 | <i>c</i> |
| 12 ^d | 20,000 | 4.7 | <i>b</i> | <i>b</i> | 540 | <i>c</i> |
| 13 ^d | 39,000 | 1.8 | 7 | 110 | 270 | <i>c</i> |
| 14 ^d | 20,000 | 1.3 | <i>b</i> | 86 | <i>c</i> | <i>c</i> |
| 16 (roof) | 70 | 0.03 | <i>b</i> | 43 | 40 | <i>c</i> |
| 21 ^d | 150 | 0.05 | 10 | 86 | 59 | <i>c</i> |
| 23 | 30 | 0.019 | <i>b</i> | 29 | <i>c</i> | <i>c</i> |
| 24 | 200 | 0.02 | 7 | <i>b</i> | <i>c</i> | <i>c</i> |

^aSee Figs. 4, 6, 8, 10, 12, and 14.

^bMeasurement could not be distinguished from background.

^cNo measurement taken.

^dIncluded in areas for which occupancy time was requested.

^eAt flange outside duct.

^fInside duct.

Table 4. Concentrations of ^{220}Rn and ^{222}Rn daughters in air inside Building 23

| Date | Floor | Location | ^{220}Rn (pCi/L) | ^{222}Rn daughters (WL) |
|---------|------------|-----------------------|------------------------------|-------------------------------------|
| Oct. 6 | 2 | Laboratory | 0.05 ± 0.01 | <0.001 |
| | 3 | Lunchroom | 0.4 ± 0.06 | <0.001 |
| | 5 | Storage, center | 0.02 ± 0.006 | <0.001 |
| | 5 | Storage, duct | 1.3 ± 0.2 | <0.001 |
| | 5 | Storage, duct | 5.0 ± 0.7 | <0.001 |
| Oct. 7 | 1 | South end | 0.03 ± 0.01 | <0.001 |
| | 1 | North end | 0.01 ± 0.006 | <0.001 |
| | 2 | South end | 0.03 ± 0.01 | <0.001 |
| | 2 | North end | 0.04 ± 0.02 | <0.001 |
| | 3 | Elevator | 0.06 ± 0.02 | <0.001 |
| | 3 | Lunchroom | 1.8 ± 0.3 | <0.001 |
| | 3 | North end | 0.22 ± 0.04 | <0.001 |
| | 4 | Elevator | 0.06 ± 0.02 | <0.001 |
| | 4 | North end | 0.2 ± 0.05 | <0.001 |
| 5 | Above duct | $12. \pm 1.7$ | <0.001 | |
| Oct. 8 | 5 | Near duct | 0.13 ± 0.02 | <0.001 |
| Dec. 8 | 3 | Lunchroom, center | 1.6 | <0.001 |
| | 5 | Duct (removed) | 0.02 | <0.001 |
| Dec. 13 | 3 | Lunchroom, center | 0.43 | <0.001 |
| | 4 | East end, waste drums | 0.04 | <0.001 |

Table 5. High-volume air samples inside Building 23^a

| Sample No. ^b | Floor | Location No. | Gross alpha (% mpc) ^c |
|-------------------------|-------|--------------|----------------------------------|
| 7 | 4 | 7 | 5 |
| 11 | 4 | 7 | 11 |
| 9 | 5 | 12 | 10 |
| 13 | 5 | 12 | 10 |

^aHigh-volume: 0.57 or 1.33 m³/min.

^bLocations shown by sample number on Figs. 10, 12, and 14.

^cmpc: maximum permissible concentration. (Th-natural, 1×10^{-12} $\mu\text{Ci/mL}$).

Table 6. Results of solid (dust) sample analyses inside Building 23

| Location No. ^a | Floor | Radionuclide concentration (pCi/g) | | |
|-----------------------------------|-------|------------------------------------|--------------------------------|-------------------------------|
| | | ²²⁶ Ra ^b | ²³² Th ^b | ²³⁸ U ^c |
| Control sample^d | | | | |
| 25 | 1 | 0.42 ± 0.1 | 0.50 ± 0.2 | 0.39 |
| Biased samples^e | | | | |
| 28 | 1 | 1 ± 0.2 | 5.4 ± 0.9 | 2.0 |
| 17 | 4 | <0.34 | 26 ± 4. | 0.70 |
| 18 | 4 | 0.49 ± 0.3 | 1.8 ± 0.4 | 0.64 |
| 19 | 4 | 0.50 ± 0.2 | 2.4 ± 0.6 | 0.93 |
| 20 | 4 | 0.50 ± 0.2 | 9.5 ± 1. | 1.3 |
| 21 | 5 | 1.0 ± 0.1 | 7.3 ± 0.8 | 1.8 |
| 23 | 5 | 0.43 ± 0.07 | 1.2 ± 0.3 | 0.41 |
| 24 | 5 | 1.5 ± 0.2 | 11 ± 1.0 | 1.6 |

^aDust samples are shown by the location number on Figs. 4, 10, 12, and 14.

^bIndicated counting error is at the 95% confidence level ($\pm 2\sigma$).

^cTotal analytical error of measurement results is less than $\pm 5\%$ (95% confidence level).

^dControl sample taken in building's newer area which was not involved in the thorium process.

^eBiased samples are taken from areas shown to have elevated gamma exposure rates.

Maximum observed measurements of direct and transferable alpha and beta-gamma contamination on surfaces are shown as numbered locations on figures of each floor, with areas of elevated gamma activity marked by hatching (Figs. 4, 6, 8, 10, 12, and 14), and the results are listed in Table 3. Additionally, radon daughter, air, and solid material (dust) sample locations are shown by sample and/or location numbers on the appropriate figures and in Tables 4–8.

Annual exposures were calculated for personnel working in areas having significantly elevated gamma exposure rates. These estimates were based on radiation levels measured (at 1 m from the floor) in each area and occupancy factors provided by the W. R. Grace Company (Tables 7 and 8).

**Table 7. Average gamma dose rates
in work areas in Building 23^a**

| Area | Fig. No. | Elevation (ft) | Exposure rate (μ R/h) |
|------------------|----------|----------------|----------------------------|
| <i>1st Floor</i> | | | |
| 1 | 4 | 100.50 | 50 |
| 2 | 4 | 100.50 | 50 |
| <i>2nd Floor</i> | | | |
| 3 | 6 | 114.50 | 25 |
| 4 | 6 | 114.50 | 25 |
| <i>3rd Floor</i> | | | |
| 5 | 8 | 124.00 | 50 |
| | | | 30 |
| 6 | 8 | 124.00 | 20 |
| 7 | 8 | 127.67 | 15 |
| <i>4th Floor</i> | | | |
| 8 | 10 | 138.00 | 20 |
| 9, 10, 12 | 10 | 138.00 | 25 (avg.) |
| 11 | 10 | 140.00 | 20 |
| 13 A, B, C, D | 12 | 140.00 | 95 (avg.) |
| <i>5th Floor</i> | | | |
| 14, 15, 16 | 14 | 151.00 | 120 (avg.) |

^aRegions of elevated gamma levels are shown as shaded and numbered areas on Figs. 4, 6, 8, 10, 12, and 14.

First Level

The ground floor of the building contains large, open areas and walled-in areas housing equipment for the rubber-reserve catalyst plant, as well as a dumping station, ball mill, and the P&S dryer. Two restrooms are located on the west end of the building. Groups of large tanks resting on concrete supports are located in several areas. An outside electrical shop and substation were also on this floor, but inaccessible to the survey. Barrels and equipment stored on large areas of the floor restricted the survey in some places.

Table 8. Occupancy factors—Building 23
(h/year)^a

| Area marked by cross hatching | Laborer | Operators | | | | Process controller |
|----------------------------------|---------|-----------|-----|-----|-----|-----------------------|
| | | A | B | C | D | |
| 1. Crystalizers | — | 250 | — | — | 125 | — |
| 2. Filtering | — | — | 375 | — | — | — |
| 3. Samples | — | — | — | — | — | 250 |
| 4. Laboratory | — | — | — | — | — | 750 |
| 5. Storage | 125 | — | — | 125 | — | — |
| Remainder of Area 5 | 375 | — | — | 125 | — | — |
| 6. Mixing tanks | — | — | — | — | 250 | — |
| 7. Mixing tanks | — | 125 | — | 125 | — | — |
| 8. Calciner | 375 | 125 | — | 125 | — | — |
| 9. Walk-through ^b | 20 | 20 | 20 | 20 | 20 | 20 |
| 10. Walk-through | 20 | 20 | 20 | 20 | 20 | 20 |
| 11. 205 Calciner feed | 125 | — | 125 | — | 125 | — |
| 12. Walk-through | 20 | 20 | 20 | 20 | 20 | 20 |
| 13. A, B, C, and D ^b | 60 | 60 | 60 | 60 | 60 | 60 |
| 14–16. Storage | 50 | 50 | 50 | 50 | 50 | 50 |

^aThe occupancy times have been calculated on an annual total and are based on time estimates supplied by W. R. Grace.

^bThese time estimates were not supplied by W. R. Grace and are based on estimates only.

Large parts of the building are occupied only for short periods of time, except for an area that contains a shaker in the northwest corner of this floor and has a 50% occupancy rate. Although the passageways are used throughout the day by two shifts, the other areas on this floor are occupied only about 10% of the time. Figure 3 shows the layout of the entire first level and the gamma exposure rates measured during the general scan of this floor.

Although most areas generally measured background, the exposure rates at the surface ranged to 81 $\mu\text{R}/\text{h}$ in spots along the floor, occasionally scanned to 140 $\mu\text{R}/\text{h}$ in cracks and along the base of the wall supports, and ranged to 160 $\mu\text{R}/\text{h}$ on concrete tank supports. Gamma levels at 1 m above the surface ranged from 11 to 54 $\mu\text{R}/\text{h}$ (see Fig. 3).

Most of the areas around the shaker measured at or near background levels; however, there were several spots which ranged from 27 to 54 $\mu\text{R}/\text{h}$. A slightly larger area against the far east wall also measured 54 $\mu\text{R}/\text{h}$.

Outside on the asphalt near the roll-up door at the southwest corner of the building, gamma exposure rates ranged up to 110 $\mu\text{R}/\text{h}$ on contact with the blacktop.

Direct and transferable alpha and beta-gamma measurements were taken at selected locations, generally where higher gamma levels were found. These areas, designated by numbers 25 through 28, are shown in Fig. 4 and listed by location number in Table 3.

The new area on the north end of the building was scanned and sampled for a control measurement (No. 25). The gamma exposure rate at this point was $5 \mu\text{R}/\text{h}$, with a corresponding direct alpha contamination level of $16 \text{ dpm}/100 \text{ cm}^2$ (Table 3). The beta-gamma dose rate was $<0.01 \text{ mrad}/\text{h}$ at 1 cm, and transferable alpha and beta levels were negligible.

Gamma levels ranging from 32 to $74 \mu\text{R}/\text{h}$ on the floor surface and decreasing to a range of 9 to $19 \mu\text{R}/\text{h}$ at 1 m were measured at the other numbered locations on this level (see Table 3). Beta-gamma dose rates of $\sim 0.04 \text{ mrad}/\text{h}$ were found in association with direct alpha activities ranging from 7 to $120 \text{ dpm}/100 \text{ cm}^2$.

The maximum observed direct alpha measurement of $120 \text{ dpm}/100 \text{ cm}^2$ was found on the floor next to concrete supports under the tanks (No. 28), where the gamma exposure rate averaged $54 \mu\text{R}/\text{h}$ and the beta-gamma dose rate was $0.04 \text{ mrad}/\text{h}$. Transferable alpha contamination was $<7 \text{ dpm}/100 \text{ cm}^2$ at this point, and transferable beta contamination levels did not exceed $86 \text{ dpm}/100 \text{ cm}^2$.

In the center of the floor near a large tank where the gamma exposure rate was $74 \mu\text{R}/\text{h}$ at the surface and $19 \mu\text{R}/\text{h}$ at 1 m (No. 27), the corresponding direct alpha and beta-gamma measurements were $56 \text{ dpm}/100 \text{ cm}^2$ and $0.04 \text{ mrad}/\text{h}$, respectively. A smear sample taken here showed a transferable beta activity of $29 \text{ dpm}/100 \text{ cm}^2$.

Second Level

The second floor of the building contains large, open areas housing the rubber-reserve catalyst plant, hoppers, crystallizers, thickener tanks, and a dryer area, in addition to a laboratory and storage room adjacent to the elevator. Two monazite silos that had been located on the west end of this floor have been removed.

In general, the second floor is used only about 5% of the time, except for the laboratory (south end of the floor), which is used fairly often and has about a 40% occupancy rate. The layout of the entire second level with gamma exposure rates measured during the general scan of the second floor is shown in Fig. 5.

The preliminary scan of this floor showed that gamma exposure rates at the surface generally ranged from 5 to $11 \mu\text{R}/\text{h}$. The scan included the new area of the building on the north end and a dryer tank area in the northeast corner, which were not part of the monazite process. Gamma levels increased slightly to $16 \mu\text{R}/\text{h}$ to the south and west at the base of a crystallizer tank and in a passageway between tanks and to $81 \mu\text{R}/\text{h}$ in the laboratory and storage area at the south end of the floor. At 1 m the maximum gamma measured was $27 \mu\text{R}/\text{h}$ in the latter area.

A maximum gamma rate of $110 \mu\text{R}/\text{h}$ was measured on contact with the brick on the outside of a tank located adjacent to and south of the passageway. The inside of the tank showed gamma exposure rates to $120 \mu\text{R}/\text{h}$.

Locations of direct and transferable alpha and beta-gamma measurements taken at the maximum gamma points on this floor are shown in Fig. 6 and are designated by numbers 29 and 32. Results are listed by location in Table 3.

The maximum gamma exposure rate of 120 $\mu\text{R}/\text{h}$, measured inside the brick-lined tank (No. 32), had a corresponding direct alpha contamination level of 140 dpm/100 cm^2 . Transferable alpha and beta levels at this point were 3 and 57 dpm/100 cm^2 , respectively.

In the laboratory at the south end, a direct alpha contamination level of 840 dpm/100 cm^2 was measured on the tile floor near an oven (No. 29). Beta-gamma dose rates were 0.06 mrad/h in both locations.

Third Level

The third floor of the building consists of a bag house, storage room, lunchroom, and large, open areas containing equipment. Equipment on this floor includes tanks, filters, hopper discharge, and a rotary dryer. Gamma exposure rates measured during the general scan of the third floor are shown on Fig. 7.

The preliminary scan showed general gamma exposure rates of 5 to 16 $\mu\text{R}/\text{h}$ throughout most of the floor; however, higher gamma levels were found in several small areas. Gamma rates in the storage area, located in the northeast corner of the building, were elevated to 54 $\mu\text{R}/\text{h}$, both at the surface and at 1 m.

At the south end of this floor, gamma measurements ranged to 110 $\mu\text{R}/\text{h}$ at the surface near the rotary filter and decreased to 20 $\mu\text{R}/\text{h}$ at 1 m. A maximum gamma rate of 220 $\mu\text{R}/\text{h}$ was measured in a small spot on the east wall near the rotary filter. And, although gamma exposure rates were generally at background in the vicinity of the lunchroom west of the elevator, two small spots of 40 and 94 $\mu\text{R}/\text{h}$ were located near the outside lunchroom walls.

Direct and transferable alpha and beta-gamma measurements were taken at selected locations (Nos. 30 and 31, Fig. 8). Results are listed by location in Table 3.

The gamma exposure rates of 49 $\mu\text{R}/\text{h}$ at the surface and 38 $\mu\text{R}/\text{h}$ at 1 m, measured between the storage room and the hopper discharge at the northeast end of the floor (No. 31), had a corresponding direct alpha contamination level of 690 dpm/100 cm^2 and a beta-gamma dose rate of 0.06 mrad/h at 1 cm. The storage area had an average gamma exposure of 54 $\mu\text{R}/\text{h}$ at 1 m. (Fig. 7). In the lunchroom on the south end, gamma exposure rates near the refrigerator (No. 30) were 26 $\mu\text{R}/\text{h}$ at the surface and decreased to 11 $\mu\text{R}/\text{h}$ at 1 m. Corresponding direct alpha contamination levels and beta-gamma dose rates were 42 dpm/100 cm^2 and 0.02 mrad/h, respectively. The transferable alpha contamination level at this point was 7 dpm/100 cm^2 . Transferable beta contamination was negligible.

Fourth Level

The fourth floor consists of two partial levels containing large, open areas housing equipment such as filters, classifier systems, dust collectors, and a drum dryer for thorium.

Two large tanks have been removed from the west end of the floor. A diagram of the fourth level showing the layout of the entire floor is presented in Figs. 9 and 10. Expanded views of the drum dryer area (used in the thorium process) located in the northeast end of the building are shown in Figs. 11 and 12.

Gamma exposure rates, measured during the general scan of the fourth floor, ranged from a background of 4 to 7 $\mu\text{R}/\text{h}$ around the classifier system and dust collectors along the west wall to levels of 16 to 54 $\mu\text{R}/\text{h}$ in other areas and increased to 68 $\mu\text{R}/\text{h}$ along the edge of the drum dryer area (Fig. 9). Elevated gamma levels were found in several scattered and localized areas: "spots" of 110 and 160 $\mu\text{R}/\text{h}$ were measured approximately in the center of the floor, and a maximum gamma rate of 340 $\mu\text{R}/\text{h}$ was measured along the east wall behind the precoat filters. At 1 m above the surface, gamma ranges were from 16 to 27 $\mu\text{R}/\text{h}$ throughout most of the floor.

Numerous elevated gamma levels were measured during the general scan of the drum dryer area, where thorium processing activities would be expected to result in residual contamination. This area, in the northeast corner of the fourth floor, is depicted in an enlarged view in Fig. 11.

Increasing from southwest to northeast, gamma exposure rates in this region generally ranged from 40 to 680 $\mu\text{R}/\text{h}$ at the surface and from 40 to 490 $\mu\text{R}/\text{h}$ at 1 m. Two elevated measurements of 400 and 680 $\mu\text{R}/\text{h}$ were measured along the floor under the ceiling duct area. At head height, the gamma level increased to 730 $\mu\text{R}/\text{h}$, indicating a contribution from an overhead duct.** The duct scanned to 2200 $\mu\text{R}/\text{h}$.

Direct and transferable alpha and beta-gamma measurements were taken at a support beam near the steps leading up to the fifth floor (Location No. 20, Fig. 10). The alpha contamination level at this point was 180 dpm/100 cm^2 with a corresponding beta-gamma dose rate of 0.02 mrad/h. Transferable beta contamination here was 43 dpm/100 cm^2 , and the corresponding gamma exposure rate was 81 $\mu\text{R}/\text{h}$ at the surface.

Direct and transferable alpha and beta-gamma measurements taken at other selected points in this area and designated by Location Nos. 1 to 8 and 17 to 19 in Fig. 12 are listed by location in Table 3.

The maximum level of direct alpha contamination of 200,000 dpm/100 cm^2 was found in the drum dryer area on the flange of the duct in the ceiling. At the same location, the beta-gamma dose rate was 15 mrad/h. Smears were taken from the flange and inside the duct. The transferable alpha contamination levels on the flange and inside the duct were 170 and 320 dpm/100 cm^2 , respectively. Transferable beta contamination levels were 340 and 560 dpm/100 cm^2 , respectively.

**This duct had apparently been used to vent thorium processing equipment on the fourth floor. The duct passed through the ceiling of the fourth floor to the fifth level. There the vent ended approximately three feet above the floor and was open. It appeared that a section of duct had been removed, and another process line had been tied into the former thorium vent, which continued through the roof and was currently in use. The duct was later removed; however, no dose rate measurements were made after removal. Dose rates are calculated assuming a 75% reduction in exposure rates and 4% (80 h/year) occupancy.

A direct alpha contamination level of 7800 dpm/100 cm² was measured on a ceiling beam west of the duct area (No. 17, Fig. 12) and had a beta-gamma dose rate of 0.11 mrad/h.

A maximum beta-gamma dose rate of 1.6 mrad/h was observed at the north end of the duct area (No. 6), with a corresponding direct alpha measurement of 550 dpm/100 cm². Transferable beta was 43 dpm/100 cm² at this point.

At other designated sample points, beta-gamma dose rates, ranging from 0.01 to 0.09 mrad/h, were all less than guideline values. The associated direct alpha contamination levels ranged from 39 to 290 dpm/100 cm², while gamma radiation levels at these points ranged from 68 to 270 μ R/h (Table 3). Except as noted above, all transferable alpha and beta contamination levels were <100 dpm/100 cm².

Fifth Level

The fifth floor is mostly open space containing large filters, tanks, a rake classifier, product sample storage, and a dryer area. Figure 13 shows the layout of the entire fifth level. Also exhibited on this figure are the gamma radiation measurements made at the surface and 1 m above the floor during the preliminary scan of the building.

Preliminary scan results indicated that the highest gamma exposure rates on this level were concentrated in the northern end of the building; however, some elevated gamma measurements were found scattered throughout the entire fifth level.

The maximum surface gamma rate of 570 μ R/h was measured in the vicinity of the dryer area, located in the northeast end directly above the contaminated drum dryer area on the level below. In this same location gamma levels ranged from ~220 to 270 μ R/h at 1 m (Fig. 13).

As indicated on Fig. 13, various areas on the rest of the fifth floor had elevated gamma levels ranging from 110 to 340 μ R/h at the surface and from 32 to 120 μ R/h at 1 m. A gamma exposure rate of 1600 μ R/h with an alpha contamination level of 30,000 dpm/100 cm² was measured directly above the abandoned duct outlet in the extreme northeast corner.

Direct and transferable alpha and beta-gamma measurements taken at elevated gamma points on this floor are designated by Location Nos. 9, 11-14, 16, 21, 23, and 24 in Fig. 14. Results are listed by location in Table 3.

The maximum level of direct alpha contamination, 39,000 dpm/100 cm², was measured on the floor west of the dryer area and had an associated beta-gamma dose rate of 1.8 mrad/h (Location No. 13, Fig. 14). Transferable alpha and beta contamination levels were 7 and 110 dpm/100 cm², respectively, at this point.

On the floor outside the dryer area, associated with an elevated gamma rate of 570 μ R/h (Location No. 12, Fig. 14), the beta-gamma dose rate reached 4.7 mrad/h at 1 cm. The direct alpha activity measured here was 20,000 dpm/100 cm².

Direct alpha activities, found in other areas showing elevated gamma readings throughout this level, ranged from 6200 to 20,000 dpm/100 cm². Corresponding beta-gamma dose rates ranged from 0.48 to 1.9 mrad/h, and transferable alpha and beta activity ranged from <1 to 7 dpm/100 cm² and from <1 to 86 dpm/100 cm², respectively, at these points (Location Nos. 9 and 11 to 14).

Alpha levels measured on three ceiling beams (Location Nos. 21 to 24, Fig. 14) ranged from 30 to 200 dpm/100 cm². The maximum reading was found on a beam on the extreme southern end (Location No. 24), while the lowest reading was found on the beam in the center of the floor (Location No. 23). The transferable alpha contamination level at Location No. 24 was 7 dpm/100 cm². A smear taken from the beam in the dryer area on the north end (Location No. 21) yielded maximum readings of 10 dpm/100 cm² transferable alpha and 86 dpm/100 cm² transferable beta activities.

A survey of the roof concentrated around the duct on the northeast end. The roof vent above a contaminated spot read to 40 μ R/h of gamma activity at the surface (Location No. 16, Fig. 14) and had direct alpha and beta-gamma activities of 70 dpm/100 cm² and 0.03 mrad/h, respectively.

Representative sampling for transferable alpha and beta-gamma activities from the rest of the floor, roof, and ceiling beams disclosed readings ranging from <1 to 7 dpm/100 cm² for alpha contamination levels and from <1 to 43 dpm/100 cm² for beta activities (Table 3).

Results of Radon Daughter Measurements Made Inside the Building

Radon daughter concentration measurements were taken in Building 23 at various locations on all levels and on three different dates during October and December. Radon and radon daughter measurements made over a brief period of time often do not reflect average annual conditions. Furthermore, radon and radon daughter concentrations in a building are affected drastically by changes in its ventilation rate and by the wide variety of mechanical and human activities within the building.

Particulate ²²²Rn and ²²⁰Rn daughters attached to airborne dust are collected on a membrane filter and analyzed by alpha spectrometry techniques.² Measurement locations are shown on Figs. 4, 6, 8, 10, and 14, and results are provided in Table 4.

Two radon daughter measurements were taken at different locations on the first level, one sample at each end of the building (Fig. 4). Concentrations of ²²⁰Rn were 0.01 pCi/L at the north end and 0.03 pCi/L at the south end of the ground floor. Concentrations of ²²²Rn daughters were <0.001 WL at each location.

On the second level, radon daughter measurements were taken in three locations and on two different occasions. Two measurements were made at the south end of the floor, one inside and one outside the laboratory; one measurement was made at the north end (Fig. 6). Ranges of ²²⁰Rn concentrations were from 0.03 to 0.05 pCi/L, while working levels for ²²²Rn daughters were <0.001.

On the third level, several radon daughter measurements were taken in October and December (Fig. 8). In October ^{220}Rn measurements in the lunchroom ranged from 0.4 to 1.8 pCi/L, and ^{222}Rn daughter levels were <0.001 WL (Table 4). In December concentrations on two different days in the lunchroom were 0.43 and 1.6 pCi/L for ^{220}Rn and <0.001 WL for ^{222}Rn daughters. Other measurements taken at the elevator and at the north end of the building in October ranged from 0.06 to 0.22 pCi/L for ^{220}Rn and <0.001 WL for ^{222}Rn daughters.

Radon samples were taken in October and again in December on the north end of the fourth level where elevated gamma rates were measured (Figs. 10 and 12). Concentrations of ^{220}Rn decreased from 0.2 pCi/L at the first sampling date to 0.04 pCi/L at the second. Samples taken at the elevator on the south end of this floor showed negligible ^{220}Rn concentrations. Concentrations of ^{222}Rn were <0.001 WL in all cases.

Six radon daughter concentration measurements were taken in the sample storage room in the northeast quadrant of the fifth level (Fig. 14). Concentrations of ^{220}Rn were 0.02 pCi/L in the center of the storage room and ranged from 1.3 to 5.0 pCi/L over the duct in the floor (before its removal). All ^{222}Rn daughter concentrations were <0.001 WL. In October, and again in December after the duct was removed, measurements were taken over the duct area at the northeast end of the fifth level. Radon-220 concentrations were 12 pCi/L on October 7 and 0.13 pCi/L near the duct on October 8, but decreased to 0.02 pCi/L in December after removal of the duct. The concentration of ^{222}Rn daughters here was <0.001 WL at this time.

Airborne Contamination

At one time, the entire building was used in the thorium process, and it was assumed that all floors may have been contaminated. In order to determine if residual contamination was being resuspended to present an air contamination problem, air sampling was done throughout the building. Results of these measurements are provided in Tables 5 and 6 and shown by the sample and location numbers on Figs. 4, 10, 12, and 14.

Two high-volume air samples were taken on the fourth floor in the drum dryer area on the northeast end of the building (samples 7 and 11, Fig. 12). Analysis of filters used to collect the airborne nuclides was performed, and the results are presented in Table 5.

Gross alpha concentrations were measured in two high-volume air samples taken in the dryer area near the stairs at the northeast end of the fifth floor (samples 9 and 13, Fig. 14).

The highest concentration of airborne radioactivity measured was 11% of the maximum permissible concentration (mpc_a), assuming all activity was due to ^{232}Th .

Miscellaneous Solid Samples

Layers of a powderlike dust were so thick on some areas of the floor and overhead surfaces that no direct alpha measurements could be made. Random samples were taken of the "dust" from interior surfaces such as steel "I" beams, ducts, and floors. The samples were analyzed for ^{238}U , ^{226}Ra , and ^{232}Th . Results of analyses of this material removed

from interior surfaces in Building 23 are shown in Table 6. Locations of the samples are shown on Figs. 4, 12, and 14.

Two samples of dust taken at Location Nos. 25 and 28 (Fig. 4) on the ground floor were analyzed for ^{226}Ra , ^{232}Th , and ^{238}U , and results are listed in Table 6. The sample from Location No. 25 was taken in the building's newer area, which was not involved in the Thorium process and was used as a control sample for background radionuclide measurements at the site (Table 1). Concentrations of ^{226}Ra , ^{232}Th , and ^{238}U for this control sample were 0.42, 0.5, and 0.4 pCi/g, respectively. The sample taken on the floor near some large tanks south of the dryer area (Location No. 28) showed concentrations of 1.0, 5.4, and 2.0 pCi/g for ^{226}Ra , ^{232}Th , ^{238}U , respectively.

Four samples of this solid material were taken from beams in and around the drum dryer area at the northeast end of the fourth level (Location Nos. 17 to 20, Figs. 10 and 12). Concentrations of ^{226}Ra in the samples ranged from 0.34 to 0.5 pCi/g and averaged 0.45 pCi/g. Concentrations of ^{232}Th ranged from 1.8 to 26 pCi/g and averaged 9.9 pCi/g. The range for ^{238}U was 0.64 to 1.3 pCi/g, with an average of 0.89 pCi/g. The maximum concentration of 26 pCi/g for ^{232}Th (Location No. 17, Fig. 12) was found on a ceiling beam in the center of the drum dryer area in the northeast end of the building. A beam (Location No. 20) in the dryer area under the steps leading to the fifth level had a ^{232}Th concentration of 9.5 pCi/g (Fig. 10).

Samples were taken from three beams in various locations on the fifth level. Results are listed in Table 6 as Location Nos. 21, 23, and 24 and are shown on Fig. 14. The results of the radionuclide analyses showed concentrations of ^{226}Ra that ranged from 0.43 to 1.5 pCi/g and averaged 1.0 pCi/g on the three beams. Concentrations of ^{232}Th ranged from 1.2 to 11 pCi/g and averaged 6.5 pCi/g. Concentrations of ^{238}U ranged from 0.41 to 1.8 pCi/g with an average of 1.3 pCi/g. The maximum ^{232}Th concentration of 11 pCi/g was found on the beam near the elevator on the south wall of the fifth level (Location No. 24). A sample collected from a beam at the steps leading from the dryer area contained 7.3 pCi/g ^{232}Th (Location No. 21).

SUMMARY

During the period 1956 to 1957, the Curtis Bay site of the W. R. Grace Company in Baltimore was used for development research and extraction of thorium from monazite ore. A radiological survey was conducted on the site during October and December 1986 by the ORNL Environmental Assessments Group. The survey was conducted on all levels of Building 23, where radioactive materials may have been handled in connection with the thorium project, with special attention being given to the areas and equipment used in that project. Because significant quantities of thorium were found on some building surfaces such as floors and ceiling beams (located primarily on the northeast end of the fourth and fifth floors associated with the ducts leading out of the drum dryer area), it must be assumed that thorium is the most prominent radionuclide when applying DOE guidelines. The maximum ^{232}Th concentration of 26 pCi/g was measured in the dust from a beam on

the northeast end of the fourth floor. The maximum ^{238}U concentration of 1.8 pCi/g was measured in a sample collected from a beam directly above on the fifth floor.

A large fraction of the regions surveyed inside the building indicated only background or near-background radiation levels. Elevated gamma rates were limited to very small areas.

In the following, a brief summary concerning radiation and contamination levels is given for each level of the building interior.

On the ground floor, gamma exposure rates at the surface and at 1 m were generally background except for small, slightly elevated areas on the floor, in cracks, and along the base of wall and tank supports. The maximum gamma exposure rate of 160 $\mu\text{R}/\text{h}$ was measured on contact with the concrete supports under the large tanks in the center of the floor. Radionuclide analysis of the solid (dust) samples taken from the floor under these tanks showed a concentration of 5.4 pCi/g of ^{232}Th . All directly measured and transferable alpha and beta-gamma contamination levels were below guidelines. Air and radon concentrations were likewise below criteria.

Gamma exposure rates on the second level were for the most part within background levels. A maximum of 81 $\mu\text{R}/\text{h}$ found in the laboratory was limited to a very small area on the tile floor near an oven. Elevated gamma levels were also measured on contact with the brick lining of a large tank. Direct and transferable alpha and beta-gamma concentrations were well below guidelines. All radon daughter measurements in the laboratory and at either end of the floor were also below criteria.

Although the majority of the gamma exposure rates found on the third floor were within background range, several small areas with elevated gamma levels were found in isolated spots scattered throughout the floor. Gamma exposure rates in the storage room in the northeast corner of the floor was to 54 $\mu\text{R}/\text{h}$ both at the surface and at 1 m. Radon measurements taken here on the north end indicate ^{220}Rn concentrations of 0.22 pCi/L and ^{222}Rn daughter working levels of <0.001 . The maximum direct alpha contamination level found on this floor was 690 dpm/100 cm^2 , well below the DOE guidelines. Direct and transferable alpha and beta-gamma contamination levels taken at both ends of the building were all below criteria, as were radon daughter and alpha and beta concentrations in air.

Although most elevated gamma measurements on the fourth floor were limited to small areas or spots at the base of wall supports or filter equipment, the entire northeast quadrant showed elevated gamma levels due to the residual contamination from the thorium-processing operation. The maximum gamma rates were measured around the ceiling duct in the extreme northeast corner of the drum dryer area. A gamma rate of 700 $\mu\text{R}/\text{h}$ was measured at the floor's surface and reached to 730 $\mu\text{R}/\text{h}$ at 2 m, with a maximum of 2200 $\mu\text{R}/\text{h}$ inside the open duct at the ceiling. Direct and transferable alpha and beta-gamma measurements exceeded DOE guidelines inside the open duct leading up through the ceiling. However, this duct has now been removed, and dose rate calculations are based on a 75% dose rate reduction in this area. (Radon and air activity measured in this area are all below guidelines.) A beam in the center of the drum dryer area exceeded

DOE guidelines for surface contamination with a maximum direct alpha activity of 7800 dpm/100 cm². A ²³²Th concentration of 26 pCi/g was measured in the "dust" that was removed from the beam and analyzed for radionuclides. Another dust sample taken from a nearby beam under the steps leading to the fifth floor had a ²³²Th concentration of 9.5 pCi/g. The "dust" samples included the loose, flaky iron rust from the beam on which the dust had settled.

Elevated gamma radiation levels were observed during the preliminary scan in scattered, localized regions throughout the fifth floor. Surface contamination was most evident in the northeast quadrant, where gamma rates ranged from ~270 to 600 μR/h at the surface and from 100 to 200 μR/h at 1 m from the surface. In the floor, the open duct (now removed) leading to the drum dryer area on the fourth floor below measured 1600 μR/h on contact and 30,000 dpm/100 cm² gross alpha. Direct alpha and beta-gamma activities exceeding DOE guidelines ranged from 6200 to 39,000 dpm/100 cm² and from 1.3 to 4.7 mrad/h, respectively, in scattered, localized regions throughout the floor. The maximum direct alpha activity of 39,000 dpm/100 cm² was located near a filter on the north end of the building, west of the dryer area, and had a corresponding direct beta-gamma dose rate of 1.8 mrad/h. The maximum beta-gamma dose rate of 4.7 mrad/h was measured near the dryer area on the northeast end of the floor, where gamma exposure rates reached 540 μR/h. Samples of the dustlike solid material were collected from beams and analyzed for radionuclides. A maximum of 11 pCi/g ²³²Th was found on one beam, and two other beams (one at the north end and one at the south end near the elevator) had ²³²Th concentrations of 7 and 11 pCi/g, respectively. Radon concentrations in air exceeded the guidelines for ²²⁰Rn above the duct on the northeast end of the floor; however, after the duct was removed, subsequent sampling resulted in a ²²⁰Rn concentration of 0.02 pCi/L. Concentrations of ²²²Rn were below guidelines in every case. High-volume air samples taken in the center and south end of the floor disclosed gross alpha activities that averaged 10% of the mpc_a (Table 5).

Occupied and/or work areas having significant levels of gamma radiation were identified for each floor of the former thorium processing building and are shown with cross hatching and identification numbers in Figs. 4, 6, 8, 10, 12, and 14. The average gamma exposure rate for each area is given in Table 7, with corresponding occupancy factors (provided by W. R. Grace Company) listed in Table 8. Using these data, annual personnel exposures were calculated for workers who spend some part of their workday in or in close proximity to these areas. The resulting estimated exposures (six cases) ranged from 27 to 41 mrem/year.

SIGNIFICANCE OF FINDINGS

Although there were several areas having significant levels of radiation, most areas were small spots and in locations of low occupancy and hence would result in no significant exposure to workers. However, larger areas having significant levels of radiation could result in slight exposures to personnel working in these areas. Annual radiation exposure estimates of these workers ranged from 27 to 41 mrem/year or a maximum of 41% of the

basic dose limit of 100 mrem/year for members of the general public. Considering the spotty nature of much of the contamination on the lower floors, and the fact that the contaminated duct was removed, these dose estimates are likely to be conservative even though they were based on generally realistic occupancy data.

After removal of the contaminated duct on the fourth floor, all radon and radon daughter concentrations were well below the guideline values.

All high-volume air samples had values well below the recommended guidelines, the highest being 11% of the guideline.

Based on current work operations and use of the building, the probability of personnel exposures exceeding guidelines is minimal. However, should conditions or operations carried out in this building change, further evaluation or review may be necessary.

REFERENCES

1. *A Background Report for the Formerly Utilized Manhattan Engineer District, Atomic Energy Commission Sites Program*, DOE/EV-0097A (September 1980).
2. T. E. Myrick, B. A. Berven, W. D. Cottrell, W. A. Goldsmith, and F. F. Haywood, *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, Oak Ridge National Laboratory, ORNL/TM-8600, April 1987.

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