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Results of the Radiological Survey at the Former Chapman Valve Manufacturing Company, Indian Orchard, Massachusetts (CIO001)

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
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HEALTH AND SAFETY RESEARCH DIVISION

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Results of the Radiological Survey at the Former Chapman Valve Manufacturing Company, Indian Orchard, Massachusetts (CIO001)

R. D. Foley and M. S. Uziel

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ABSTRACT

At the request of the U.S. Department of Energy (DOE), a team from Oak Ridge National Laboratory conducted a radiological survey at Building 23 (Department No. 40) at the former Chapman Valve Manufacturing Company, Indian Orchard, Massachusetts. The survey was performed in August 1991. The purpose of the survey was to determine whether the property was contaminated with radioactive residues, principally ^{238}U, as a result of work done for the Atomic Energy Commission (AEC) during the 1940s. The survey included a gamma scan, a beta-gamma scan, and measurement of alpha activity; measurement of direct and removable alpha and beta-gamma levels; and the collection of soil, dust, debris, and smear samples for radionuclide analyses. Survey emphasis was on interior floors, walls, and overhead beams.

Radionuclide analysis of soil, dust, and debris, and analysis of smear samples indicate that residual ^{238}U attributable to former AEC-supported operations is present at this site. Elevated levels of radioactivity were particularly evident on the floors and walls in the western part of the central area of the building (grid blocks A1 through A6). Concentrations of ^{238}U in dust samples collected from overhead beams exceeded DOE guidelines in grid blocks A1 through A14 and remained elevated in grid blocks A15 through A19. Dust on a movable overhead crane in grid block A23 was well above the guideline, probably because the crane had at some time been located further west. Some contamination was evident in grid blocks B1 through B5, but clutter and debris in this area prevented a thorough survey.

Results of the Radiological Survey at the former Chapman Valve Manufacturing Company, Indian Orchard, Massachusetts (CIO001)*

INTRODUCTION

The Chapman Valve Manufacturing Company in Indian Orchard, Massachusetts, was one of many companies performing work associated with the development of nuclear energy for defense-related projects during the 1940s. This work, conducted under government contract to the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC), included the procurement, storage, and processing of uranium oxides, salts, and metals, and the subsequent machining of these products. As a result of these activities, equipment, buildings, and land at some of the sites became radiologically contaminated resulting in low levels of contamination on the properties. At contract termination, sites used by contractors were decontaminated in accordance with the standards and survey methods in use at that time. Since the original assessments, radiological criteria and guidelines for the release of such sites for unrestricted use have become more stringent. In some instances, records documenting decontamination efforts cannot be found, and the final radiological conditions of the site cannot be adequately determined. As a result, the Formerly Utilized Sites Remedial Action Program (FUSRAP) was established in 1974 to identify these formerly used sites and to reevaluate their radiological status.[1]

The radiological survey detailed in this report was performed under the FUSRAP program at the site of the former Chapman Valve Manufacturing Company. Chapman Valve was a principal supplier of regular and special valves and manifolds for the MED and the AEC. Records also indicate that Chapman Valve, under contract with Brookhaven Laboratory, machined uranium metal during the period January through November 1948. In a letter dated January 9, 1948, shipment of approximately 26 tons of extruded rods was directed to a Chapman Valve facility in Indian Orchard, Massachusetts. Machining operations may not have started until May 1948. One AEC memorandum indicates that Chapman Valve may also have conducted rolling operations on the uranium metal. The health and safety program for this work at the Chapman Valve facility was set up by the AEC.[2]

There was a fire in the restricted area of the AEC project, probably in June 1948. The exact nature of the fire and extent of the damage is unknown. The involvement of uranium metal in the fire is suggested by a Chapman Valve letter dated January 19, 1949.[2]

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*The survey was performed by members of the Measurement Applications and Development Group of the Health and Safety Research Division at Oak Ridge National Laboratory under DOE contract DE-AC05-84OR21400.

After the contract work was completed, Chapman Valve had in their possession over 27,000 pounds of metal scrap, oxides, and sweepings. Termination of these operations is indicated in a Chapman Valve letter dated November 8, 1948, which requested termination of AEC film badge services. All radioactive residues and contaminated materials were surveyed by the Brookhaven Medical Group and shipped off-site. The actual shipment date is unknown, but the shipment probably took place in December 1948.[2]

A former Chapman employee recalls that in 1947 Chapman set aside approximately one-third of Department No. 40 at the Chapman site, 203 Hampshire Street, Indian Orchard, Massachusetts, for the machining of uranium rods for Brookhaven Laboratory. The "set aside" portion of the building measured approximately 200 by 60 ft and was separated from the remainder of the building by a floor-to-ceiling wooden partition, which has since been removed. Chapman became part of the Crane Company in 1959. The building that contained the uranium operations has been vacant since Crane discontinued all manufacturing at Indian Orchard early in 1987.[3]

In August 1991, a radiological survey was conducted at the former Chapman Valve Manufacturing Company by members of the Measurement Applications and Development Group of the Oak Ridge National Laboratory (ORNL) at the request of the U.S. Department of Energy (DOE). The survey and sampling at this site covered selected areas outdoors and accessible areas inside Building 23 (formerly Department No. 40, Fig. 1, p. 10). Survey emphasis was on interior floors, walls, and overhead beams.

SCOPE OF THE SURVEY

The radiological survey included (1) a surface gamma scan of the floor and walls in all accessible areas inside the building and a gamma scan of the ground surface in selected areas outdoors; (2) measurement of surface and 1-m gamma exposure rates at the center of the north and south sections of main-bay survey blocks; (3) a beta-gamma scan of dose rates in accessible areas of the floors and walls inside the building; (4) measurement of alpha activity levels at selected locations; (5) collection and radionuclide analysis of 26 dust and debris samples from overhead beams, 1 from a high-wall window sill, 1 from floor debris, and 2 from a concrete floor anchor; (6) measurement of direct and removable alpha and beta-gamma levels at 31 locations inside the building; (7) collection and radionuclide analysis of 2 soil samples outside the building. It was judged unsafe to conduct a survey of the deteriorating roof.

SURVEY METHODS

A comprehensive description of the survey methods and instrumentation used in this survey is given in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600 (April 1987).[4]

To facilitate reporting of results, the east-west support columns and overhead beams in Building 23 were numbered 1 to 31 (Fig. 2, p. 11), and the north-south columns were

labeled AA, A, B, and C, dividing the building into a series of survey blocks. The northwest corner of each survey block was designated as the grid block identifier.

Using a NaI scintillation probe connected to a Victoreen ratemeter, surface gamma levels were recorded for accessible areas of the floor and walls inside the building and in selected areas outdoors. The detector was held approximately 2 in. above the floor/ground surface, and measurements were recorded and then converted to μR/h. Using a Geiger-Mueller pancake detector, beta-gamma levels were recorded and then converted to mrad/h. Alpha levels were measured at selected locations with a Bicron ratemeter connected to an ORNL ZnS scintillation probe and were then converted to dpm/100 cm^2.

Dust and debris samples were collected inside the building from areas where residuals may have been deposited; these samples were analyzed for ^{226}Ra, ^{232}Th, and ^{238}U. Smears were obtained from selected surfaces to establish transferable alpha and beta-gamma activity levels. Soil samples collected outdoors to depths of 15 cm were analyzed for ^{226}Ra, ^{232}Th, ^{238}U.

SURVEY RESULTS

DOE guidelines are summarized in Table 1 (p. 30). Typical background radiation levels for Massachusetts are presented in Table 2 (p. 32). These data are provided for comparison with survey results presented in this section. All direct measurement results presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations measured in soil, dust, and debris samples. Removable radioactivity levels (smears) are reported as net disintegrations per minute (dpm) with background subtracted.

Current photographs of the site are shown in Figs. 3 and 4 (p. 12).

GAMMA EXPOSURE RATE MEASUREMENTS

Results of gamma exposure rate measurements at Building 23 are shown in Figs. 5 and 6 (pp. 13 and 14). Gamma exposure rates at 1 m above the floor in the center of the north and the center of the south sections of grid blocks A1 through A30 (Fig. 5, p. 13) ranged from 5 to 11 μR/h; surface exposure rates at the same points ranged from 5 to 13 μR/h. A gamma scan (Fig. 6, p. 14) of accessible floor and wall surfaces showed that, generally, highest gamma levels were associated with bricks, concrete, and other such naturally radioactive materials used in paving and building construction. Gamma levels in the east end of the building were near typical background levels for Massachusetts (Table 2, p. 32); however, some gamma exposure rates in the west end of the building were definitely elevated: 30 μR/h on the north side of the west entrance, 32 μR/h in grid block A1, and 26 μR/h in grid block A5.

BETA-GAMMA DOSE RATE MEASUREMENTS

Ranges of beta-gamma dose rates measured in grid blocks at Building 23 are shown in Fig. 7 (p. 15). Highest beta-gamma levels were 4 and 2.9 mrad/h found in grid blocks A1 and A2, respectively. Beta-gamma dose rates exceeded background levels of 0.02 to 0.08 mrad/h in grid blocks A1 through A6, A8, A9, A11, A13, B1, B2, and B5.

DIRECT AND REMOVABLE ALPHA AND BETA-GAMMA RADIOACTIVITY LEVELS

Direct alpha and beta-gamma activity levels were measured at 30 locations in grid blocks A1 through A17. Results are given in Table 3 (p. 33). Directly measured alpha activity ranged from below the minimum detectable activity (MDA*) to 2900 dpm/100 cm^2 with 15 locations showing measurable alpha activity. One measurement exceeded 1000 dpm/100 cm^2. Directly measured beta-gamma activity ranged from 0.02 to 4 mrad/h with 15 locations showing measurable beta-gamma activity. Four measurements exceeded the DOE guideline of 1.0 mrad/h in a 100-cm^2 area.

After recording the direct measurements, the locations were smeared to determine if removable activity was present. Results from smear analyses (Table 3, p. 33) indicate no removable beta-gamma activity above the instrument-specific MDA*; removable alpha activity was above the instrument-specific MDA in 4 of the 30 smear samples.

SOIL AND INDOOR DUST AND DEBRIS SAMPLES

Radionuclide analysis was performed on 2 outdoor soil samples and 32 indoor dust and debris samples. Samples locations are shown on Fig. 8 (p. 16), and analytical results are listed in Table 4 (p. 36). Soil concentrations of ^{226}Ra (0.3 and 1.0 pCi/g), ^{232}Th (0.4 and 1.4 pCi/g), and ^{238}U (<1.4 and 1.9 pCi/g) were similar to typical background concentrations for Massachusetts (Table 2, p. 32).

Concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in dust and debris samples ranged from 0.16 to 0.75 pCi/g, 0.11 to 0.8 pCi/g, and 6.0 to 36,000 pCi/g, respectively. (Elevated concentrations of uranium sometimes mask the true concentration of ^{226}Ra; in these cases, concentrations of ^{226}Ra are reported as less than (<) the minimum concentration that can be detected by the analytical procedure in the presence of elevated uranium.) Highest concentrations of ^{238}U (36,000 pCi/g) were found in dust deposited inside a concrete floor anchor located underneath the wooden flooring of grid block A5. Uranium-238 concentrations of 240 and 120 pCi/g were found in floor debris samples (M11 and M31); chips from the brick facing of column B2 (M32) contained 900 pCi/g ^{238}U. Uranium-238 concentrations in dust samples from overhead beams were converted from pCi/g to dpm/100 cm^2 in order to compare these values with DOE guideline values for removable

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*The instrument-specific minimum detectable activities (MDAs) for directly measured and removable alpha radiation levels are 25 and 10 dpm/100 cm^2, respectively. For directly measured and removable beta-gamma radiation levels the MDAs are 0.01 mrad/h and 200 dpm/100 cm^2, respectively.

surface contamination (Table 1, p. 30). Table 5 (p. 38) shows that 17 of 23 dust samples from overhead beams contained ^{238}U at concentrations ≥100% of the DOE guideline of 1000 dpm/100 cm^2 for removable surface contamination (Table 1, p. 30).

Two dust samples, M10 and M31, were selected for uranium isotopic analysis to determine if the uranium content was normal or enriched. Normally, uranium contains 0.711% ^{235}U. Uranium in which the 235 isotope concentration has been artificially increased above the normal level is called enriched uranium. Sample M10 contained the normal percentage of ^{235}U; sample M31 had been slightly enriched to 2.16% ^{235}U.

Radiation measurements prior to and after collection of dust and debris samples are given in Table 6 (p. 39). Frequently, alpha radiation levels, and in some cases beta-gamma radiation levels, remained elevated after sample collection, showing that scraping away the dust or debris did not completely eliminate all contamination.

DISTRIBUTION OF CONTAMINATION

Radiological contamination in Building 23 was concentrated in the westernmost 15 grid areas, primarily in grid blocks A1 through A15. This central area of the building was relatively free of debris and clutter, allowing good access to the area. Only a few spots of contamination were found on the floors and walls, but overhead beams and horizontal surfaces were consistently elevated. Some contamination was evident in the westernmost B grid blocks, but clutter and debris in this area prevented a thorough survey. Anomalies identified in this area (Fig. 7, p. 15) included a radiator on the south wall of grid block B1 with beta-gamma dose rates of 0.1 to 0.4 mrad/h; a spot on the floor at column C2 with beta-gamma dose rates of 0.2 mrad/h; elevated beta-gamma dose rates in the northwest corner of grid block B2; and a circular area on the floor near the southeast corner of grid block B5 with beta-gamma dose rates of 0.3 mrad/h. No anomalies were identified in grid blocks AA1 through AA10. Highlights of the survey of the central part of the building are presented in Figs. 9 through 19 (pp. 17 through 27).

Grid Block A1 and Building Exterior

On the west end of the building, contamination was identified on the building exterior surface, underneath a former window approximately 4 ft south of the main entrance and 1 ft above the ground. At this location (Fig. 20, p. 28), beta-gamma dose rates measured 0.7 mrad/h and maximum alpha activity reached 2900 dpm/100 cm^2. Smear 17 from this area demonstrated that the contamination was not removable (Table 3, p. 33).

Other details of the survey of grid block A1 are diagramed in Fig. 9 (p. 17). (Solid lines represent the floor area; extended dashed lines represent the walls.) North of the concrete ramp immediately inside the main entrance, an elevated area (Fig. 21, p. 28) contained gamma exposure rates of 32 μR/h and beta-gamma dose rates up to 1.3 mrad/h. Debris sample M31 collected at this location was slightly enriched (2.16% ^{235}U) and contained 120 pCi/g ^{238}U (Table 4, p. 36). Beta-gamma dose rates of 1.5 mrad/h were found on the wall and on a ledge just north of the main entrance (Fig. 22, p. 29). The west wall south of

the main entrance had beta-gamma dose rates up to 4 mrad/h and alpha levels of 650 dpm/100 cm^2. Smear 11 (Table 3, p. 33) from this area showed that 36 dpm/100 cm^2 of the alpha activity was removable. Beta-gamma levels near column B2 reached 2.9 mrad/h. Beta-gamma dose rates in grid block A1 consistently exceeded the DOE guideline of 0.2 mrad/h averaged over not more than 1 m^2 and 1.0 mrad/h in any 100-cm^2 area (Table 1, p. 30). Dust samples from overhead beams (M3–M6, Table 5, p. 38) contained 170 to 340 pCi/g (2000 to 5300 dpm/100 cm^2) ^{238}U, which is 2 to 5 times the DOE guideline for residual removable surface contamination (Table 1, p. 30).

Grid Block A2

Beta-gamma dose rates in grid block A2 (Fig. 10, p. 18) reached 2.9 mrad/h on the brick facing of column B2 (Fig. 23, p. 29); alpha levels were 300 dpm/100 cm^2. Radiological analysis of chips of the brick facing material (M32, Table 4, p. 36) demonstrated the presence of 900 pCi/g ^{238}U. Smear 13 (Table 3, p. 33) from this area showed that 32 dpm/100 cm^2 of the alpha activity was removable. Dust from a high-wall window sill located between columns B2 and B3 contained 1300 pCi/g (M30, Table 4, p. 36). Dust from an overhead beam in grid block A2 also contained 1300 pCi/g ^{238}U (1400 dpm/100 cm^2, M29, Table 5, p. 38), which was 1.4 times the DOE guideline for removable alpha activity (Tables 1 and 5, pp. 30 and 38).

Other areas of elevated beta-gamma radiation were observed around column B3 (>0.2 mrad/h), column A2 (1.4 and 1.9 mrad/h), and column A3 (>0.2 mrad/h). Spots on the floor measured 1.2 mrad/h (beta-gamma) and 28 dpm/100 cm^2 (alpha).

Grid Block A3

In grid block A3 (Fig. 11, p. 19), columns B3 and B4 showed beta-gamma dose rates of 0.4 and 0.1 mrad/h, respectively. Beta-gamma dose rates on the radiator and behind the radiator on the north wall reached 0.8 mrad/h; alpha levels reached 120 dpm/100 cm^2. Smears 14, 15, and A3 from these areas (columns B3, B4, and the north wall) did not contain removable radioactivity (Table 3, p. 33) above the instrument-specific MDA. Beta-gamma dose rates of 0.2 mrad/h were measured on top of an electrical box and in an elevated area near the base of column A4; dose rates of 0.6 mrad/h were measured on the wall below the radiator near the floor. Dust samples from overhead beams (M7–M9, Table 5, p. 38) demonstrated the presence of ^{238}U at concentrations of 48 to 130 pCi/g (1500 to 4000 dpm/100 cm^2), which is 150% to 400% of the DOE guideline for residual removable surface contamination (Table 1, p. 30).

Grid Block A4

On the north wall of grid block A4 (Fig. 12, p. 20), beta-gamma dose rates on the brick behind the radiator reached 0.1 mrad/h; alpha radiation levels measured 110 dpm/100 cm^2. Beta-gamma dose rates of 0.2 mrad/h were measured at several places on column A5 and at the floor and column join of column B5. Smear A5 (Table 3, p. 33) from column A5 did not exhibit removable radioactivity above the MDA.

Grid Block A5

In grid block A5 (Fig. 13, p. 21), a spot on the floor near column A5 showed gamma exposure rates of 14 to 26 μR/h, alpha activity levels of 2900 dpm/100 cm^2, and beta-gamma dose rates up to 0.2 mrad/h. Beta-gamma levels on the radiator on the north wall ranged from 0.2 to 0.5 mrad/h; three spots near column A6 measured 0.4 mrad/h, and a contaminated region at column A6 ranged from 0.05 to 0.2 mrad/h. Smear A5 from the north wall and smear 16 from column B5 (Table 3, p. 33) did not contain removable radioactivity above the MDA.

Samples M1 and M2 mark the location of a concrete floor anchor that was probably used to anchor machinery. Dust collected from this location (M1, Table 4, p. 36) contained 36,000 pCi/g ^{238}U. Dust from two overhead beams (M10, M14, Table 5, p. 38) contained 25 and 35 pCi/g (1000 and 1200 dpm/100 cm^2) ^{238}U, which is 100% and 120% of the DOE guideline for residual removable surface contamination (Table 1, p. 30).

Grid Block A6

Grid block A6 (Fig. 14, p. 22) showed elevated beta-gamma levels on the north wall. Contaminated spots on column A6 and around the radiator ranged from 0.2 to 0.6 mrad/h. The brick behind the radiator ranged from 0.02 to 0.1 mrad/h. Smear A6 (Table 3, p. 33) from the wall behind the radiator contained 90 dpm/100 cm^2 removable alpha activity. Firebrick in the center of the floor exhibited beta-gamma levels of 0.02 to 0.1 mrad/h. Dust samples M12 and M13 (Table 5, p. 38) from overhead beams contained 330 and 60 pCi/g (9000 and 2600 dpm/100 cm^2) ^{238}U, which is 9 and 2.6 times the DOE guideline for residual removable surface contamination, respectively.

Grid Block A7 and A8

Elevated gamma exposure rates of 12 and 16 μR/h in grid block A7 and A8 (Figs. 15 and 16, pp. 23 and 24) are typical of naturally occurring radioactive substances present in bricks, concrete, and other such materials used in building construction. Beta-gamma dose rates in these grid blocks generally ranged from 0.02 to 0.08 mrad/h on the walls and floor. Alpha activity measured less than the MDA (<25 dpm/100 cm^2) on low walls. Smears A7 and A8 contained no removable radioactivity above MDA. Dust sample M15 (Table 5, p. 38) from an overhead beam contained 350 pCi/g (12,000 dpm/100 cm^2) ^{238}U, which is 1200% of the DOE guideline for residual removable surface contamination (Table 1, p. 30).

Grid Block A9

In grid block A9 (Fig. 17, p. 25), an area of contamination on the floor near column B10 showed beta-gamma dose rates of 0.02 to 0.5 mrad/h and alpha levels of 43 dpm/100 cm^2. Composite floor debris collected at this location (M11, Table 4, p. 36) contained 240 pCi/g ^{238}U. Two additional spots of slightly elevated alpha activity were noted on the floor (57 and 77 dpm/100 cm^2). Beta-gamma activity on the floor ranged from 0.02 to 0.08 mrad/h, and gamma levels reached 16 μR/h in an area where firebrick was present. Dust samples (M16, M17, and M18, Table 5, p. 38) collected from overhead beams

contained 16, 57, and 65 pCi/g (900, 1300, and 2800 dpm/100 cm^2) ^{238}U, which is 90%, 130%, and 280%, respectively, of the DOE guideline for residual removable contamination (Table 1, p. 30).

Grid Block A11

An area with spots of elevated surface beta-gamma activity ranging from 0.1 to 0.8 mrad/h was identified in grid block A11 (Fig. 18, p. 26) on the west side of the furnace (Fig. 4, p. 12). Similar spots on the east side of the furnace ranged from 0.1 to 0.2 mrad/h. Overhead beams in the block showed beta-gamma activity of 0.1 mrad/h, and an electrical conduit on the north wall measured 0.3 mrad/h.

Grid Block A13

Surface gamma exposure rates, beta-gamma dose rates, and alpha activity levels for the floors and lower walls in grid block A13 (Fig. 19, p. 27) were near typical background levels for Building 23. Dust sample M19 (Table 5, p. 38) from an overhead beam contained 50 pCi/g (1400 dpm/100 cm^2) ^{238}U, which is 1.4 times the DOE guideline residual removable surface contamination (Table 1, p. 30).

SIGNIFICANCE OF FINDINGS

Radionuclide analysis of soil, dust, and debris, and analysis of smear samples collected at Building 23 from the former Chapman Valve facility, Indian Orchard, Massachusetts, indicate that residual ^{238}U attributable to former AEC-supported operations is present at this site. Elevated levels of radioactivity were particularly evident on the floors and walls in the western part of the central area of the building (grid blocks A1 through A6), but contamination on overhead beams was not limited to this area. Concentrations of ^{238}U in dust samples collected from overhead beams exceeded DOE guidelines in grid blocks A1 through A14 and remained elevated but below guidelines in grid blocks A15 through A19. Dust on a movable overhead crane in grid block A23 was well above the guideline, probably because the crane had at some time been located further west. A floor debris sample collected just north of the main entrance in grid block A1 contained uranium that had been slightly enriched (from 0.711% to 2.16% ^{235}U). Some contamination was evident in grid blocks B1 through B5, but clutter and debris in this area prevented a thorough survey. No anomalies were identified in grid blocks AA1 through AA10.

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4. 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*, ORNL/TM-8600, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., April 1987.

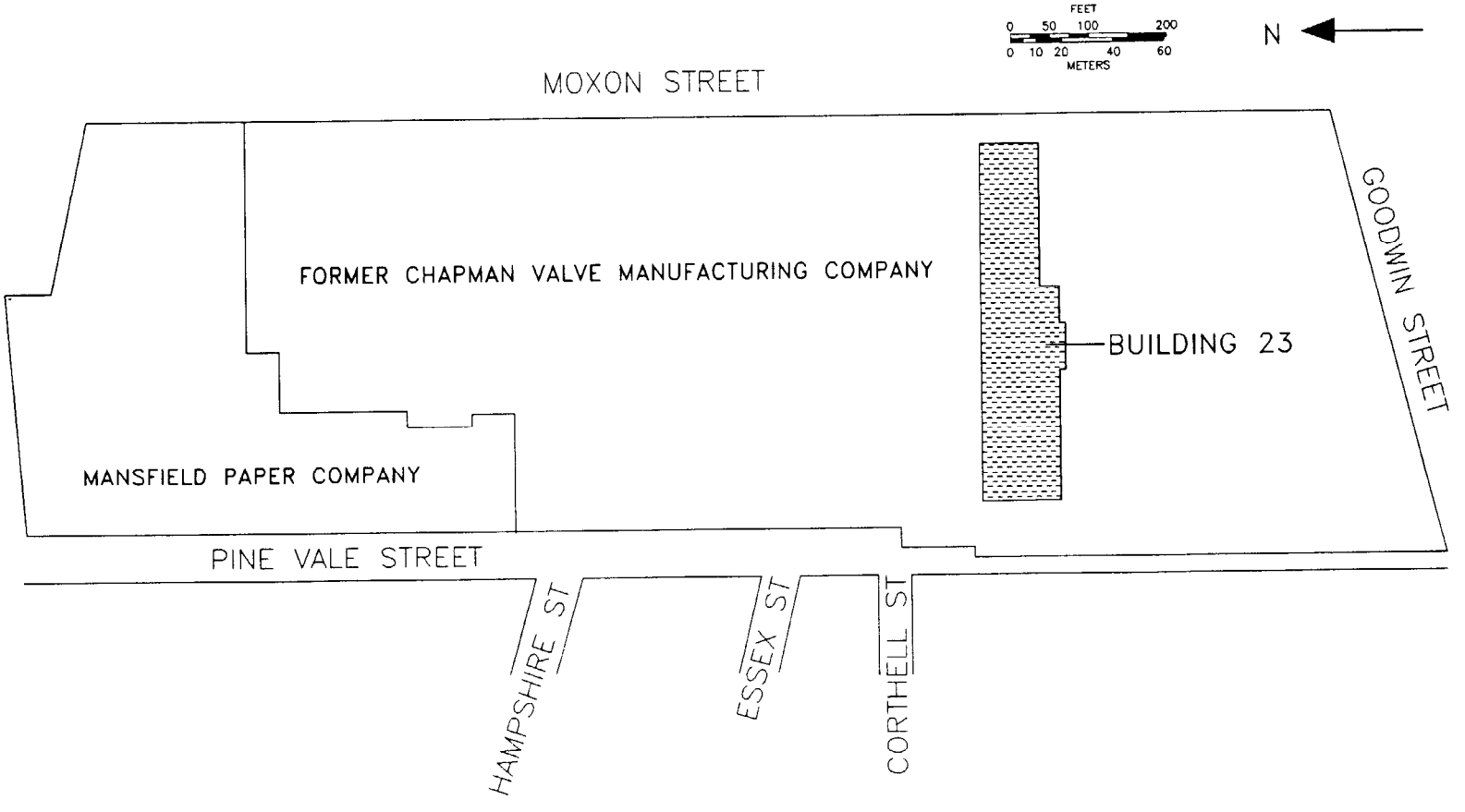

Fig. 1. Location of Building 23 (Department No. 40) at the site of the former Chapman Valve Manufacturing Company, Indian Orchard, Massachusetts.

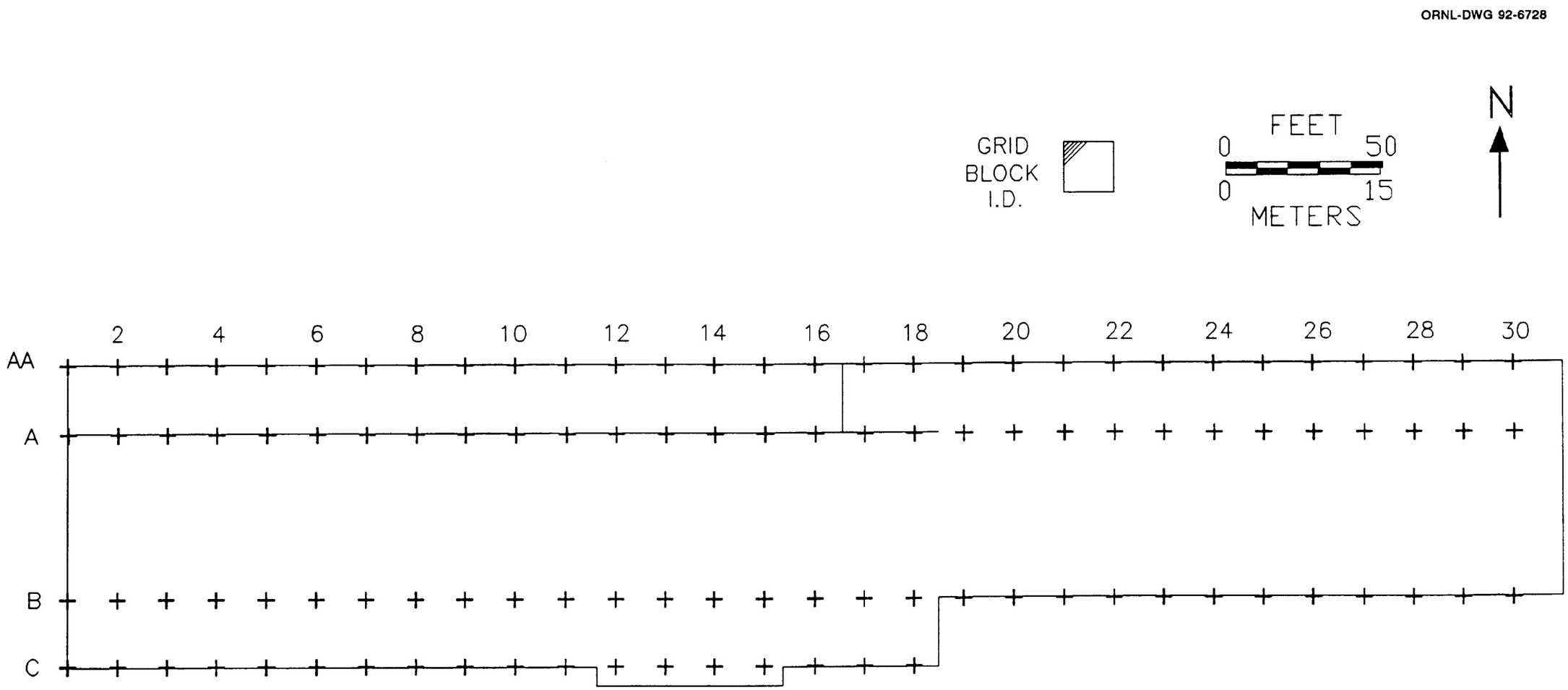

Fig. 2. Building 23 at the site of the former Chapman Valve Manufacturing Company, Indian Orchard, Massachusetts. To facilitate reporting of results, the east-west support columns and overhead beams were numbered 1 to 31 and the north-south columns were labeled AA, A, B, and C.

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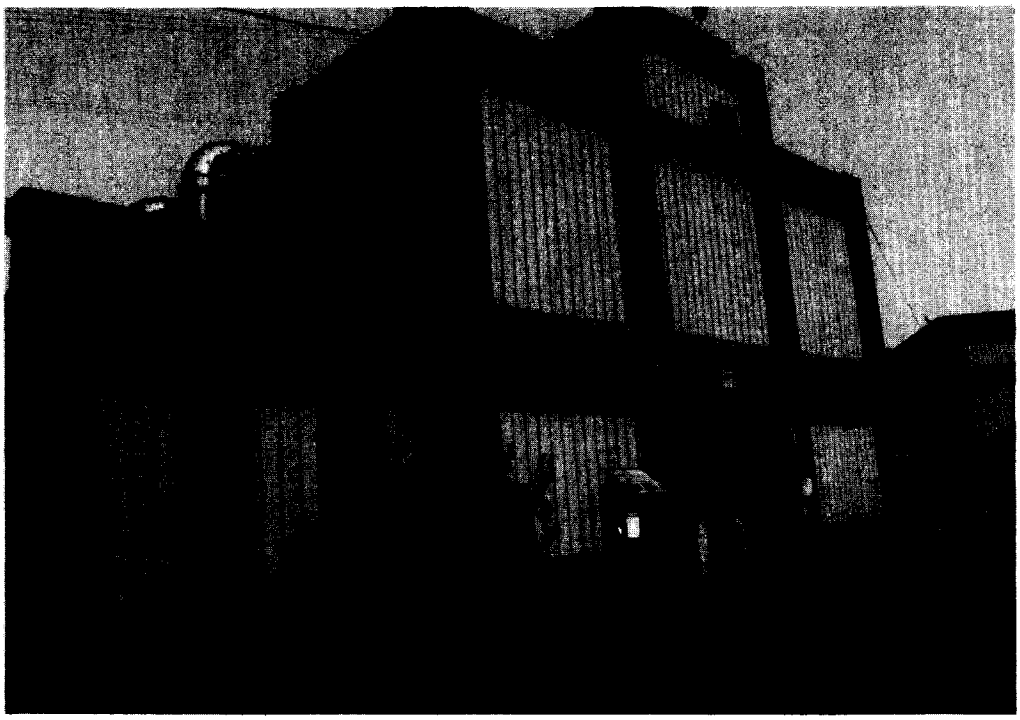

Fig. 3. View looking east at the main entrance to Building 23 at the site of the former Chapman Valve facility, Indian Orchard, Massachusetts.

ORNL-PHOTO 1141-92

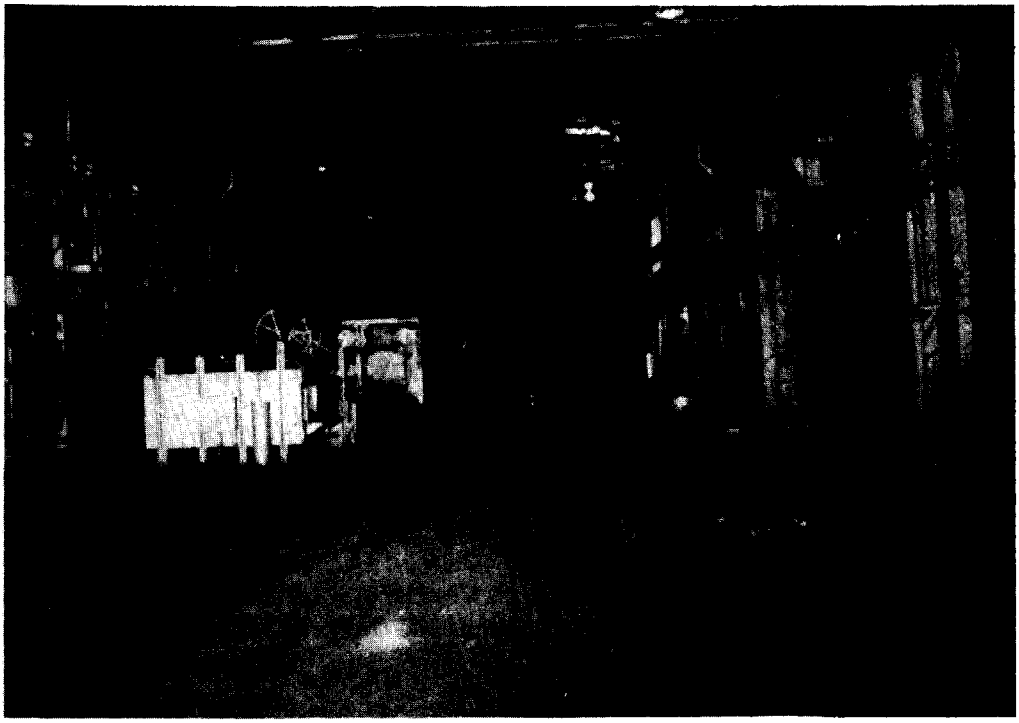

Fig. 4. View inside the main entrance looking east at grid blocks A1 through A30 in the center of Building 23 (Indian Orchard, Massachusetts). Columns labeled B are on the right; those labeled A are on the left. Dust samples were collected from overhead beams visible at the top of the photo.

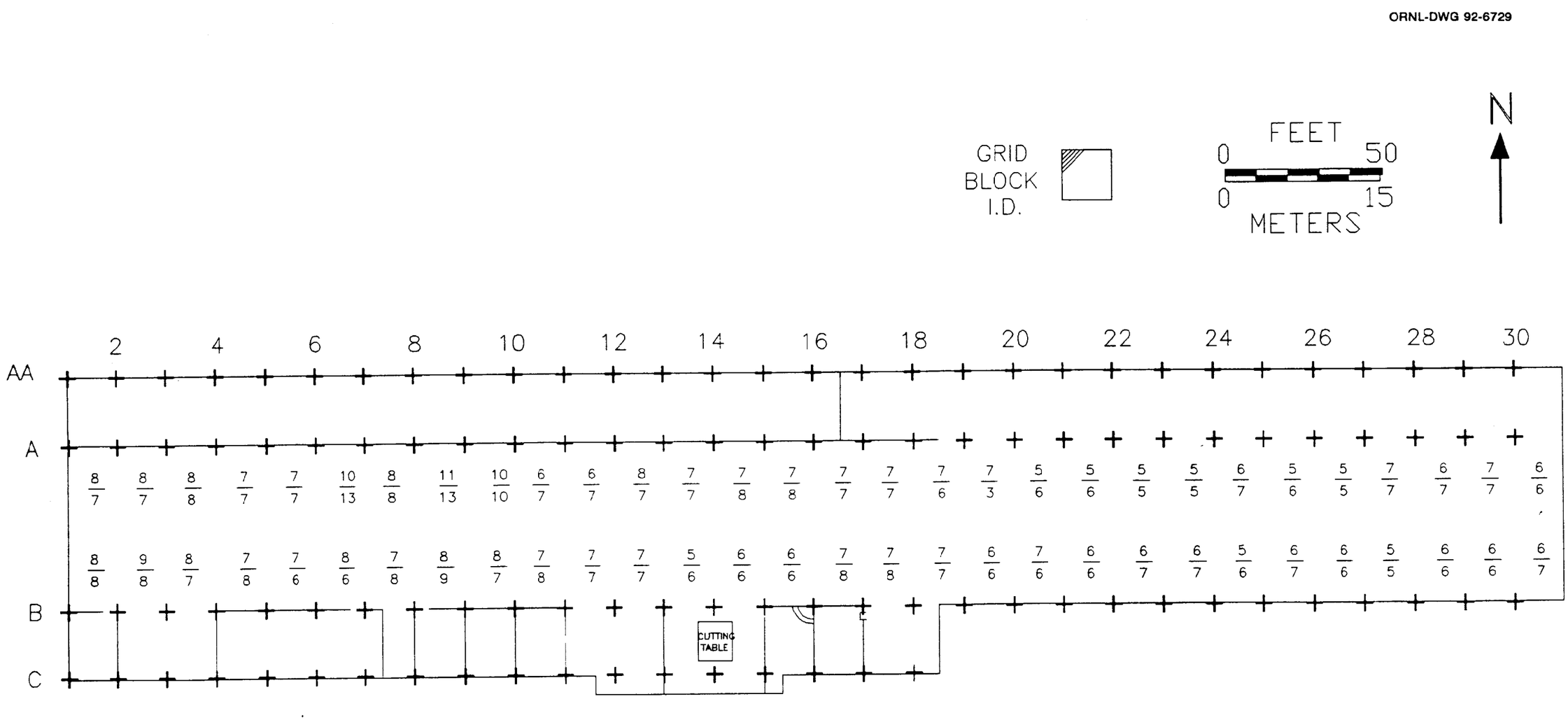

Fig. 5. Surface and 1-m gamma exposure rates (μR/h) taken at the center of the north and south sections of grid blocks A1 through A30, Building 23, Indian Orchard, Massachusetts. Lower number = surface; upper number = 1 m.

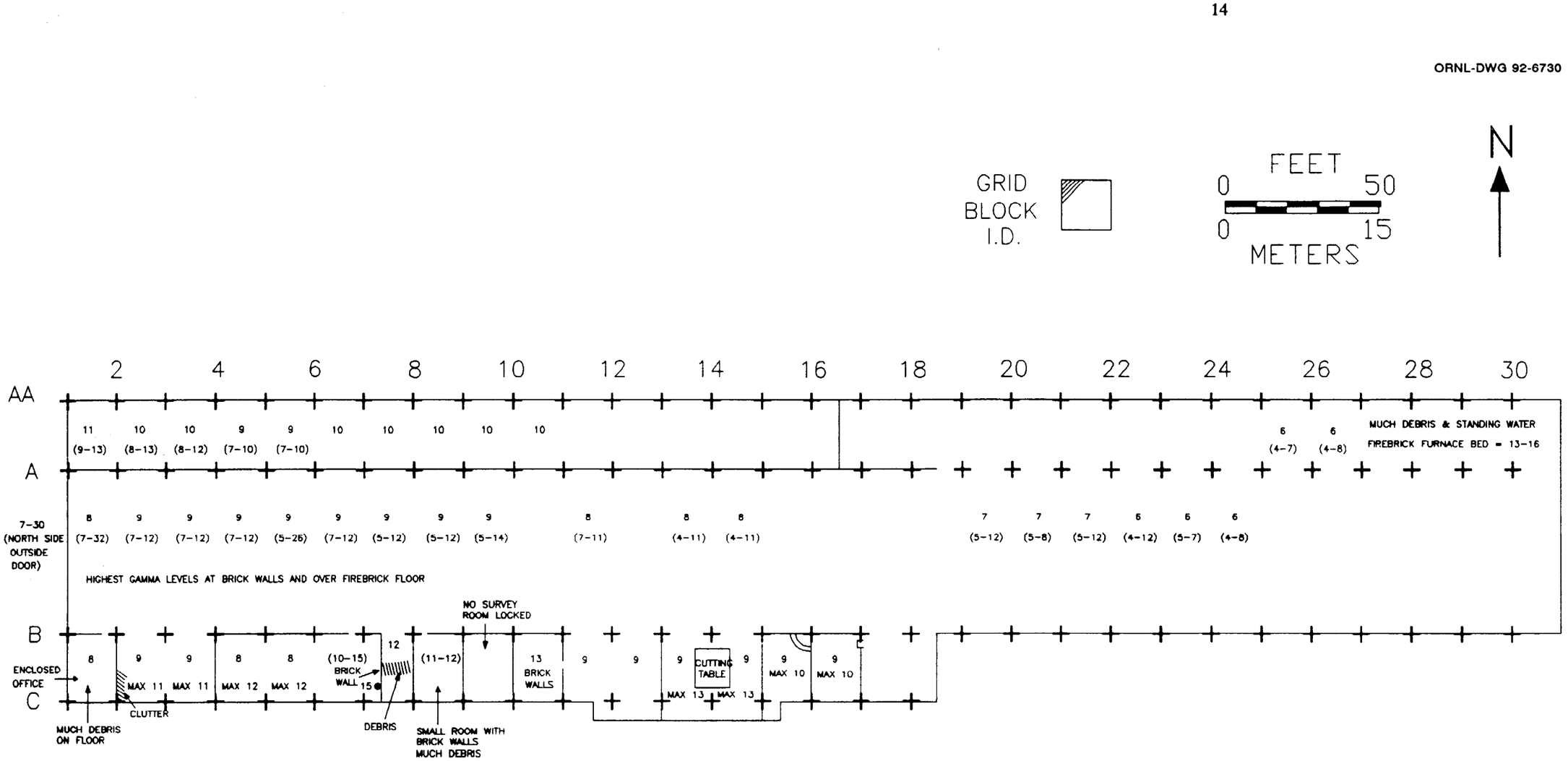

Fig. 6. Average surface gamma exposure rates (μR/h) measured in grid blocks at Building 23, Indian Orchard, Massachusetts. Ranges are given in parentheses.

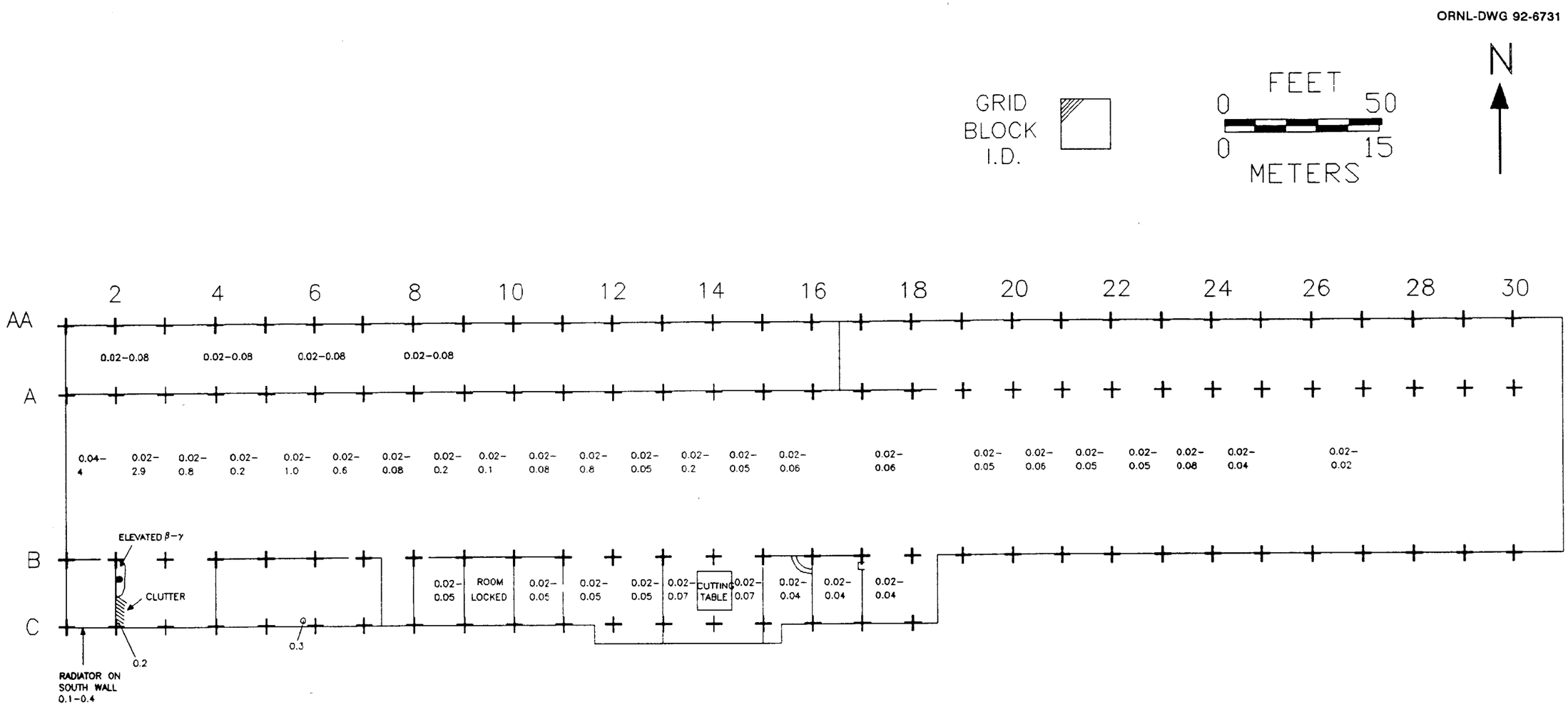

Fig. 7. Ranges of beta-gamma dose rates (mrad/h) measured in grid blocks at Building 23, Indian Orchard, Massachusetts.

ORNL-DWG 92-6732

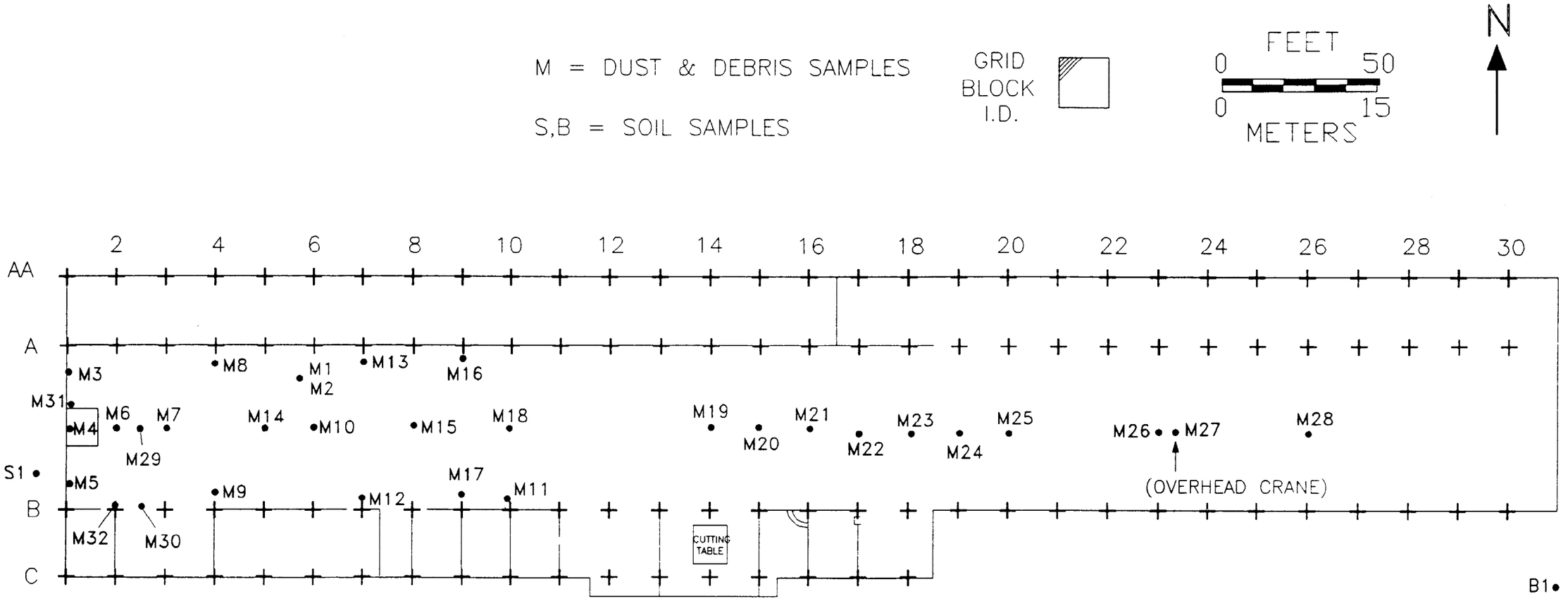

Fig. 8. Locations of soil, dust, and debris samples collected at the site of the former Chapman Valve facility, Indian Orchard, Massachusetts.

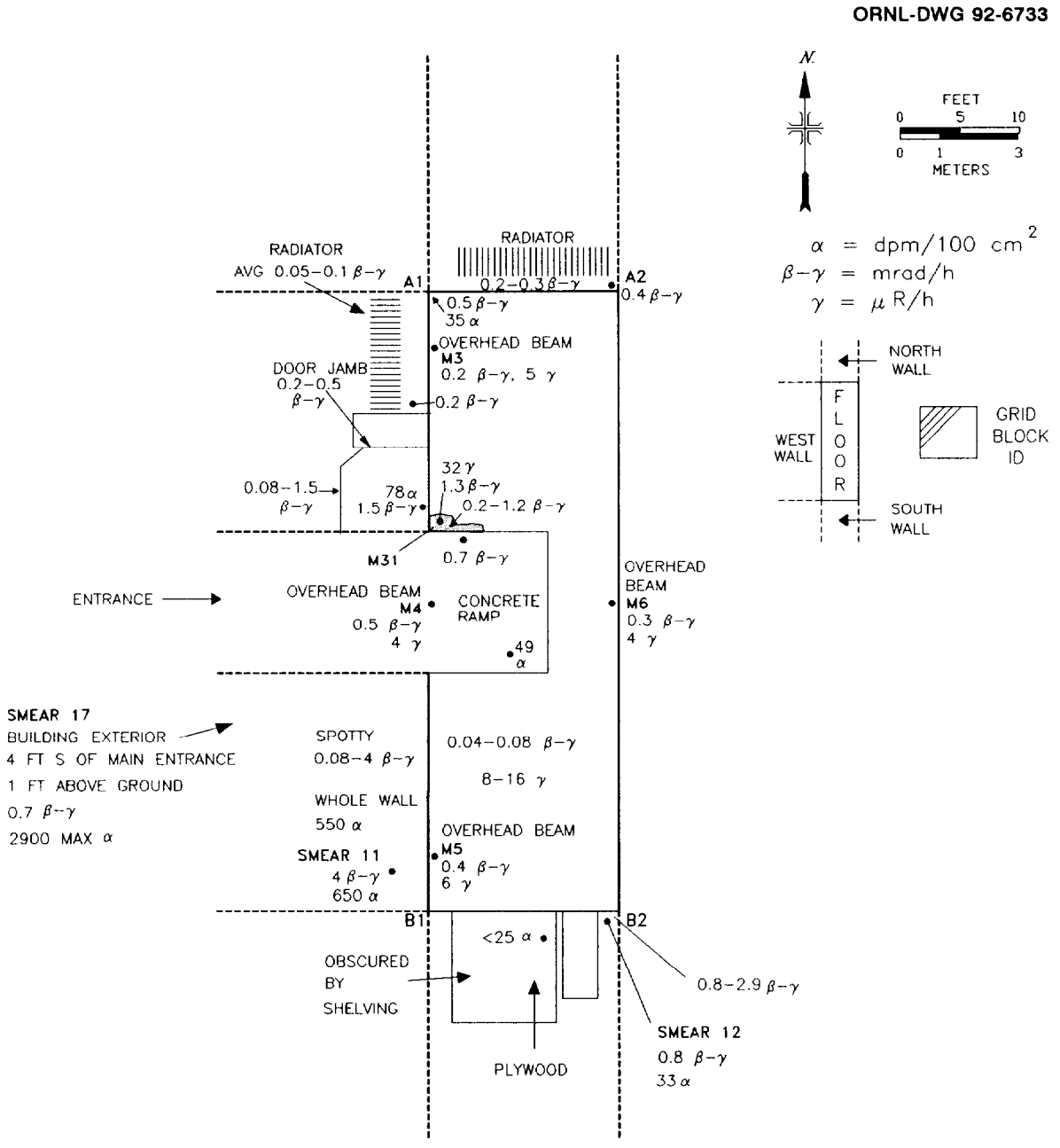

Fig. 9. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A1.

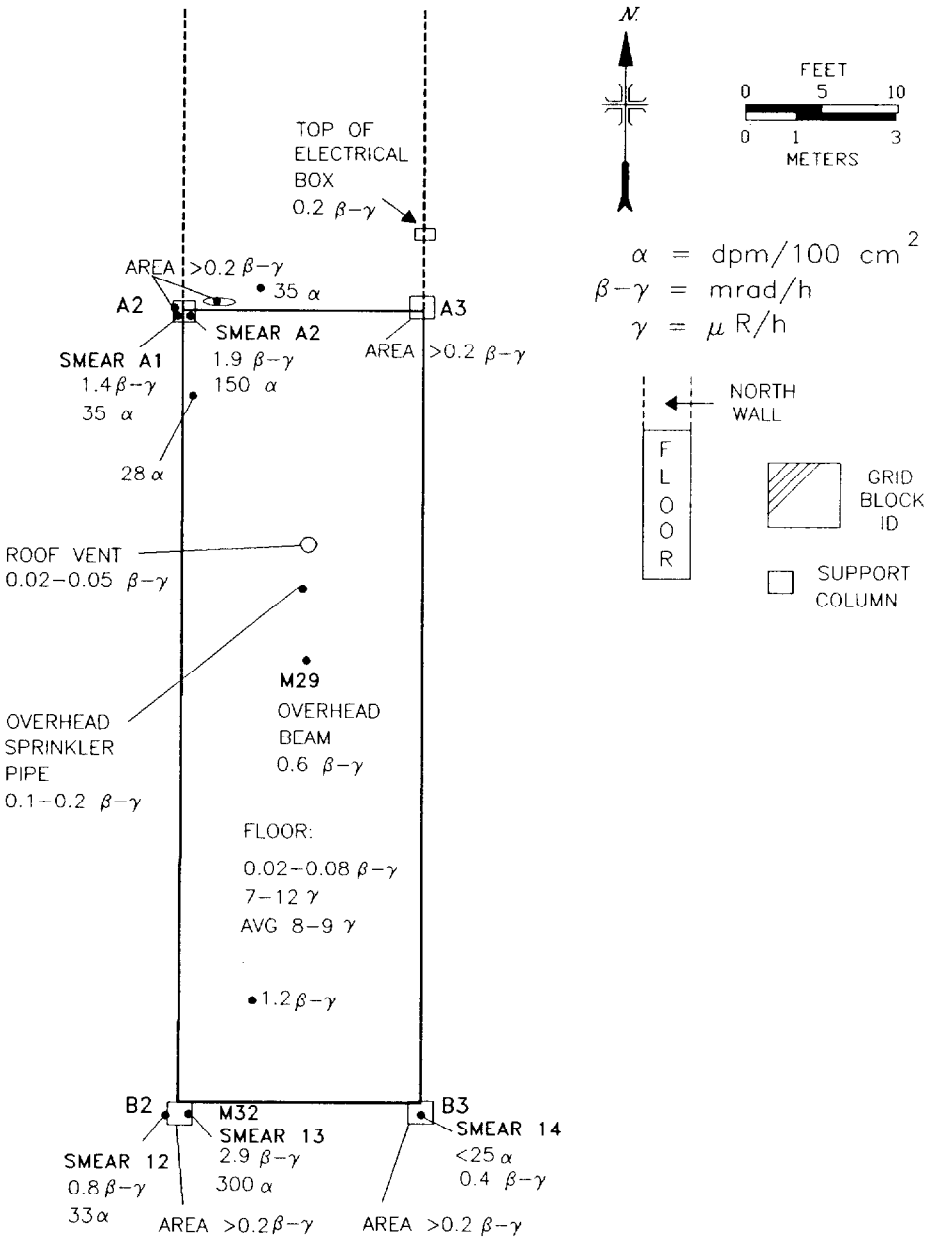

Fig. 10. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A2.

ORNL-DWG 92-6735

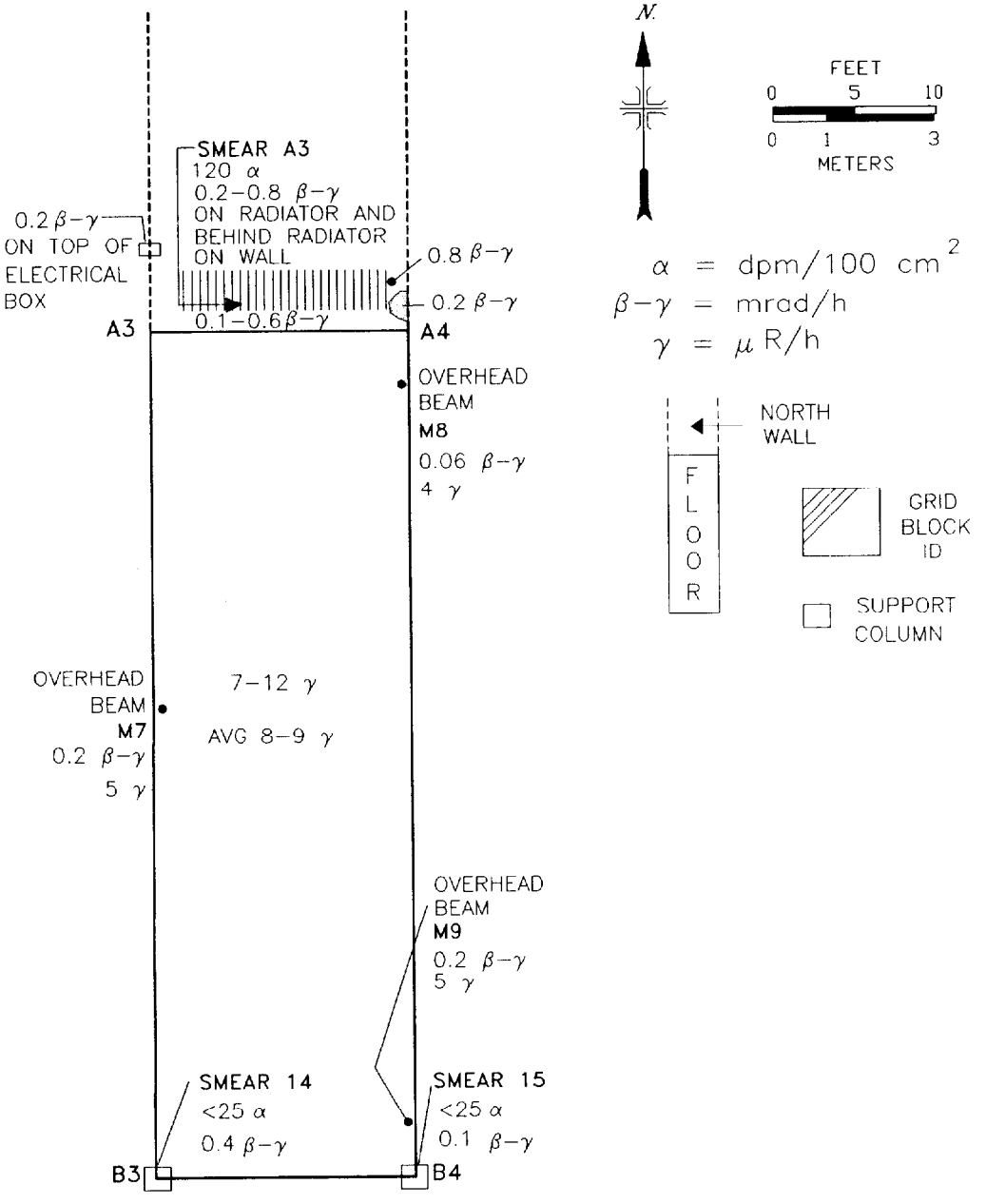

Fig. 11. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A3.

ORNL-DWG 92-6736

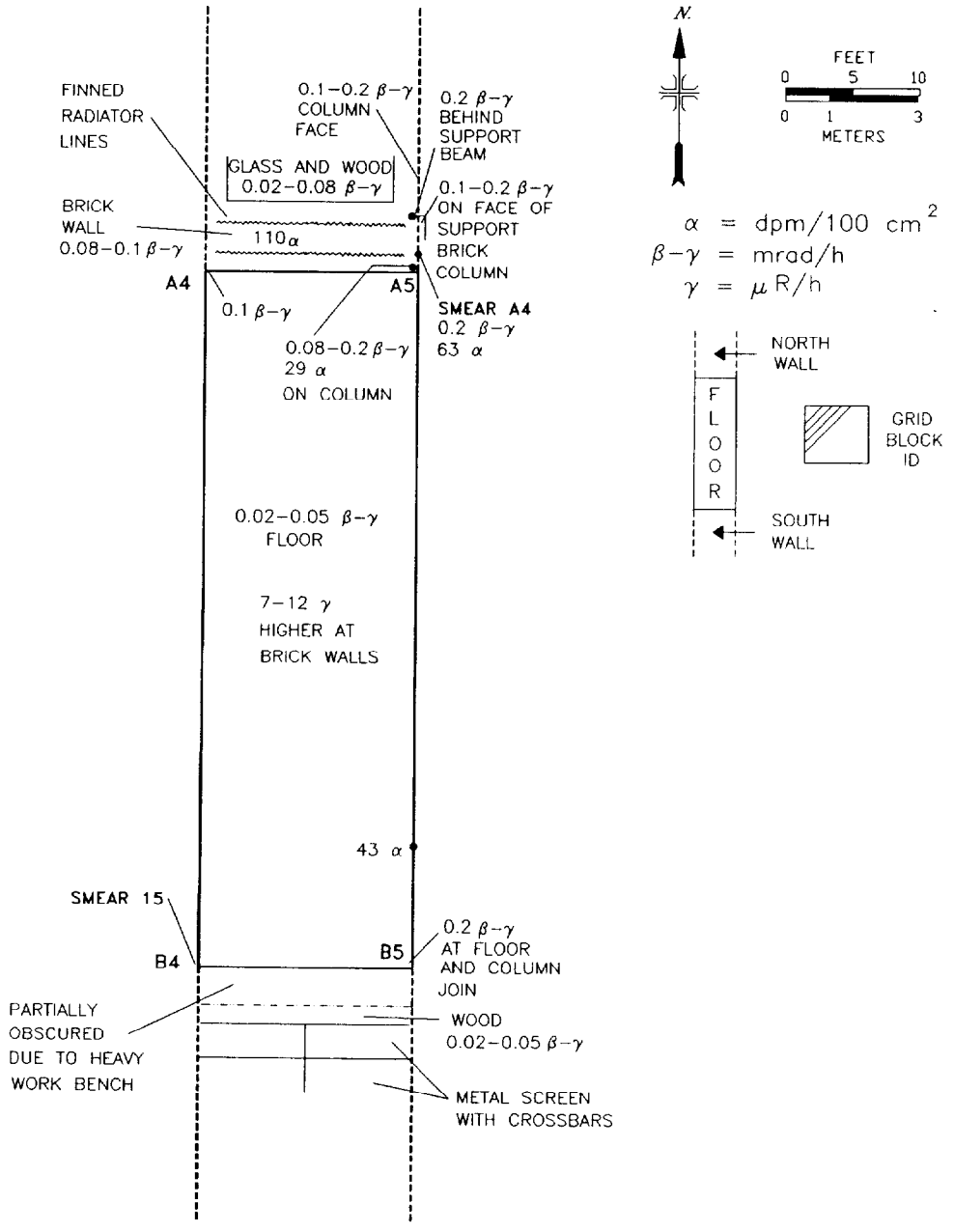

Fig. 12. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A4.

ORNL-DWG 92-6737

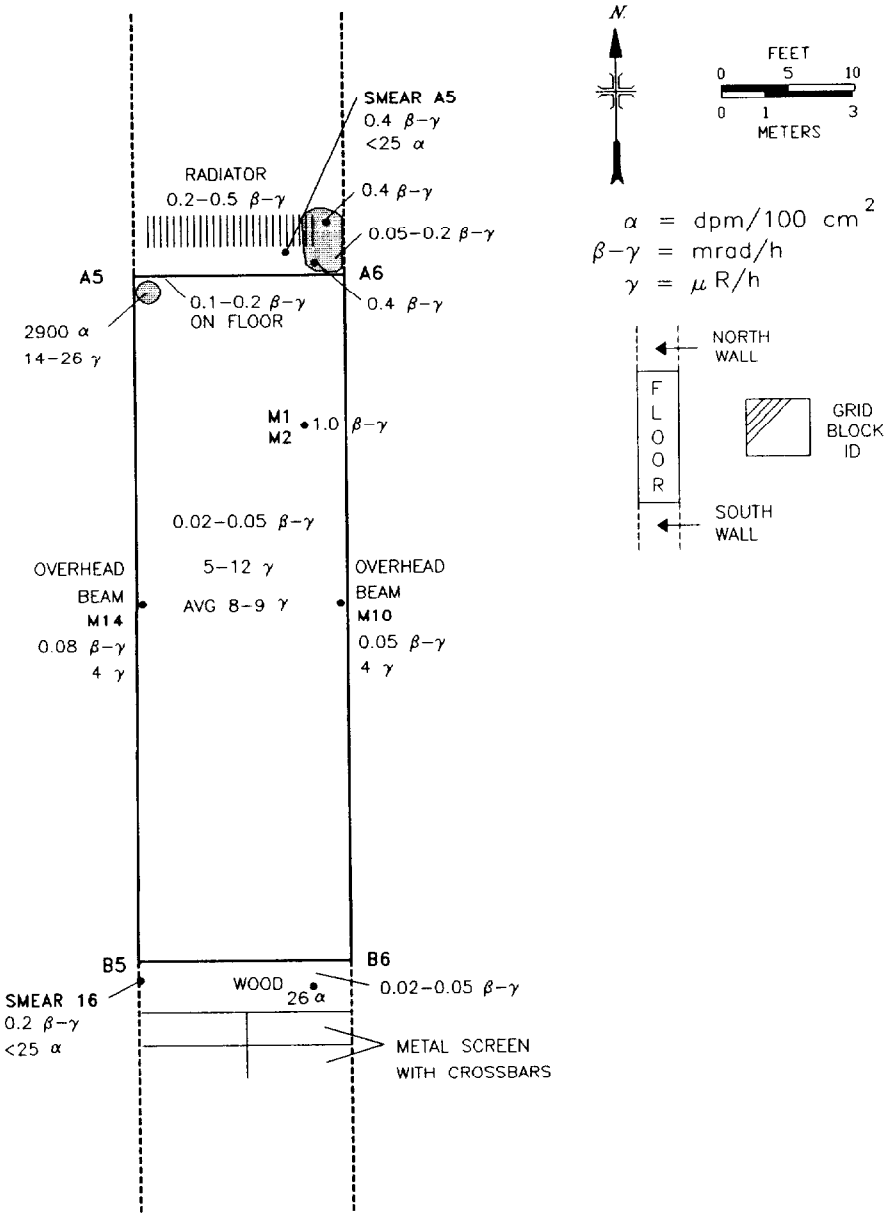

Fig. 13. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A5.

ORNL-DWG 92-6738

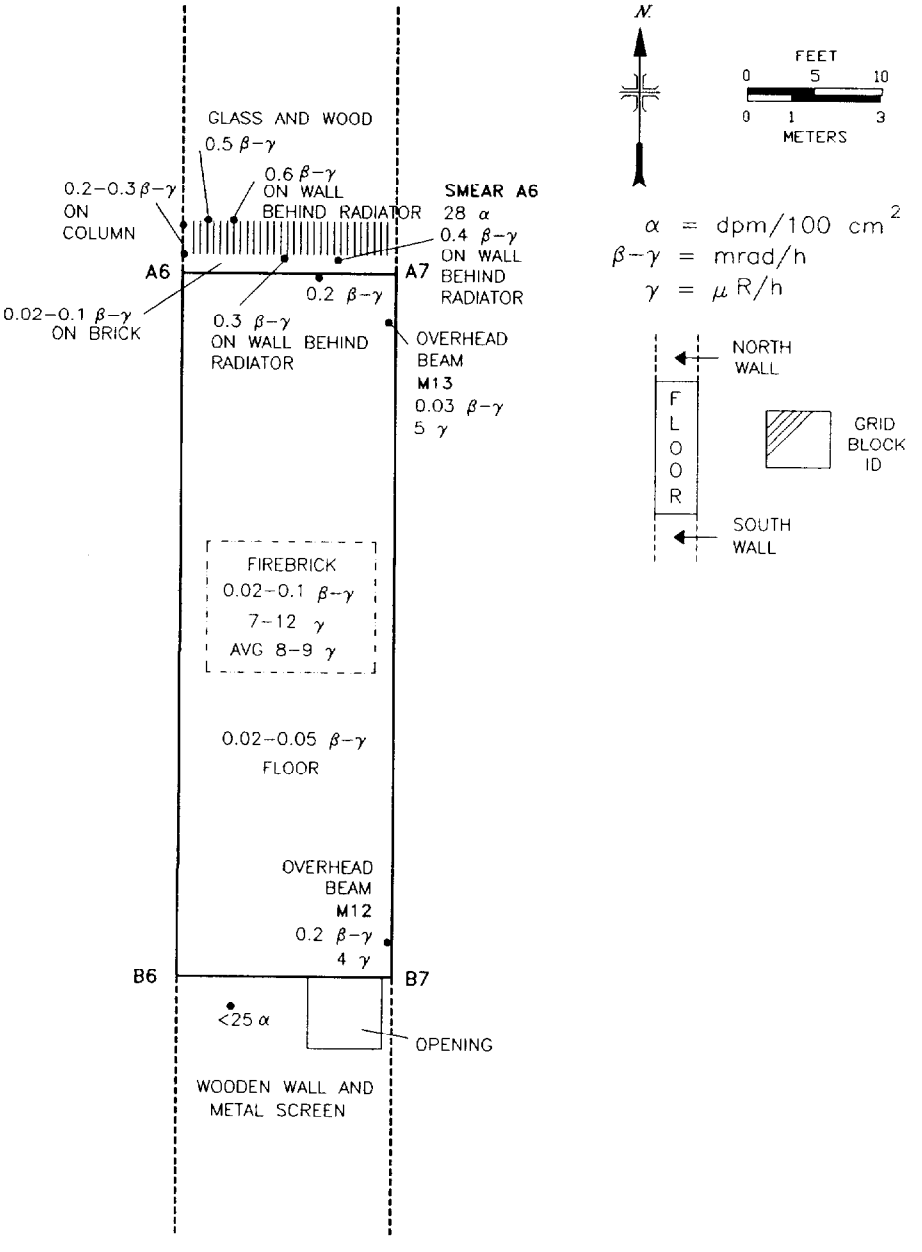

Fig. 14. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A6.

ORNL-DWG 92-6739

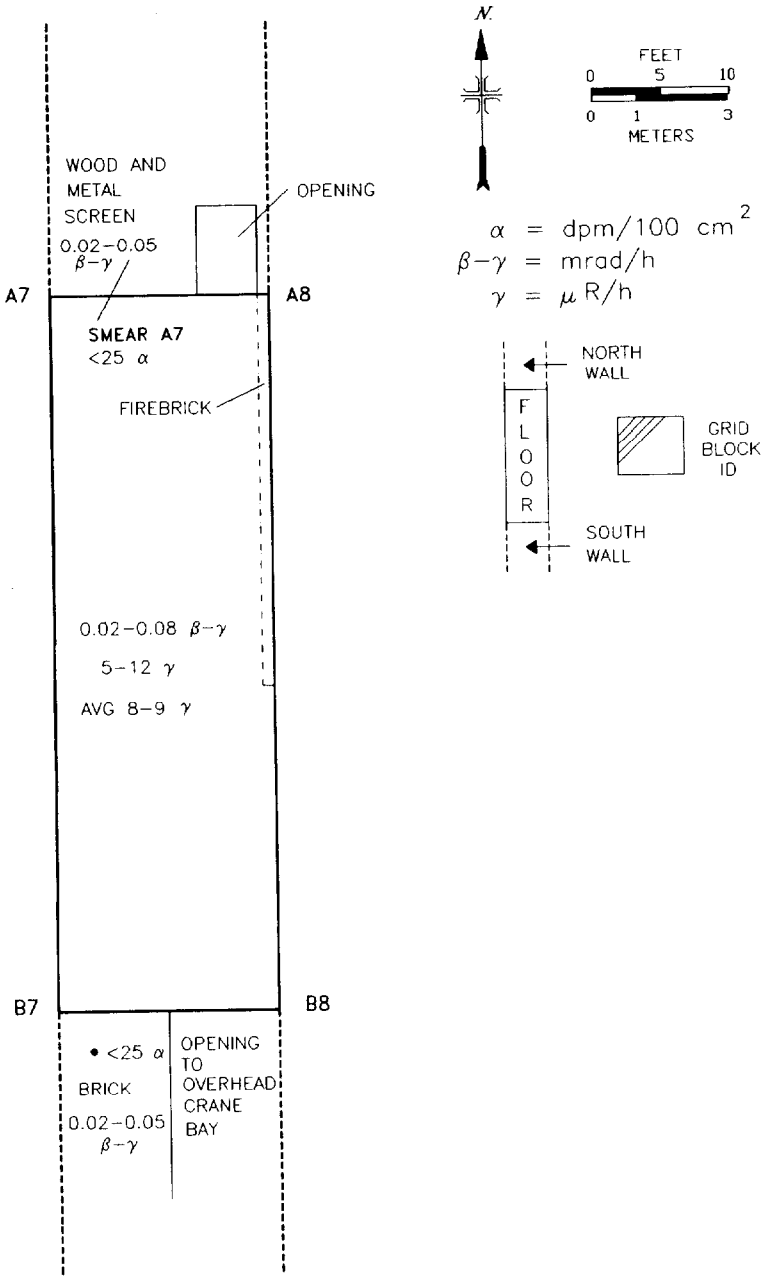

Fig. 15. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A7.

ORNL-DWG 92-6740

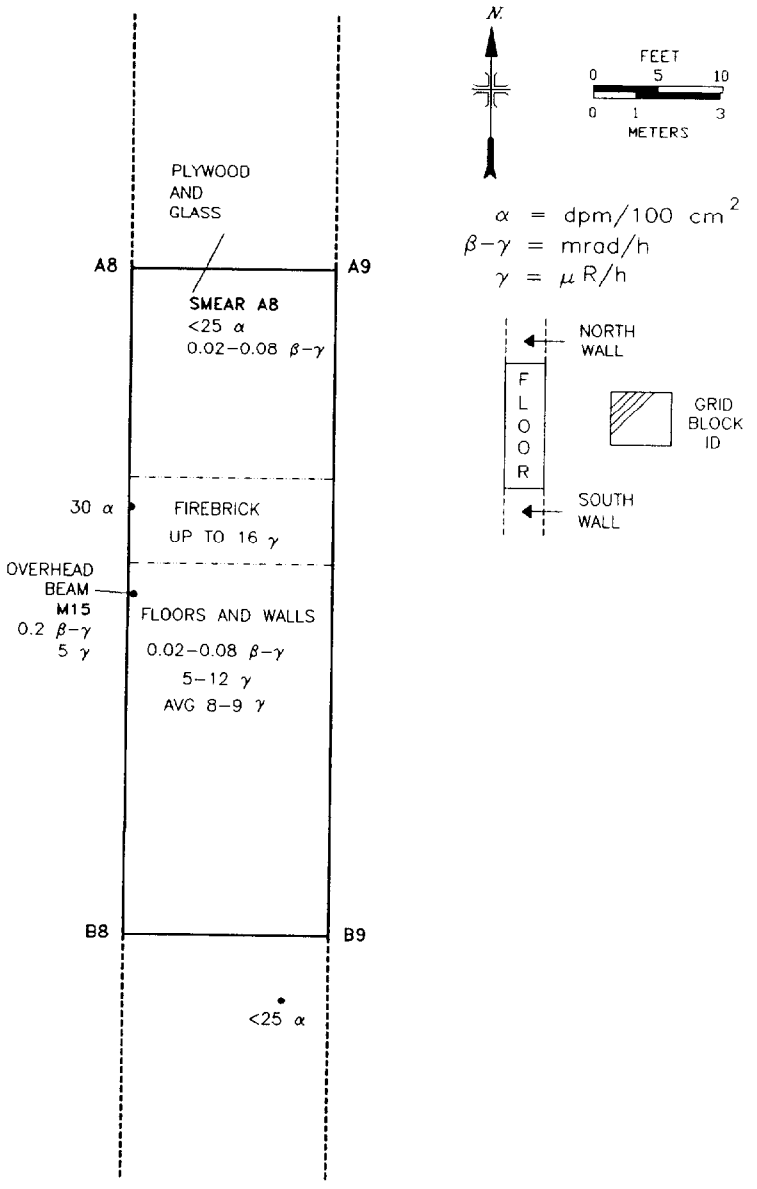

Fig. 16. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A8.

ORNL-DWG 92-6741

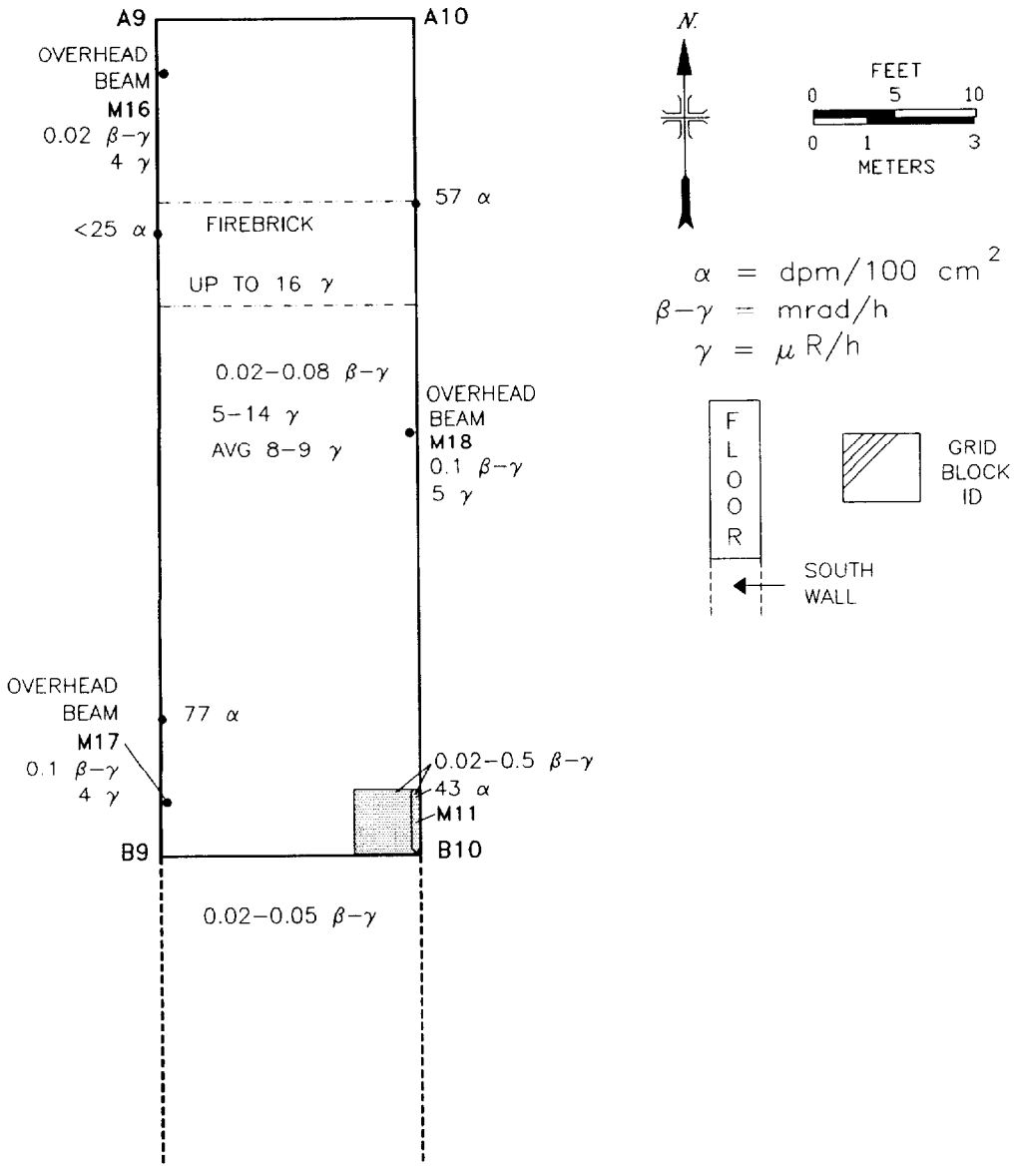

Fig. 17. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A9.

ORNL-DWG 92-6742

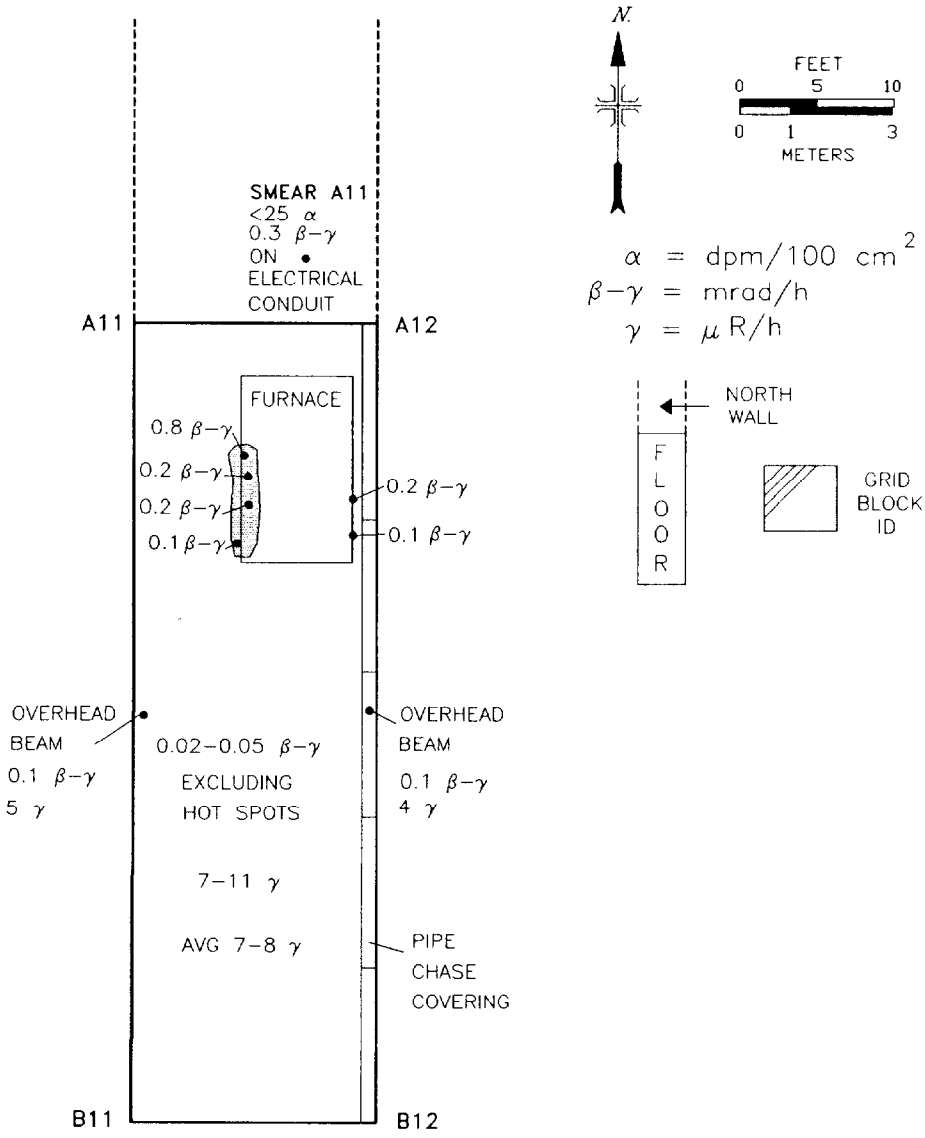

Fig. 18. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A11.

ORNL-DWG 92-6743

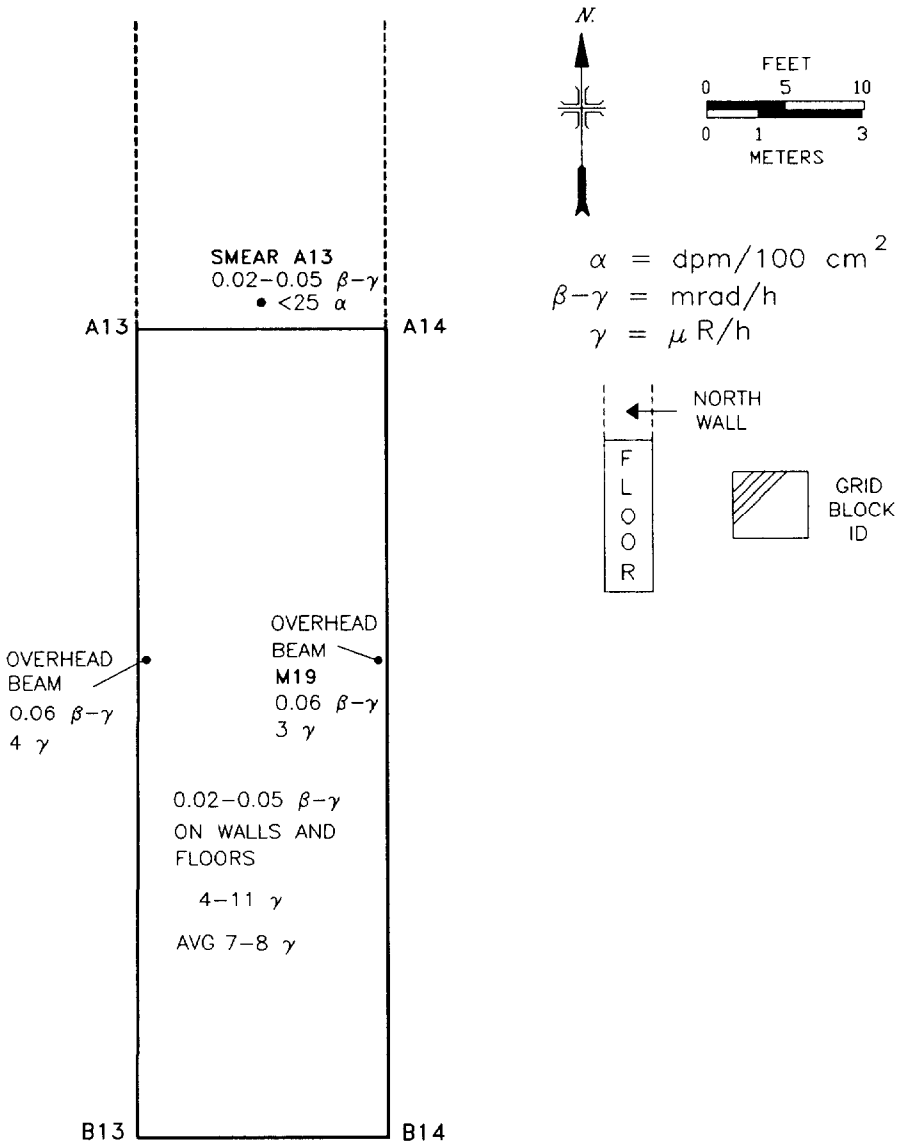

Fig. 19. Surface gamma exposure rates (μR/h), beta-gamma dose rates (mrad/h), and alpha activity levels (dpm/100 cm^2) in grid block A13.

ORNL-PHOTO 1142-92

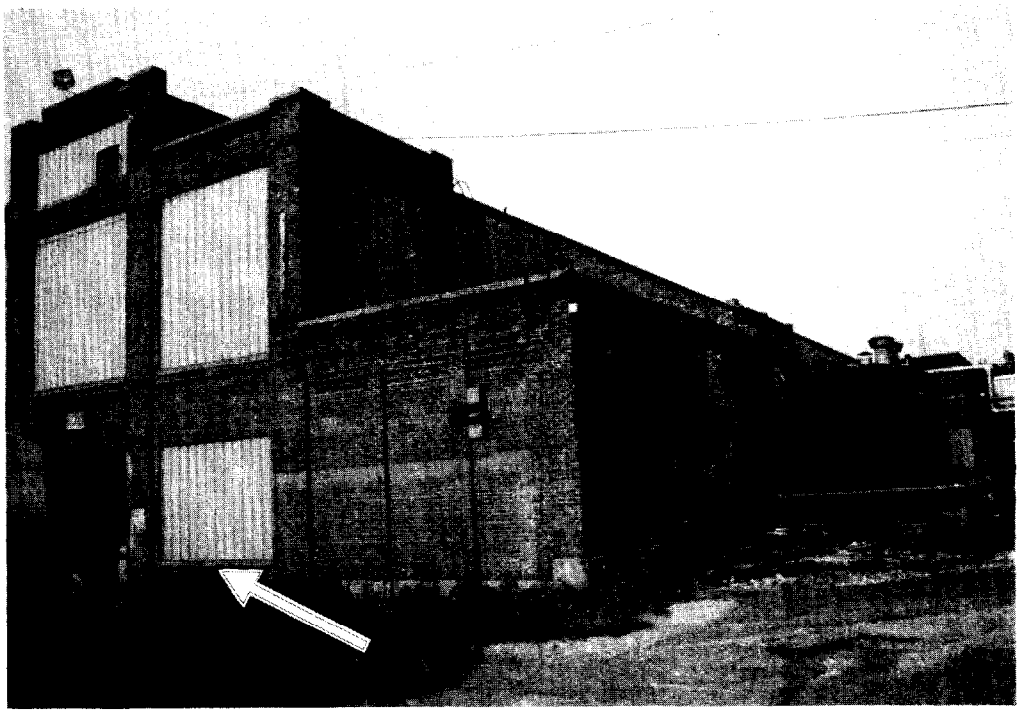

Fig. 20. View looking east northeast at Building 23, Indian Orchard, Massachusetts. Contamination was identified on the exterior of the building in the vicinity of the arrow.

ORNL-PHOTO 1143-92

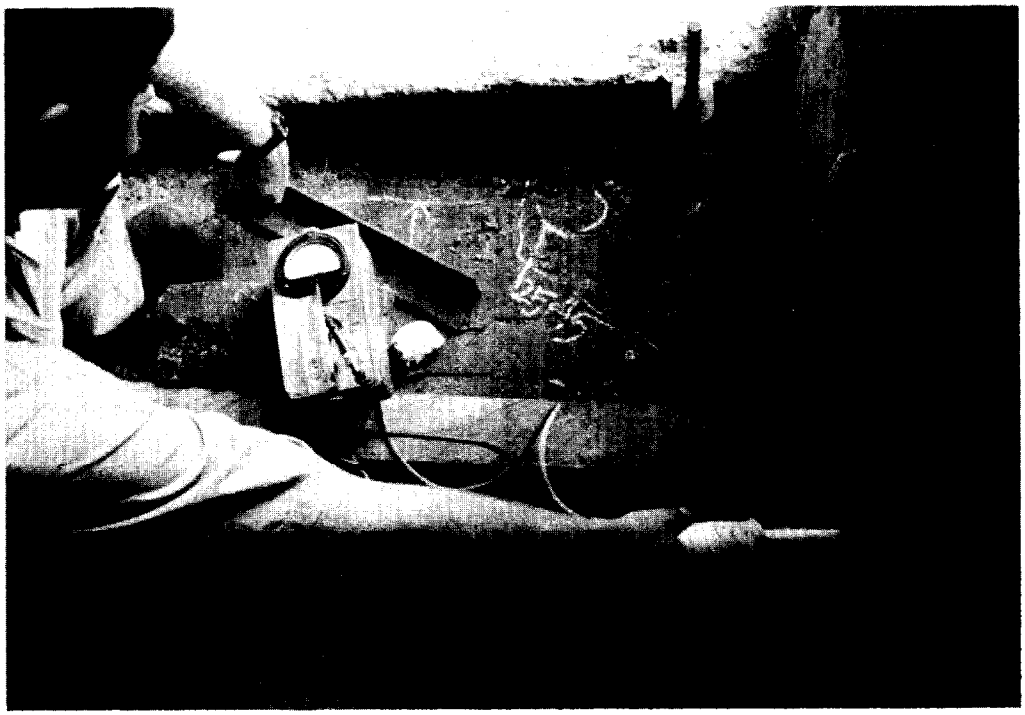

Fig. 21. View of contaminated area located north of the concrete ramp immediately inside the main entrance. The concrete entrance ramp is at the top of the photo; west wall of Building 23 is on the right.

ORNL-PHOTO 1144-92

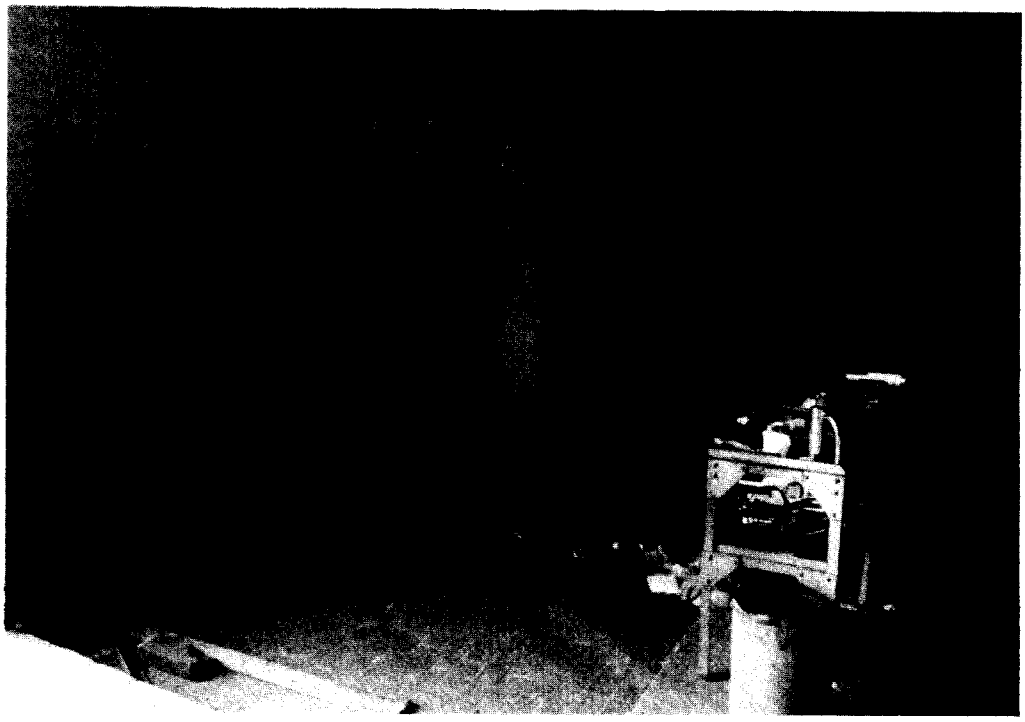

Fig. 22. View of area just north of main entrance with elevated beta-gamma levels on the wall, a ledge, and the door jamb.

ORNL-PHOTO 1145-92

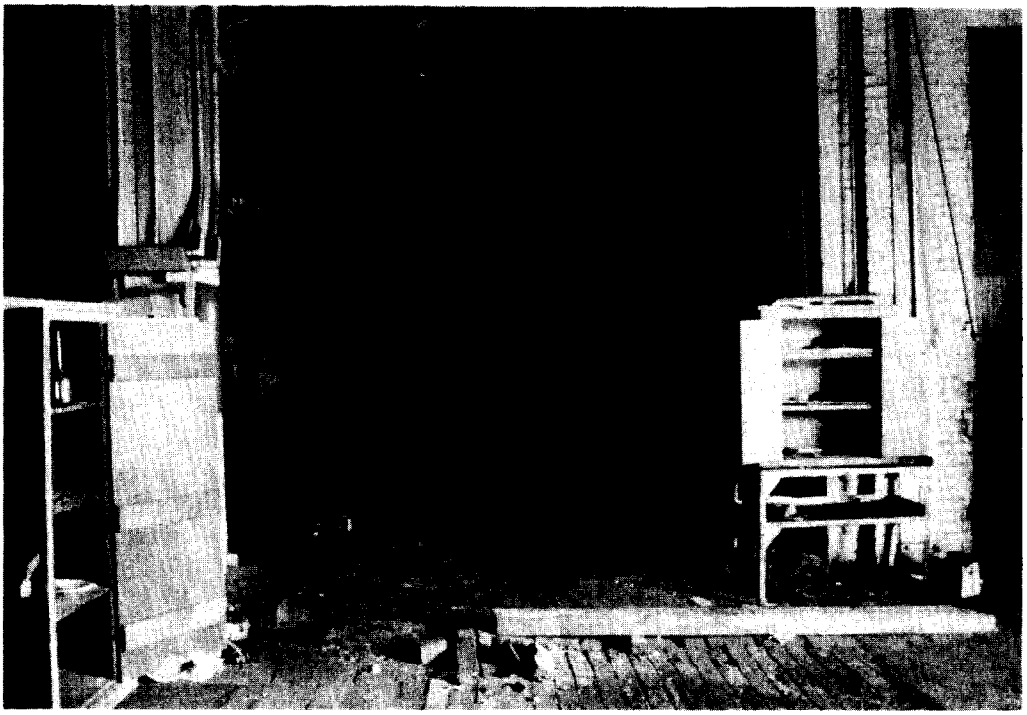

Fig. 23. View of brick facing on column B2 (right side of photo behind cabinet). Chips of the brick facing material contained 900 pCi/g ^{238}U.

Table 1. Applicable guidelines for protection against radiation
(Limits for uncontrolled areas)

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation	Indoor gamma radiation level (above background)	20 μR/h[a]
Total residual surface contamination[b]	^{238}U, ^{235}U, U-natural (alpha emitters)	
	or	
	Beta-gamma emitters[c]	
	Maximum	15,000 dpm/100 cm^2
	Average	5,000 dpm/100 cm^2
	Removable	1,000 dpm/100 cm^2
	^{232}Th, Th-natural (alpha emitters)	
	or	
	^{90}Sr (beta-gamma emitter)	
	Maximum	3,000 dpm/100 cm^2
	Average	1,000 dpm/100 cm^2
	Removable	200 dpm/100 cm^2
	^{226}Ra, ^{230}Th, transuranics	
	Maximum	300 dpm/100 cm^2
	Average	100 dpm/100 cm^2
	Removable	20 dpm/100 cm^2
Beta-gamma dose rates	Surface dose rate averaged over not more than 1 m^2	0.20 mrad/h
	Maximum dose rate in any 100-cm^2 area	1.0 mrad/h
Radionuclide concentrations in soil (generic)	Maximum permissible concentration of the following radionuclides in soil above background levels, averaged over a 100-m^2 area	5 pCi/g averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15-cm-thick soil layers more than 15 cm below the surface
	^{226}Ra	
	^{232}Th	
	^{230}Th	

Table 1 (continued)

Mode of Exposure	Exposure conditions	Guideline value
Derived concentrations	^{238}U	Site specific[d]

[a]The 20 μR/h shall comply with the basic dose limit (100 mrem/year) when an appropriate-use scenario is considered.

[b]DOE surface contamination guidelines are consistent with *NRC Guidelines for Decontamination at Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material*, May 1987.

[c]Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr, ^{228}Ra, ^{223}Ra, ^{227}Ac, ^{133}I, ^{129}I, ^{126}I, ^{125}I.

[d]DOE guidelines for uranium are derived on a site-specific basis. Guidelines of 35–40 pCi/g have been applied at other FUSRAP sites. *Source:* J. L. Marley and R. F. Carrier, *Results of the Radiological Survey at 4 Elmhurst Avenue, Colonie, New York (AL219)*, ORNL/RASA-87/117, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., February 1988; B. A. Berven et al., *Radiological Survey of the Former Kellex Research Facility, Jersey City, New Jersey*, DOE/EV-0005/29, ORNL-5734, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., February 1982.

Sources: Adapted from U.S. Department of Energy, DOE Order 5400.5, April 1990, and U.S. Department of Energy, *Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites*, Rev. 2, March 1987.

Table 2. Background radiation levels and concentrations of selected radionuclides in soil for Massachusetts

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at ground surface (μR/h)[a]	6–9	7
Concentration of radionuclides in soil (pCi/g)[a]		
^{226}Ra	0.70–1.8	1.1
^{232}Th	0.76–1.2	0.97
^{238}U	0.69–2.7	1.2

[a]Values obtained from six locations in the Beverly, Massachusetts, area.

Source: W. D. Cottrell and R. F. Carrier, *Results of the Radiological Survey at the Ventron Site, Beverly, Massachusetts*, ORNL/TM-10053, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., May 1988 and R. D. Foley and M. S. Uziel, *Radiological Survey Results at 9 and 11 Congress Street, Beverly, Massachusetts (VB002)*, ORNL/RASA-91/13, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., May 1992.

Table 3. Alpha and beta-gamma measurements at Building 23 at the site of the former Chapman Valve facility, Indian Orchard, Massachusetts

Smear sample ID[a]	Directly measured radioactivity		Removable radioactivity[d] (smears)		Location
	Alpha[b] (dpm/100 cm^2)	Beta-gamma[c] (mrad/h)	Alpha[e] (dpm/100 cm^2)	Beta-gamma[f] (dpm/100 cm^2)	
2	36	0.02–0.05	<10	<200	Block A8, high wall A8–9, ~17 ft above floor
3	<25	0.02–0.05	<10	<200	Block A8, wall B8–9
4	<25	0.02–0.05	<10	<200	Block A6, high wall B6–7, brick ~17 ft above floor
5	<25	0.02–0.05	<10	<200	Block A6, high wall A6–7, metal vent on wall adjacent to A6, ~17 ft above floor
6	*g*	0.02	<10	<200	Block A6, high wall A6–7, inside metal vent on wall adjacent to A6, ~17 ft above floor
7	71	0.05–0.08	<10	<200	Block A4, high wall B4–5
8	43	0.02–0.08	<10	<200	Block A4, high wall A4–5, ~17 ft above floor
9	57	0.05–0.08	<10	<200	Block A2, high wall A2–3, ~17 ft above floor
10	550	0.05–0.2	14	<200	Block A2, high wall B2–3, verticle window sill, contamination washed from horizontal surface
11	650	4	36	<200	Block A1, west wall, 3.5 ft N of column B1, 2 ft above floor
12	33	0.8	<10	<200	Block A1, south wall, 1.5 ft W of column B2, 1 ft above floor
13	300	2.9	32	<200	Block A2, south wall, 1 ft above floor at column B2
14	<25	0.4	<10	<200	Block A3, south wall, 1 ft above floor at column B3
15	<25	0.1	<10	<200	Block A3, south wall, 1 m above floor at column B4
16	<25	0.2	<10	<200	Block A5, south wall, on column B5

Table 3 (continued)

Smear sample ID[a]	Directly measured radioactivity		Removable radioactivity[d]		Location
	Alpha[b] (dpm/100 cm^2)	Beta-gamma[c] (mrad/h)	Alpha[e] (dpm/100 cm^2)	Beta-gamma[f] (dpm/100 cm^2)	
17	2900	0.7	<10	<200	Outside wall, 4 ft S of main (west) entrance, 1 ft above ground
A1	35	1.4	<10	<200	Block A1, bottom corner of column A2
A2	150	1.9	<10	<200	Block A2, bottom corner of column A2
A3	120	0.02–0.8	<10	<200	Block A3, 6 ft E of Column A3, 2 ft above floor, behind radiator
A4	63	0.2	<10	<200	Block A4, ledge at corner of column A5
A5	<25	0.4	<10	<200	Block A5, 13 ft E column A5, 3 ft above floor
A6	28	0.4	90	<200	Block A6, north wall, 11 ft E of column A6, 2 ft above floor
A7	<25	0.02–0.05	<10	<200	Block A7, north wall, wood wall 6 ft E of column A7, 3 ft above floor
A8	<25	0.02–0.08	<10	<200	Block A8, wood wall 7 ft E of column A8, 3 ft above floor
A11	<25	0.3	<10	<200	Block A11, 12 ft E of column A11, 6 ft above floor, metal box on wall
A12	<25	0.02–0.05	<10	<200	Block A12, 9 ft E of column A12, 2 ft above floor
A13	<25	0.02–0.05	<10	<200	Block A13, 8 ft E of column A13, 2 ft above floor
A15	<25	0.02–0.05	<10	<200	Block A15, 6 ft E of column A15, 1 ft above floor

Table 3 (continued)

Smear sample ID[a]	Directly measured radioactivity		Removable radioactivity[d]		Location
	Alpha[b] (dpm/100 cm^2)	Beta-gamma[c] (mrad/h)	Alpha[e] (dpm/100 cm^2)	Beta-gamma[f] (dpm/100 cm^2)	
A16	<25	0.02–0.05	<10	<200	Block A16, 6 ft E of column A16, 2 ft above floor
A17	28	0.02–0.05	<10	<200	Block A17, 7 ft E of column A17, 3 ft above floor

[a]Some sample locations are shown on Figs. 9–19 (p. 17-27, Smear #).
[b]Instrument-specific minimum detectable activity (MDA) level = 25 dpm/100 cm^2.
[c]MDA = 0.01 mrad/h.
[d]Removable radioactivity reported as net disintegration rates. Background radiation levels have been subtracted.
[e]MDA = 10 dpm/100 cm^2.
[f]MDA = 200 dpm/100 cm^2.
[g]Not measured.

Table 4. Concentrations of radionuclide in soil, dust, and debris samples collected at the site of the former Chapman Valve facility, Indian Orchard, Massachusetts

Sample[a]	Location	Radionuclide concentration (pCi/g)[b]		
		^{226}Ra	^{232}Th	^{238}U
		Soil Samples		
S1[c]	West of Bldg. 23	0.33±0.01	0.4 ±0.02	<1.4
B1[d]	Southeast corner of Bldg. 23	1.0 ±0.03	1.4 ±0.06	1.9± 0.8
		Dust and debris samples		
M1[e]	Concrete floor anchor, grid block A5	<48	*f*	36,000 ±400
M2[g]	Concrete floor anchor, grid block A5	<0.9	*f*	220 ± 10
M3	Overhead beam No. 1	0.75± 0.1	0.76±0.2	250 ± 50
M4	Overhead beam No. 1	<0.8	*f*	340 ± 6
M5	Overhead beam No. 1	<0.5	*f*	170 ± 5
M6	Overhead beam No. 2	<0.8	*f*	310 ± 6
M7	Overhead beam No. 3	0.43± 0.09	<0.3	130 ± 5
M8	Overhead beam No. 4	0.7 ±0.07	0.5 ±0.1	48 ± 5
M9	Overhead beam No. 4	0.6 ±0.1	0.7 ±0.1	95 ± 2
M10	Overhead beam No. 6	0.4 ±0.07	0.3 ±0.1	25 ± 7
M11[h]	Composite floor debris, grid block A9	0.6 ±0.1	0.6 ±0.1	240 ± 20
M12	Overhead beam No. 7	0.6 ±0.1	0.7 ±0.2	330 ± 10
M13	Overhead beam No. 7	0.22±0.05	0.23±0.07	60 ± 5
M14	Overhead beam No. 5	0.4 ±0.06	0.5 ±0.07	35 ± 5
M15	Overhead beam No. 8	0.4 ±0.08	0.5 ±0.1	350 ± 50
M16	Overhead beam No. 9	0.16±0.03	0.11±0.03	16 ± 4
M17	Overhead beam No. 9	0.6 ±0.08	0.4 ±0.1	57 ± 10
M18	Overhead beam No. 10	0.20±0.04	0.20±0.07	65 ± 7
M19	Overhead beam No. 14	0.6 ±0.07	0.6 ±0.1	50 ± 5
M20	Overhead beam No. 15	0.6 ±0.1	0.7 ±0.2	37 ± 5

Table 4 (continued)

Sample[a]	Location	Radionuclide concentraation (pCi/g)[b]		
		^{226}Ra	^{232}Th	^{238}U
M21	Overhead beam No. 16	0.6 ±0.1	0.7 ±0.2	35 ± 2
M22	Overhead beam No. 17	0.7 ±0.08	0.8 ±0.1	20 ± 5
M23	Overhead beam No. 18	0.7 ±0.08	0.6 ±0.1	20 ± 2
M24	Overhead beam No. 19	0.6 ±0.07	0.7 ±0.1	19 ± 1
M25	Overhead beam No. 20	<1.0	<1.0	10 ± 3
M26	Overhead beam No. 23	0.5 ±0.03	0.6 ±0.06	6.0± 1.5
M27	Moveable overhead crane, grid block A23	0.2 ±0.04	0.2 ±0.04	10 ± 3
M28	Overhead beam No. 26	<1.5	*f*	6.4± 0.3
M29	Overhead beam, grid block A2	<5.0	*f*	1,300 ±100
M30	High-wall window sill, grid block A2	<3.0	*f*	1,300 ± 50
M31[h]	West door ramp, north corner	<1.0	<1.0	120 ± 10
M32	Chips from brick facing, column B2	<1.4	*f*	900 ± 20

[a]Sample locations are shown on Fig. 8 (p. 16).

[b]Indicated counting error is at the 95% confidence level (±2σ).

[c]Systematic soil sample (S) taken at location irrespective of gamma exposure rates. Sample depth 0–8 cm.

[d]Biased soil sample (B) taken from area with elevated gamma exposure rates. Sample collected 3 ft under edge of concrete slab. Sample depth 0–15 cm.

[e]Sample depth 0–1 cm.

[f]Not measured.

[g]Sample depth 1–3 cm.

[h]Sample depth 0–2 cm.

Table 5. Comparison of ^{238}U concentrations in selected dust samples from overhead beams with DOE guideline value for removable surface contamination

Sample[a]	Location	^{238}U		Percent of guideline value
		(pCi/g)	(dpm/100 cm^2)	
M3	Overhead beam No. 1	250	5,300	530
M4	Overhead beam No. 1	340	3,600	360
M5	Overhead beam No. 1	170	2,000	200
M6	Overhead beam No. 2	310	3,500	350
M7	Overhead beam No. 3	130	4,000	400
M8	Overhead beam No. 4	48	1,500	150
M9	Overhead beam No. 4	95	2,800	280
M10	Overhead beam No. 6	25	1,000	100
M12	Overhead beam No. 7	330	9,000	900
M13	Overhead beam No. 7	60	2,600	260
M14	Overhead beam No. 5	35	1200	120
M15	Overhead beam No. 8	350	12,000	1,200
M16	Overhead beam No. 9	16	900	90
M17	Overhead beam No. 9	57	1,300	130
M18	Overhead beam No. 10	65	2,800	280
M19	Overhead beam No. 14	50	1,400	140
M22	Overhead beam No. 17	25	500	50
M23	Overhead beam No. 18	20	530	53
M24	Overhead beam No. 19	19	490	49
M26	Overhead beam No. 23	6	200	20
M27	Moveable overhead crane, grid block A23	10	1,600	160
M28	Overhead beam No. 26	6	130	13
M29	Overhead beam, grid block A2	1,300	1,400	140

[a]Samples collected at the site of the former Chapman Valve facility, Indian Orchard, Massachusetts. Sample locations are shown on Fig. 8 (p. 16).

Table 6. Alpha, beta-gamma, and gamma radiation measurements at dust and debris sample locations at the former Chapman Valve facility, Indian Orchard, Massachusetts

		Alpha (dpm/100 cm^2)	Beta-gamma (mrad/h)		Gamma (μR/h)
Sample[a]	Location	After collection	Prior to collection	After collection	Prior to collection
M1 and M2[b]	Concrete floor anchor under wooden flooring, grid block A5	110	1	4	11 17[c]
M3	Overhead beam No. 1	200	0.2	0.07	5 10[d]
M4	Overhead beam No. 1	170	0.5	0.5	4
M5	Overhead beam No. 1	300	0.4	0.3	6
M6	Overhead beam No. 2	260	0.3	0.3	4
M7	Overhead beam No. 3	43	0.2	0.2	5
M8	Overhead beam No. 4	200	0.06	0.06	4
M9	Overhead beam No. 4	400	0.2	0.4	5
M10	Overhead beam No. 6	46	0.05	0.06	4
M11	Composite floor debris, grid block A9	43[e]	0.02-0.5	*f*	*f*
M12	Overhead beam No. 7	320	0.2	0.06	4
M13	Overhead beam No. 7	180	0.03	0.05	5
M14	Overhead beam No. 5	210	0.08	0.2	4
M15	Overhead beam No. 8	990	0.2	0.1	5
M16	Overhead beam No. 9	300	0.02	0.09	4

Table 6 (continued)

Sample[a]	Location	Alpha (dpm/100 cm^2)	Beta-gamma (mrad/h)		Gamma (μR/h)
		After collection	Prior to collection	After collection	Prior to collection
M17	Overhead beam No. 9	65	0.10	0.06	4
M18	Overhead beam No. 10	200	0.1	0.07	5
M19	Overhead beam No. 14	*f*	0.06	0.2	3
M20	Overhead beam No. 15	160	0.06	0.06	3
M21	Overhead beam No. 16	180	0.05	0.06	4
M22	Overhead beam No. 17	220	0.06	0.04	4
M23	Overhead beam No. 18	65	0.03	0.03	4
M24	Overhead beam No. 19	65	0.04	0.03	3
M25	Overhead beam No. 20	140	0.03	0.04	2
M26	Overhead beam No. 23	110	0.03	0.03	2
M27	Moveable overhead crane, grid block A23	55	0.05	0.08	2
M28	Overhead beam No. 26	<25	0.02	0.02	2
M29	Overhead beam, grid block A2	*f*	0.6	0.3	*f*
M30	High-wall window sill, grid block A2	*f*	2	*f*	*f*

Table 6 (continued)

Sample[a]	Location	Alpha (dpm/100 cm^2)	Beta-gamma (mrad/h)		Gamma (μR/h)
		After collection	Prior to collection	After collection	Prior to collection
M31	West door ramp, north corner	*f*	0.2-1.2	*f*	32
M32	Chips from brick facing, column B2	300	2.9	*f*	*f*

[a]Sample locations are shown on Fig. 8 (p. 16).
[b]Dust samples collected inside concrete floor anchor previously used to anchor machinery. Hole was too small to accommodate measurement instruments. All alpha, beta-gamma, and gamma measurements taken at top of hole.
[c]Gamma measurement at 1 m prior to sample collection.
[d]Gamma measurement on contact after sample collection.
[e]Prior to sample collection.
[f]Not measured.

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