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Formerly Utilized MED/AEC Sites Remedial Action Program

Radiological Survey of the Former Horizons Inc., Metal Handling Facility, Cleveland, Ohio

February 1979

Final Report

Prepared for

U.S. Department of Energy
Assistant Secretary for Environment
Division of Environmental Control Technology

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PREFACE

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

This report contains the results of a survey of the current radiological condition of the former Harizons, Inc. Metal Handling Facility, Cleveland, Ohio. Results of this radiological survey show that residual radioactive contamination exists at this site and occupants of this site are receiving small radiation exposures in excess of Federal guidelines for exposure to the general public.

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

R. W. Leggett
W. D. Cottrell
W. H. Shinpaugh
R. W. Doane
F. F. Haywood
W. M. Johnson

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R. W. Leggett, W. D. Cottrell, F. F. Haywood,
W. H. Shinpaugh, R. W. Doane, and W. M. Johnson

Health and Safety Research Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

ABSTRACT

The results of a radiological survey of the former Horizons, Inc., metal handling facility in Cleveland, Ohio, are presented in this report. During the 1940's and early 1950's, two of the three buildings on this site (Buildings B and C) were used for the production of granular thorium metal. The survey included measurements related to the following: fixed and transferable alpha and beta-gamma contamination levels on the surfaces in Buildings B and C and on the roofs of these buildings; external gamma radiation levels at 1 m above the floors and grounds on and near the property; radionuclide concentrations in soil, water, and other materials collected from surfaces and drains inside Buildings B and C, from beneath the floor in Building C, and from outdoor locations on and near the site; and thoron (^{220}Rn) daughter concentrations in the air in Buildings B and C. Elevated concentrations of ^{232}Th, ^{228}Ra, ^{228}Th, and ^{230}Th were found in some samples. Alpha and beta-gamma contamination levels exceeded applicable guideline limits in some areas of Buildings B and C. External gamma radiation levels, approximately 10 times the average background level, were measured at isolated points in and near

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Building B. Thorium B (^{212}Pb) concentrations in air in Building B were near the Radioactivity Concentration Guide (RCG) level. Most of the elevated radiation levels were found indoors in areas presently used for storage. Outdoors on and near the site, significant radiation levels were found only near the east wall of Building B.

INTRODUCTION

At the request of the Department of Energy (DOE), [then the Energy Research and Development Administration (ERDA)], a radiological survey was conducted at the site of Horizons' former metal handling facility located at 2905 East 79th Street in Cleveland, Ohio. Clecon Metals, Inc., the present occupant, employs approximately 60 workers (mostly in Building C) for the production of gaskets and for the lamination of various materials. A plan view of the site and adjacent property is shown in Fig. 1, and photographs of the site are provided in Appendix I. The site is in an industrial area which is sparsely populated. There are a few dwellings, however, on adjacent property. On the lot labelled "residential" in Fig. 1, there is a combination grocery store and residence which fronts on East 81st Street; the only other structure on this lot is a garage. The block across East 81st Street from the site is sparsely populated, but there are several houses which have been abandoned or demolished. Across East 79th Street from the site, there are two dwellings just south of the parking lot shown in Fig. 1, and there is one dwelling just north of this parking lot.

During the 1940's and early 1950's, two buildings at the Horizons metal handling facility were used for the production of granular thorium metal from an initial feed of thorium nitrate tetrahydrate. The feed material was brought into the wet plant known as Building C, (see Fig. 1), weighed into batches, and placed in a dissolving tank. The thorium

nitrate was converted to ammonium thorium chloride (ATC), blended with NaCl, and then transferred as a calcined salt to the dry plant (Building B, Fig. 1) where thorium metal was produced by an electrolytic process. The metal was chipped from the cathode, crushed, washed, dried, and packaged in Building B for shipment from the plant. Building B is presently used for storage of nonradioactive materials, and Building C is used for storage and receiving of nonradioactive materials and also contains several offices.

An air hygiene survey performed in December 1954 by the Health and Safety Laboratory (HASL)[1] revealed elevated concentrations of airborne thorium in both Buildings B and C. In Building C, highest concentrations of airborne thorium occurred during the chipping, weighing, sampling, and crushing of ATC and during the transfer of NaCl and ATC from mixing drums to polyethylene bags and drums. In Building B, highest airborne thorium concentrations were measured during metal recovery operations involving removal of material from a heating element, chipping and crushing salt recovered from the furnace, brushing the Th cathodes, chipping off the Th metal from the cathode, and handpacking chipped Th metal into jars. The maximum allowable air concentration of thorium alpha at the date of the HASL survey[1] was 100 dpm/m^3. Airborne concentrations for some of the above-noted operations ranged from a factor of 18 to a factor of 377 greater than the maximum allowable concentration. These results indicated a potential for contamination of overhead and upper wall surfaces due to airborne thorium, and contamination of floors and lower walls was possible from the routine handling of thorium. It appears that much of the possibly contaminated material has been removed or covered due to substantial construction modifications since the thorium operations. In particular, Building C has been extended on

the south side to take in an old alley, and an area which is known to have been contaminated in the past (the old storage room) has a new concrete floor. Also, several sections of walls, floors, and ceilings in Buildings B and C have been repaired or replaced since the thorium operations.

The present survey was undertaken to characterize the existing radiological status of the property. It was conducted by five members of the Health and Safety Research Division, Oak Ridge National Laboratory (ORNL) during the periods February 7-18 and March 21-22, 1977. The survey included:

1. measurement of fixed alpha contamination and of transferable alpha and beta contamination on surfaces inside Buildings B and C, and measurement of fixed alpha contamination on the roofs of these buildings;
2. measurement of beta-gamma dose rates at 1 cm from surfaces inside Buildings B and C, on the roofs of these buildings, and outdoors on the Clecon Metals property;
3. measurement of external gamma radiation levels at 1 m above the floor surfaces inside Buildings B and C and outdoors on the Clecon Metals property;
4. collection of dirt and other materials from surfaces in the most-contaminated areas in Buildings B and C for determination of ^{232}Th, ^{230}Th, ^{228}Ra, and ^{228}Th concentrations;
5. drilling of core holes through new concrete floors inside Building C in areas known to be contaminated beneath the concrete; collection of soil samples from these core holes; and measurement of the gamma radiation level as a function of depth in each hole;

6. measurement of thoron (^{220}Rn) daughter concentrations in the air in Buildings B and C;
7. investigation of radioactivity in drains, including collection of mud or dirt from drains, measurement of gamma radiation inside drains, and measurement of alpha activity directly over drains;
8. collection of water samples from the site and from the city water system for the measurement of radionuclide concentrations; and
9. collection of soil samples outdoors on the site for the measurement of radionuclide concentrations.

"Contamination," as used in this report, refers to radioactive materials either on or below surfaces, whether fixed or removable. "Fixed contamination" is defined as radioactive material on or below surfaces which cannot be removed by standard smear techniques. Survey meter readings made on surfaces are used to estimate the levels of total surface contamination while standard smear techniques are used to estimate the levels of transferable contamination.

SURVEY TECHNIQUES

Measurement of Alpha and Beta Contamination Levels and Beta-Gamma Dose Rates

Direct readings of alpha contamination were taken on the floors, walls, ceilings, and supports throughout Buildings B and C and on the roofs of these buildings. Points of measurement are described below. Measurements were made with alpha scintillation survey meters described in Appendix II.

Standard smear techniques were used to measure transferable alpha and beta contamination levels throughout Buildings B and C. Smear samples were taken at approximately 700 points in the buildings, with samples being taken at (roughly) uniformly spaced intervals within each area.

Beta-gamma dose rates were measured in the buildings at approximately the same locations at which alpha contamination was measured. Direct readings were taken at approximately 1 cm from the surfaces, with Geiger-Mueller (G-M) survey meters which are described in Appendix II. Percentagewise, largest errors for the G-M meter occur near background levels, at which the G-M meter typically shows readings in the range of 0.01 to 0.05 mrad/hr. Readings in this range cannot be accurately reproduced. However, for purposes of averaging and comparing, all readings below 1 mrad/hr are reported to the nearest hundredth of a millirad per hour.

Unless otherwise specified in the survey results, a direct measurement of alpha or beta-gamma contamination reported for the floors and walls reflects an average condition over an area of not more than 1 m^2. A direct measurement reported for overhead surfaces (rafters, ceilings, ledges, etc.) generally represents a maximum of several individual instrument readings with individual instrument readings reflecting conditions over approximately 100 cm^2. For many overhead locations (for example, on supports or ledges) averaging over a square meter was not practical. All readings reported for exterior surfaces of a building reflect individual instrument readings (unless otherwise specified).

For the direct measurement of alpha contamination levels and beta-gamma dose rates, separate survey schemes were developed for each area.

The number and concentration of survey points were determined in large part by results of a preliminary survey. For example, the preliminary survey had indicated that elevated alpha and beta contamination was widespread in Building B. In that building, the floor was divided into survey squares of area 1 m^2 each. In alternate squares (see, e.g., Fig. 2) five direct alpha measurements were taken (one at each corner and one at the center), and the average of these measurements was recorded as the average for that square. Beta-gamma dose rates were averaged in a similar manner. In addition, maximum contamination levels were determined for each survey square by scanning.

In Building C, measurements were usually taken at closely spaced and (roughly) uniformly distributed points, in addition to locations at which elevated alpha and beta-gamma contamination levels are typically found (such as corners, ledges, cracks, and entrance areas).

Measurement of Thoron Daughters in the Buildings

Air samples were taken in the buildings for the measurement of ^{220}Rn daughters. Air was pumped for intervals varying from 1 to 15 hr, at approximately 12 liters/min through a membrane filter with a maximum pore size of 0.4 μm. The amounts of ^{220}Rn daughters on the filters were estimated by use of an alpha spectrometry technique described in Appendix III.

Measurement of External Gamma Radiation Levels

External gamma radiation levels were measured with NaI scintillation survey meters described in Appendix II. Readings were taken at 1 m above the floor throughout Buildings B and C, typically at intervals of

2 to 4 m. Outdoor readings were taken at 1 m above the surface at points indicated in Fig. 3. Scintillation survey meter measurements are indicative of the instantaneous exposure rates at the points of measurement.

Measurement of Nuclide Concentrations in Soil

Holes were drilled with a motorized drilling rig to depths varying from 3 to 9 ft inside Building C at the six locations shown in Fig. 4. (See also Fig. I-J.) An auger with a 5-in. inside diameter was used for the drilling. Gamma radiation was measured at various depths in the core holes by lowering a scintillation probe inside the auger. This "logging" of the core holes was done as a first step in determining the depth of contamination in the soil beneath the floor. A total of 21 soil samples were collected from these core holes. Surface soil samples were collected outdoors on the site at locations shown in Fig. 3, and several scrapings and dirt samples were taken from surfaces inside the buildings. Some of the samples were taken at random locations. However, in many cases, samples were taken at points with elevated gamma radiation; this was done in an effort to determine highest concentrations of thorium and thorium daughters on the site.

The soil samples were packaged in plastic bags before being returned to Oak Ridge, where they were dried for 24 hr at 110°C and then pulverized to a particle size no greater than 500 μm in diameter. Next, aliquots from each sample were transferred to plastic bottles, weighed, and counted using a Ge(Li) detector. The spectra obtained were analyzed by computer techniques. A description of the Ge(Li) detector and soil counting technique is given in Appendix IV. Concentrations of ^{232}Th

were determined for all soil samples. Scrapings and sludge samples were analyzed for ^{232}Th, ^{230}Th, ^{228}Ra, and ^{228}Th by the ORNL Analytical Chemistry Division using radiochemical techniques. It was not anticipated that ^{230}Th would be present in samples collected on this site since no ores containing uranium and its daughters were processed. However, it is a possibility that raffinates from pitchblendes and other ores served as a source of thorium and that the incoming feed material, thorium nitrate tetrahydrate, contained significant quantities of ^{230}Th as well as ^{232}Th.

Measurement of Radioactivity in Water

Water samples were collected from drains inside Building C at locations 2 and 3 shown in Fig. 5. In addition, a sample was taken from the city water system. The samples were analyzed by the ORNL Analytical Chemistry Division for ^{232}Th and ^{228}Th. Radionuclides were separated sequentially and analyzed using radiochemical techniques.

Measurement of Radioactivity in Drains

For the determination of radioactivity in solid matter in drains, three types of measurements were used. First, alpha activity was measured directly over the drains with alpha scintillation detectors to determine relative quantities of thoron emanation from the drains. Next, gamma scintillation probes were lowered into drain openings to measure gamma radiation inside these drains. Finally, mud, dirt, and samples of scale were taken from the drains, returned to ORNL, and analyzed for specific radionuclide concentrations. Drain locations in Buildings B and C are shown in Figs. 5 and 6.

SURVEY RESULTS

Background Radiation Levels and Nuclide Concentrations

Concentrations of ^{232}Th in background soil samples taken 10 to 100 mi from the Horizons site were in the range 0.7 to 1.2 pCi/g. This is typical for most of the U.S. Except for ^{232}Th, nuclides in the ^{232}Th chain have half-lives of at most a few years. Beginning with purified ^{232}Th, all nuclides in the thorium chain would attain more than 90% of their equilibrium activities after 30 years. Background concentrations of nuclides in the ^{238}U chain are typically less than 2 pCi/g.

Background external gamma radiation levels at 1 m above the surface in the area around the site were generally in the range 7 to 15 μR/hr. Background levels of beta-gamma dose rates, as measured with the G-M meters used at this site, are typically in the range 0.01 to 0.05 mrad/hr. Background levels for direct alpha measurements of the type made at this site are negligible.

All direct meter readings reported here represent gross readings; background radiation levels have not been subtracted. Similarly, background levels have not been subtracted from radionuclide concentrations measured in environmental samples and building materials. For the reporting of transferable alpha- and beta-contamination levels, average background counts were determined for the smear counters (at the place of counting), and these background counts were subtracted from gross counts.

Results of Analyses of Surface Materials and Soil Samples

Concentrations of ^{232}Th, ^{228}Ra, ^{228}Th, and ^{230}Th in dirt and other materials taken from drains, floors, walls, and ceilings of Buildings B and C are given in Table 1 for locations shown in Fig. 7. The results indicate that significant quantities of all four nuclides are present on some surfaces of the site. (It should be noted that surface samples were not taken at random points; rather, an effort was made to collect samples from the most-contaminated surfaces on the site.) It is also indicated by these results that ^{232}Th, ^{228}Ra, and ^{228}Th are approximately in equilibrium on the surfaces investigated.

Soil samples were taken from six core holes drilled through floors which have been built since the thorium operations. These holes were drilled in the old storage room*, and in a section of Building C built over an old alley. Locations for these six core holes are shown in Fig. 4. Sample analyses indicated that high concentrations of ^{232}Th (up to 591 pCi/g) are present in soil beneath the old storage room (see Table 2), and that contamination extends to a depth of six feet or more in some places.

Concentrations of nuclides measured in samples taken outdoors on and near the Clecon property are given in Table 3; location numbers in this table refer to points shown in Fig. 3. In a sample taken just east of Building B, concentrations of ^{232}Th and ^{228}Ra in excess of 40 pCi/g were measured. Concentrations of ^{232}Th and ^{228}Ra in all other outdoor surface samples were near background levels.

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*At the time of the thorium operations at Horizons, this was an outdoor area used for storage. Since that time, a room (referred to in this report as the "old storage room") has been built over this area.

Alpha and Beta Contamination in the Buildings

In guidelines issued by the U.S. Nuclear Regulatory Commission (NRC) for the release of property for unrestricted use, strictest limits for surfaces contaminated with alpha emitters apply to ^{228}Th, among other nuclides (see Appendix V or ref. 2). The average and maximum limits* for direct readings of alpha contamination on surfaces contaminated with ^{228}Th are 100 dpm/100 cm^2 and 300 dpm/100 cm^2, respectively; transferable alpha contamination should not exceed 20 dpm/100 cm^2. Strictest limits for transferable beta contamination (20 dpm/100 cm^2) apply to ^{228}Ra. Although purified ^{232}Th compounds were brought onto this site, there has been sufficient time for daughters of ^{232}Th to attain almost complete equilibrium with their parent. (Radium-228, ^{228}Ac, and ^{228}Th, in that order, are the first three daughter nuclides in the ^{232}Th chain. Their half-lives are 6.7 years, 6.13 hr, and 1.91 years, respectively. Thirty years is sufficient time for each of these daughters to attain more then 90% equilibrium with ^{232}Th.) Analyses of materials taken from the surfaces indicate that ^{232}Th, ^{228}Ra, and ^{228}Th are approximately in equilibrium at sampling points (see Table 1). Since NRC limits are at least 10 times more restrictive for ^{228}Th and ^{228}Ra than for ^{232}Th, it appears that the limits for ^{228}Th and ^{228}Ra should be applied to this site.

Results of direct alpha measurements are reported in Table 4. Elevated alpha contamination levels were discovered throughout Rooms 1, 2, 3, and 4 of Building B, and in some areas of Rooms 5, 6, 7, and 11 in

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*Measurements may not be averaged over more than one square meter. The maximum contamination level applies to an area of not more than 100 cm^2.

that building. Direct alpha measurements averaged over survey squares of 1 m^2 each were in the range 100 to 5000 dpm/100 cm^2 over approximately 85% of the floor area in Building B (see Fig. 8). Highest direct alpha measurements were recorded in the northeast corner of Room 1 of Building B, where several individual instrument readings were in the range of 10,000 to 200,000 dpm/100 cm^2 (see Fig. 9). Many of the horizontal surfaces (such as beams and ledges) along walls in Rooms 1, 2, 3, and 4 showed alpha contamination levels in excess of NRC limits; vertical wall surfaces showed little alpha contamination in most areas. Overhead surfaces in Rooms 1, 2, 3, and 4 showed direct alpha readings in excess of NRC limits (see Table 4).

Elevated alpha contamination levels in Building C were observed in the "flammable storage room" (Fig. 10) and in the "old storage room" (Fig. 11). In the flammable (solvent) storage room, direct alpha readings averaged more than 100 dpm/100 cm^2 in some areas, principally on window ledges, lower walls, and on the floor near the walls (see Fig. 10 and Table 4). The maximum observed direct alpha reading in this room was 40,000 dpm/100 cm^2; this reading was taken at the bottom of the east wall. In the old storage room, alpha contamination was found only near the bottom of the north wall, where readings as high as 4200 dpm/100 cm^2 were recorded. These high readings near the base of walls are probably due in part to residual ^{232}Th which was swept or otherwise deposited in cracks where floors and walls meet. It appears that a significant portion of the high readings is attributable to ^{220}Rn gas emanating from the cracks. In the large open area of Building C known as the

"old process area" (Fig. 1) all direct alpha readings were less than 100 dpm/100 cm^2.

Results of smear samples taken in Buildings B and C are given in Table 5. Levels of transferable alpha and/or beta contamination exceeding NRC guidelines were found in some areas of all rooms in Building B except Rooms 8 and 10. Highest transferable alpha contamination levels (up to 500 dpm/100 cm^2) were measured on floor, wall, and overhead surfaces of Rooms 1 and 2 and on overhead surfaces of Room 3. In Building C, transferable alpha contamination levels exceeded NRC limits only in the flammable storage room; levels there did not exceed 40 dpm/100 cm^2. Transferable beta contamination levels generally followed the same pattern as transferable alpha contamination levels and were as high as 900 dpm/100 cm^2 on overhead surfaces in Building B.

Results of direct alpha measurements taken on the roofs of Buildings B and C are given in Table 6 for locations shown in Fig. 3. Measurements in Table 6 represent individual instrument readings rather than average measurements; these readings were taken at randomly selected points. Results of direct alpha measurements suggest that most of the roof surfaces of the two buildings contain alpha contamination in excess of 100 dpm/100 cm^2.

Beta-Gamma Dose Rates

Beta-gamma dose rates were measured throughout Buildings B and C, on the roofs of these buildings at points R1-R18 shown in Fig. 3, and outdoors at locations 1 through 27 shown in Fig. 3. Results for the interior surfaces of the buildings are presented in Table 7. In Room 1

of Building B, readings (averaged over 1 m^2) exceeded 0.20 mrad/hr at some points on the overhead surfaces and on the floor (see Fig. 12); highest individual instrument readings (up to 6.8 mrad/hr) were recorded on the floor in the northeast corner of the room (see Fig. 13). In all other areas of Building B, beta-gamma dose rates were less than 0.20 mrad/hr. In Building C, beta-gamma dose rates exceeded 0.2 mrad/hr only in the southeast corner of the flammable storage room (see Fig. 14). The highest observed beta-gamma dose rate in the old storage room was 0.11 mrad/hr (see Fig. 15).

Outdoors on the site, measurements of beta-gamma dose rates did not exceed 0.09 mrad/hr (see Table 8 and Fig. 3). On the roofs of Buildings B and C, all beta-gamma dose rates were in the range 0.02 to 0.04 mrad/hr (see Table 6 and Fig. 3).

External Gamma Radiation Levels

External gamma radiation levels were measured at 1 m above the floor inside the buildings on the site and outdoors at 1 m above the ground at locations 1-34 shown in Fig. 3. Highest levels of external gamma radiation were measured in the northeast corner of Room 1 in Building B, where readings from 30 to 110 μR/hr were recorded (see Fig. 16). Readings in most other areas of Building B were in the range 7 to 30 μR/hr (Fig. 16). External gamma readings were slightly elevated in the old storage room (Fig. 17) and in the flammable storage room (Fig. 18) in Building C. Readings in the large open area and office of Building C were generally in the range of 10 to 16 μR/hr, and indoor readings on the remainder of the site did not exceed 10 μR/hr.

Outdoor measurements of external gamma radiation are listed in Table 8 for locations shown in Fig. 3. Highest readings (up to 90 μR/hr at ground level and up to 28 μR/hr at 1 m above the surface) were recorded in the parking area just east of Building B. In the remainder of the outdoor areas on and near the site, readings were generally in the range 10 to 18 μR/hr.

Radioactivity in Drains

Results of measurements of alpha activity above open drains, gamma radiation levels inside these drains, and concentrations of ^{232}Th and ^{230}Th in samples taken from the drains are presented in Table 9; locations are shown in Figs. 5 and 6. These results indicate that some of the drains contain significant quantities of ^{232}Th and ^{230}Th. It also appears that appreciable quantities of thoron (^{220}Rn) are emanating from many of the drains. Water found in drains in Building C contained only small traces of ^{232}Th and ^{228}Th (see Table 10).

Thoron Daughter Concentrations in Air

Concentrations of Thorium B (^{212}Pb) and Thorium C (^{212}Bi) in air were measured at the points shown in Fig. 19. In an air sample taken in Room 2 of Building B (location 9), the concentration of Thorium B was 0.5 pCi/liter, which is 83% of the (non-occupational) maximum permissible concentration in air (RCG_a) for that nuclide.[3] Concentrations of Thorium C in all samples were at least an order of magnitude below the RCG_a (see Table 11).

To check whether significant airborne concentrations of long-lived alpha emitters were present in Buildings B and C, counts were made

(using alpha spectrometry techniques) of the air sampling filters used at locations 1, 2, 5, and 9 (Fig. 19), after the short-lived alpha had had sufficient time to become negligible. The only potentially significant counts on these filters were near the 5.3 to 5.4 MeV energy range and apparently resulted from ^{228}Th collected on the filter. It was estimated from these counts that concentrations of ^{228}Th in air at these sampling locations, at the time of sampling, were in the range 1×10^{-14} μCi/ml to 4×10^{-14} μCi/ml. The guide value for ^{228}Th in air given in 10 CFR 20, Appendix B and ERDAM 0524, Annex A is 2×10^{-13} μCi/ml (assuming insolubility).

SUMMARY

A radiological survey was conducted at the site of the former Horizons Metal Handling Facility in Cleveland, Ohio. Records indicate that two buildings on this site were used for the production of granular thorium metal from an initial feed of thorium nitrate tetrahydrate. Some samples of soil and other materials taken from the site showed elevated concentrations of ^{232}Th, ^{228}Ra, ^{228}Th, and ^{230}Th.

Concentrations of ^{232}Th (up to 4890 pCi/g), and ^{230}Th (up to 752 pCi/g) were found in dirt and other materials taken from drains and surfaces inside Buildings B and C. Radium-228 and ^{228}Th were approximately in equilibrium with ^{232}Th in most samples taken on the site. The soil beneath the old storage room in Building C was found to be contaminated to a depth of six feet in some places. This area was apparently used originally for storage of radioactive materials, and a new floor has been built since the thorium operations. Outdoors on the

site, significant concentrations of nuclides were measured only in samples taken just east of Building B. No contamination was found off of the site.

In NRC guidelines[2] for release of property for unrestricted use, the most restrictive values given for surface contamination apply to ^{228}Ra and ^{228}Th, among other radionuclides. The survey results indicate that these are two of the principal radioactive contaminants on the site. U.S. Nuclear Regulatory Commission guidelines would require that direct alpha readings for surfaces should not exceed 300 dpm/100 cm^2 at any point or 100 dpm/100 cm^2 averaged over 1 m^2. Maximum and average beta-gamma dose rates should not exceed 1 mrad/hr and 0.2 mrad/hr, respectively. Transferable alpha or beta contamination levels for surfaces should not exceed 20 dpm/100 cm^2. Some of these criteria are exceeded in parts of Buildings B and C, particularly in Rooms 1, 2, 3, and 4 of Building B and in the "flammable storage room" and "old storage room" in Building C. All of these rooms are now used for storage. The most-contaminated surfaces on the site were in Room 1 of Building B, where direct alpha readings as high as 200,000 dpm/100 cm^2 and beta-gamma dose rates as high as 6.8 mrad/hr were recorded for the floor. Alpha contamination levels in excess of 100 dpm/100 cm^2 were found by direct measurement on the roofs of Buildings B and C.

The highest external gamma radiation level measured indoors at 1 m above the floor was 110 μR/hr; this reading was recorded in Room 1 of Building B. Most external gamma measurements indoors were in the range 7 to 15 μR/hr; gamma radiation levels in this range can be produced

by natural radiation sources, including building materials. Outdoors on the site, the highest external gamma measurements at 1 m above the surface and at ground level (28 μR/hr and 90 μR/hr, respectively) were taken in the parking area just east of Building B. Except for this parking area, no significantly high radiation levels or nuclide concentrations were measured outdoors on the Clecon grounds, nor in the area immediately outside the site.

It appears from measurements made with alpha scintillation detectors in the air just above floor drains that appreciable quantities of thoron (^{220}Rn) are emanating from many of the drains. Elevated direct alpha readings over cracks where floors and walls intersect also suggest that ^{220}Rn is emanating into the air. A thoron daughter measurement made in Room 1 of Building B revealed concentrations in air of Thorium B near the RCG_a. It appears from limited data that the airborne concentration of long-lived alpha emitters in the ^{232}Th chain in Buildings B and C are below guide values stated in 10 CFR 20, Appendix B and ERDAM 0524, Annex A.

The radioactive contamination and elevated radiation levels on this site were found, for the most part, in storage areas, in drains, and under floors, and it appears that workers on the site presently spend at most brief periods in the contaminated areas. However, since the use of the site could change, estimates of dose commitment resulting from exposure for extended lengths of time to the maximum measured external gamma level and the maximum measured thoron daughter concentrations in air have been made. Assuming an exposure time of 2000 hr/year, the

maximum measured external gamma radiation level at 1 m (110 μR/hr in Room 1 of Building B) would lead to an integrated dose equivalent of approximately 0.2 rem/year. It is estimated[4] that a single, one-year, 2000-hr exposure to the highest measured airborne Th-B concentration (0.49 pCi/liter in Room 1 of Building B) would result in a critical organ (kidney) dose equivalent of approximately 0.4 rem the first year and a dose commitment over 50 years of approximately the same amount. Similarly, it is estimated that a single, one-year 2000-hr exposure to the highest measured airborne Th-C concentration (0.19 pCi/liter in Room 2 of Building B) would result in a critical organ (kidney) dose equivalent of approximately 0.01 rem the first year and a dose commitment over 50 years of approximately the same amount.

An evaluation has been made of current radiation exposures at the Horizons, Inc., Metal Handling Facility, and is presented in Appendix VI (page 115) of this report. The purpose of this evaluation is to present information which will permit the reader to compare current radiation exposures from the site to normal background exposures for that part of Ohio, as well as to scientifically based guideline values established for the protection of radiation workers and members of the general public.

REFERENCES

1. Industrial Hygiene Branch, Health and Safety Laboratory, U. S. Atomic Energy Commission, "Horizons, Inc., Cleveland, Ohio, Occupational Exposure to Airborne Contamination," HASL-Horizons-1, February 21, 1955.

2. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct Source, or Special Nuclear Material, U.S. Nuclear Regulatory Commission, November 1976 (see Appendix V).

3. Code of Federal Regulations, Title 10 Part 20, "Standards for Protection Against Radiation," Appendix B.

4. G. G. Killough and L. R. McKay, Compilers, A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment, ORNL-4992, Oak Ridge National Laboratory, Oak Ridge, Tennessee (March 1976).

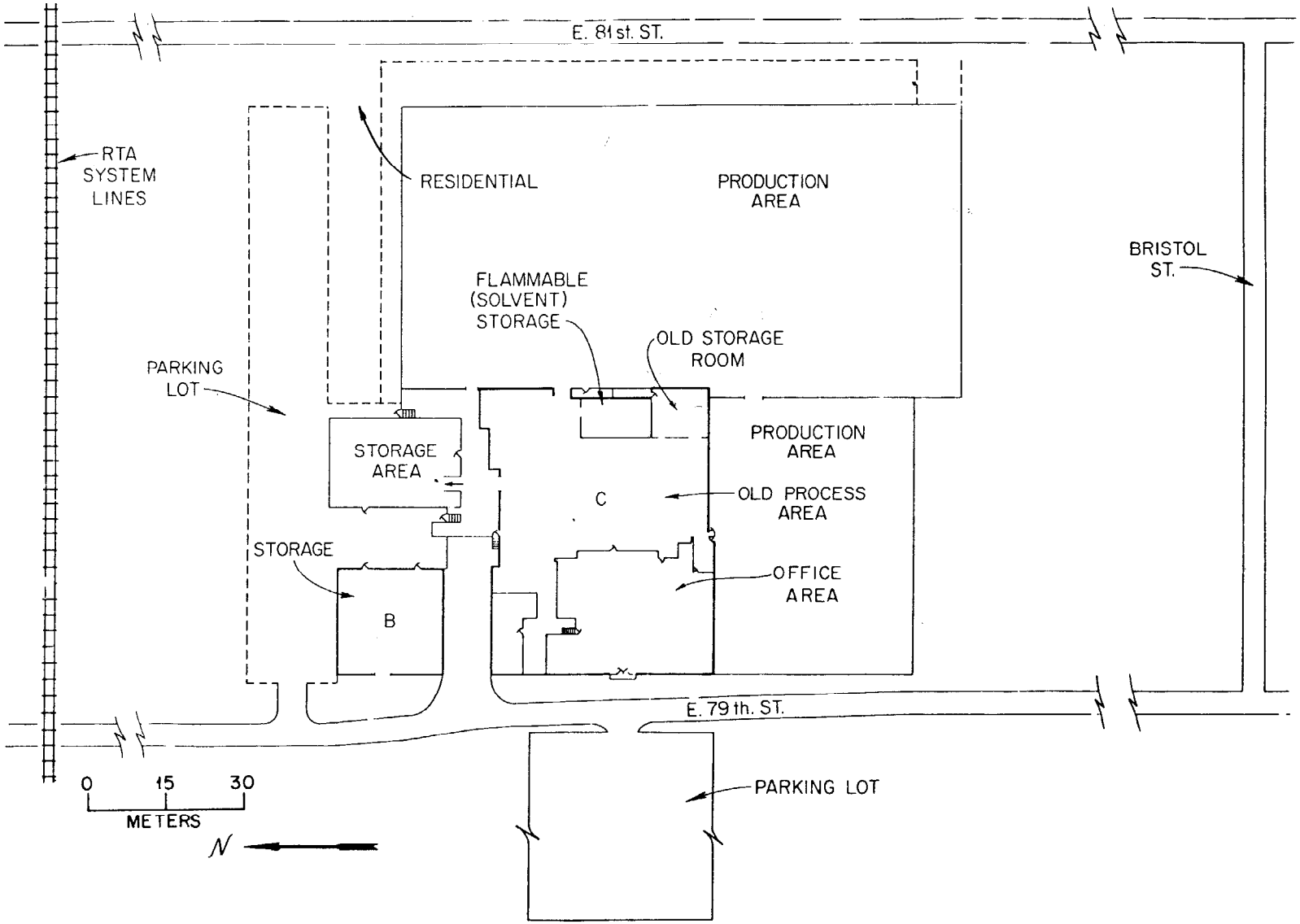

Fig. 1. Plan view of Cleeon Metals, Inc., and surrounding area.

ORNL-DWG. 77-10385

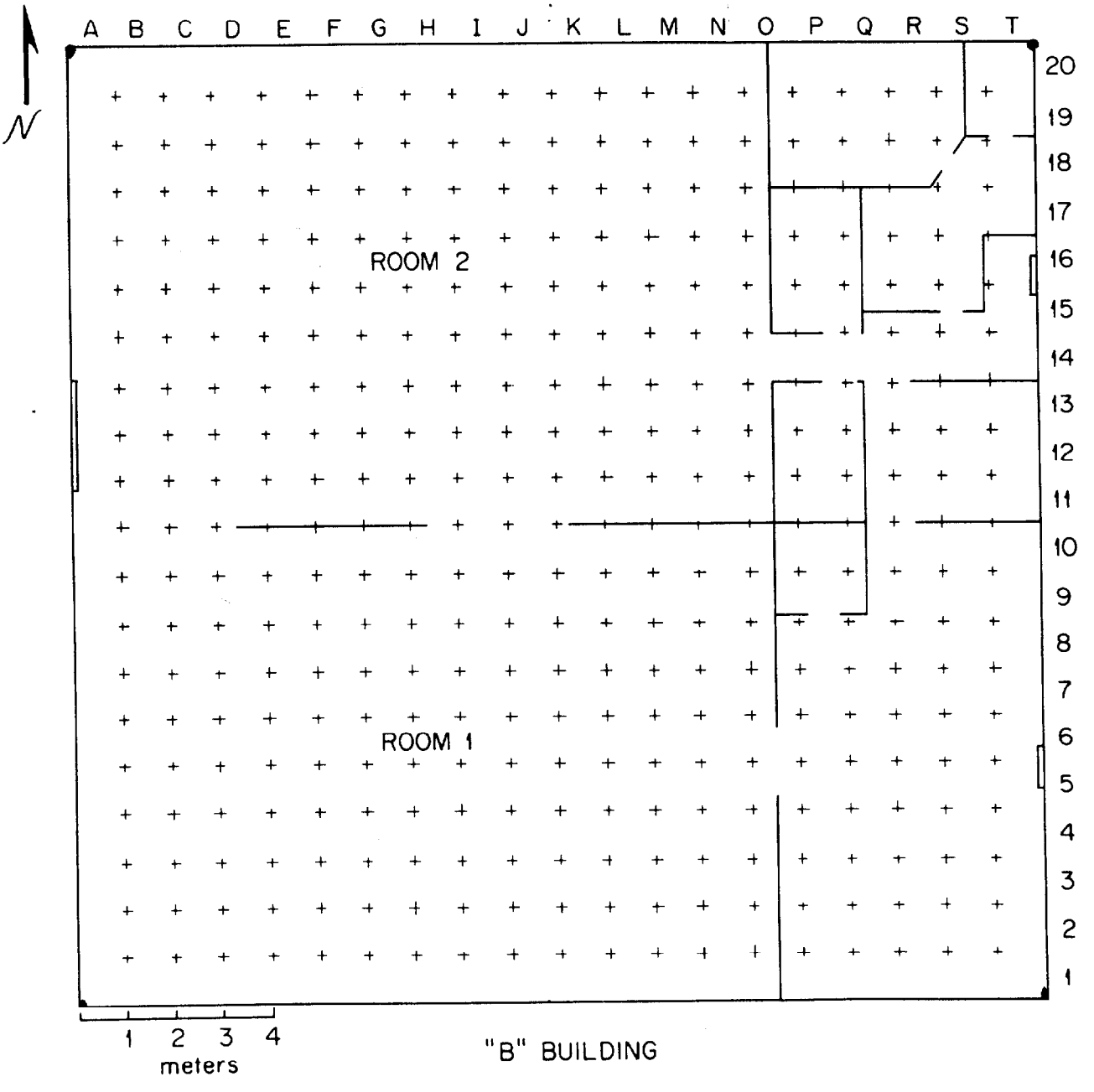

Fig. 2. Grid scheme used for measurements in Building B.

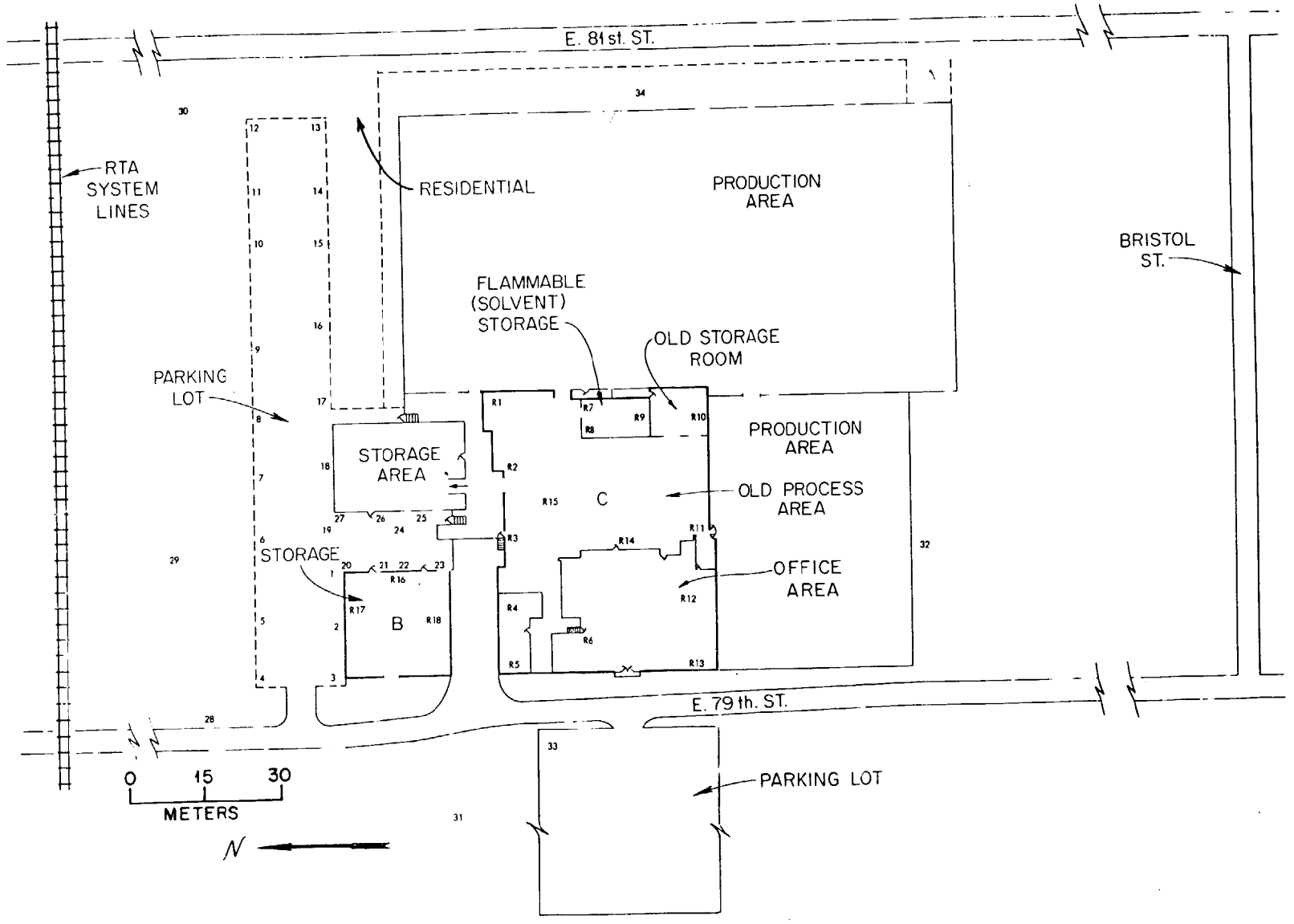

Fig. 3. Locations of measurements outdoors on and near the site, including roof (R) locations.

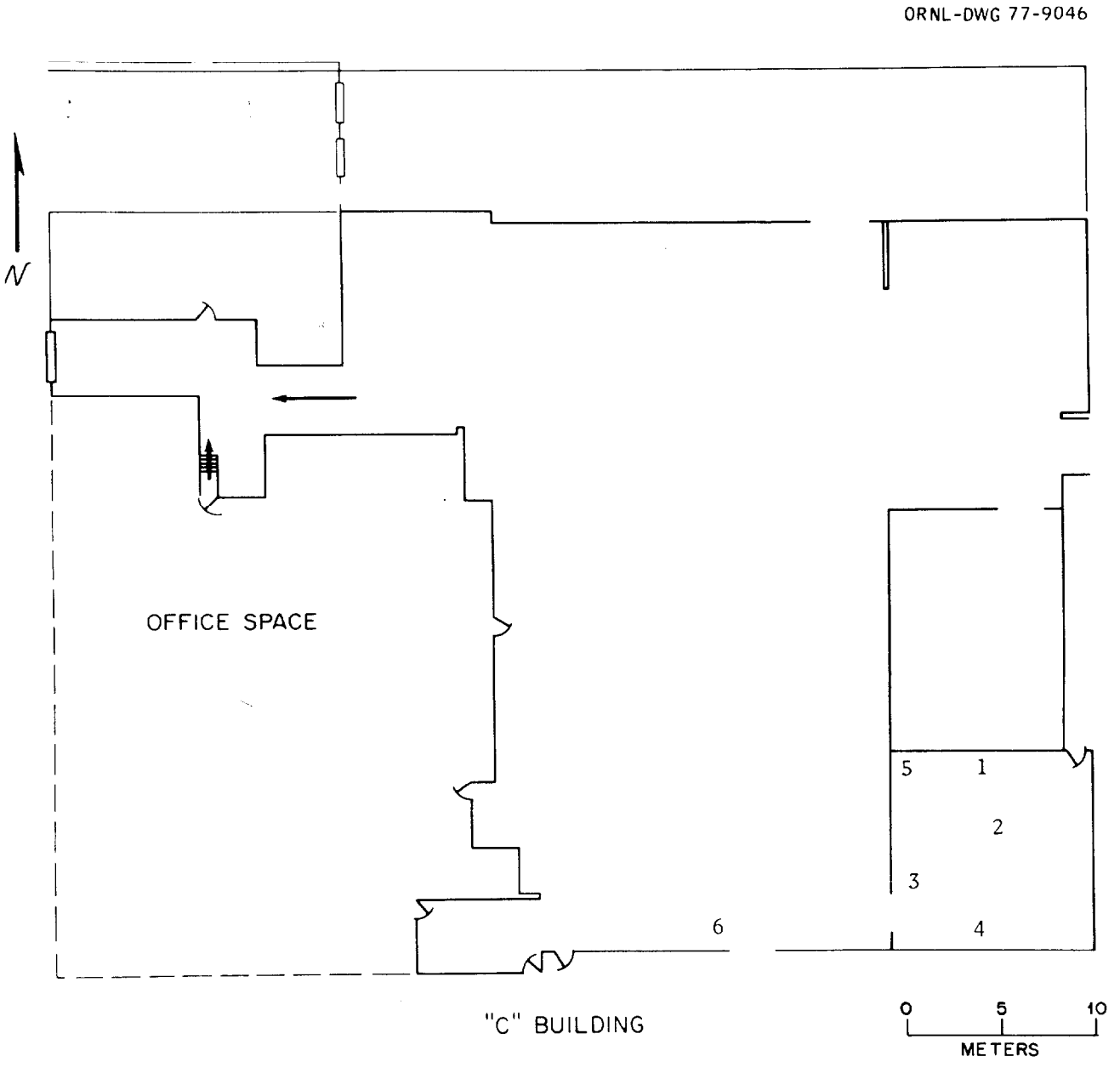

Fig. 4. Core hole locations inside Building C.

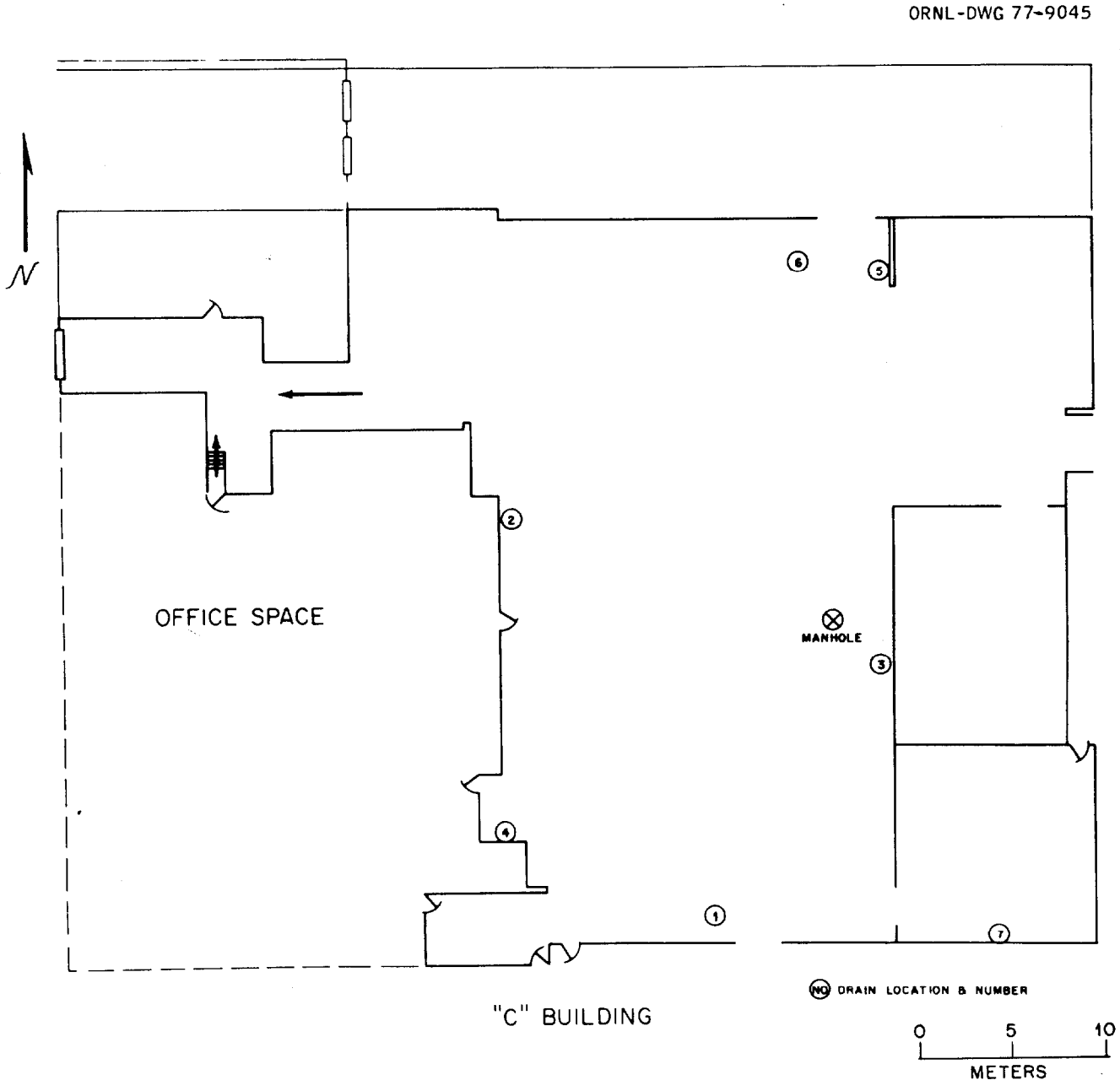

Fig. 5. Drain locations in Building C.

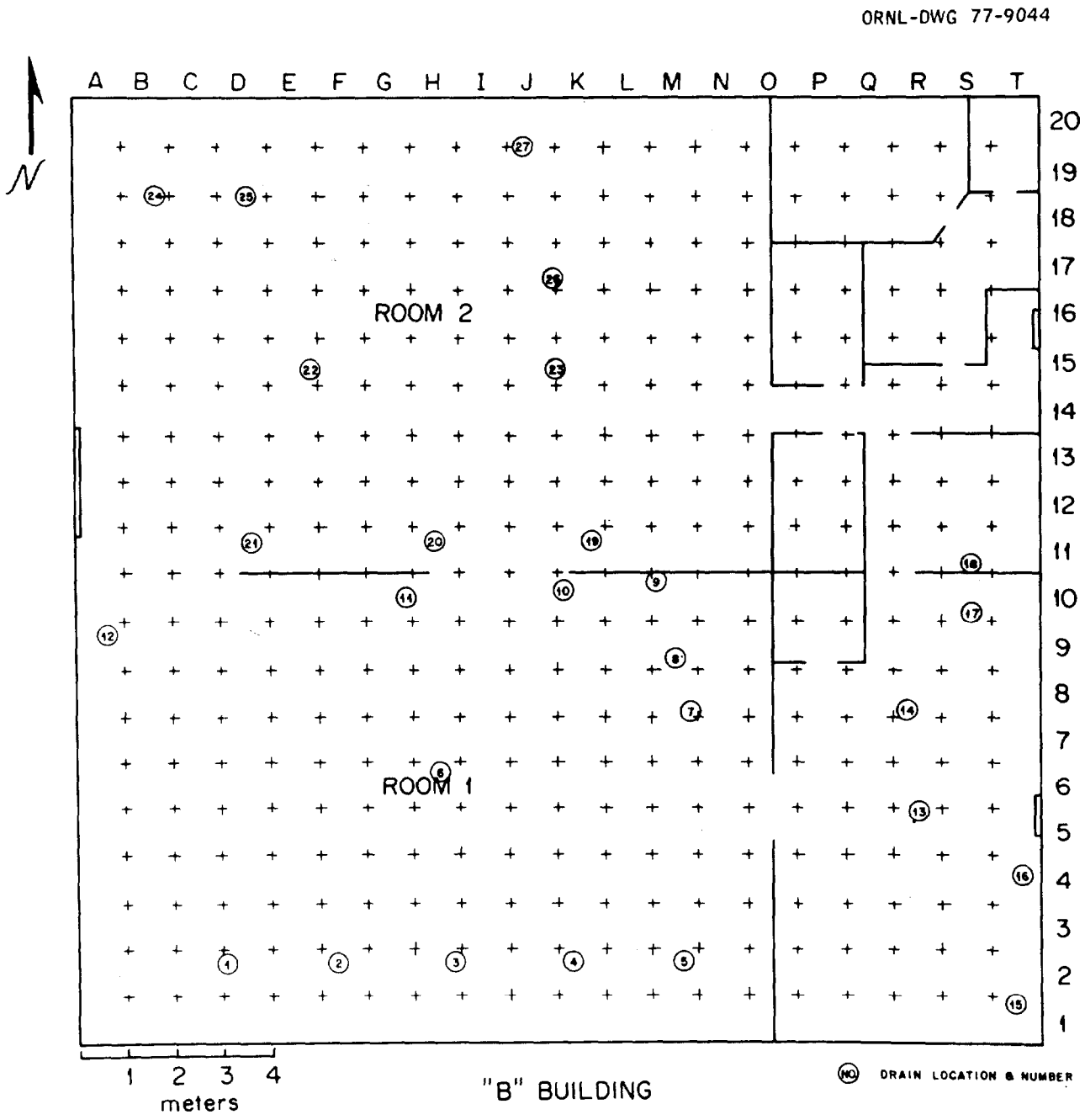

Fig. 6. Drain locations in Building B.

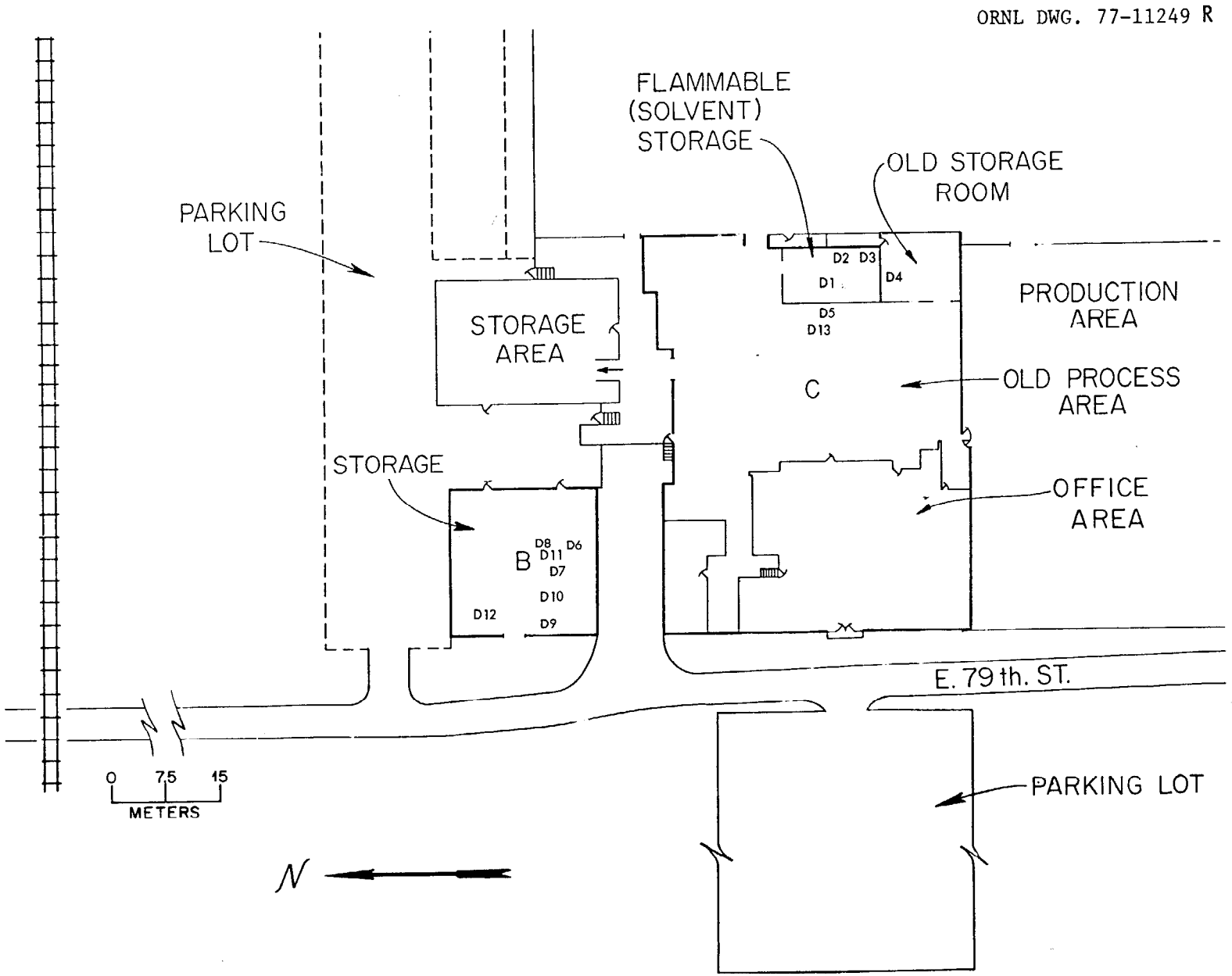

Fig. 7. Locations at which samples were taken from surfaces inside Buildings B and C.

ORNL DWG. 77-10370

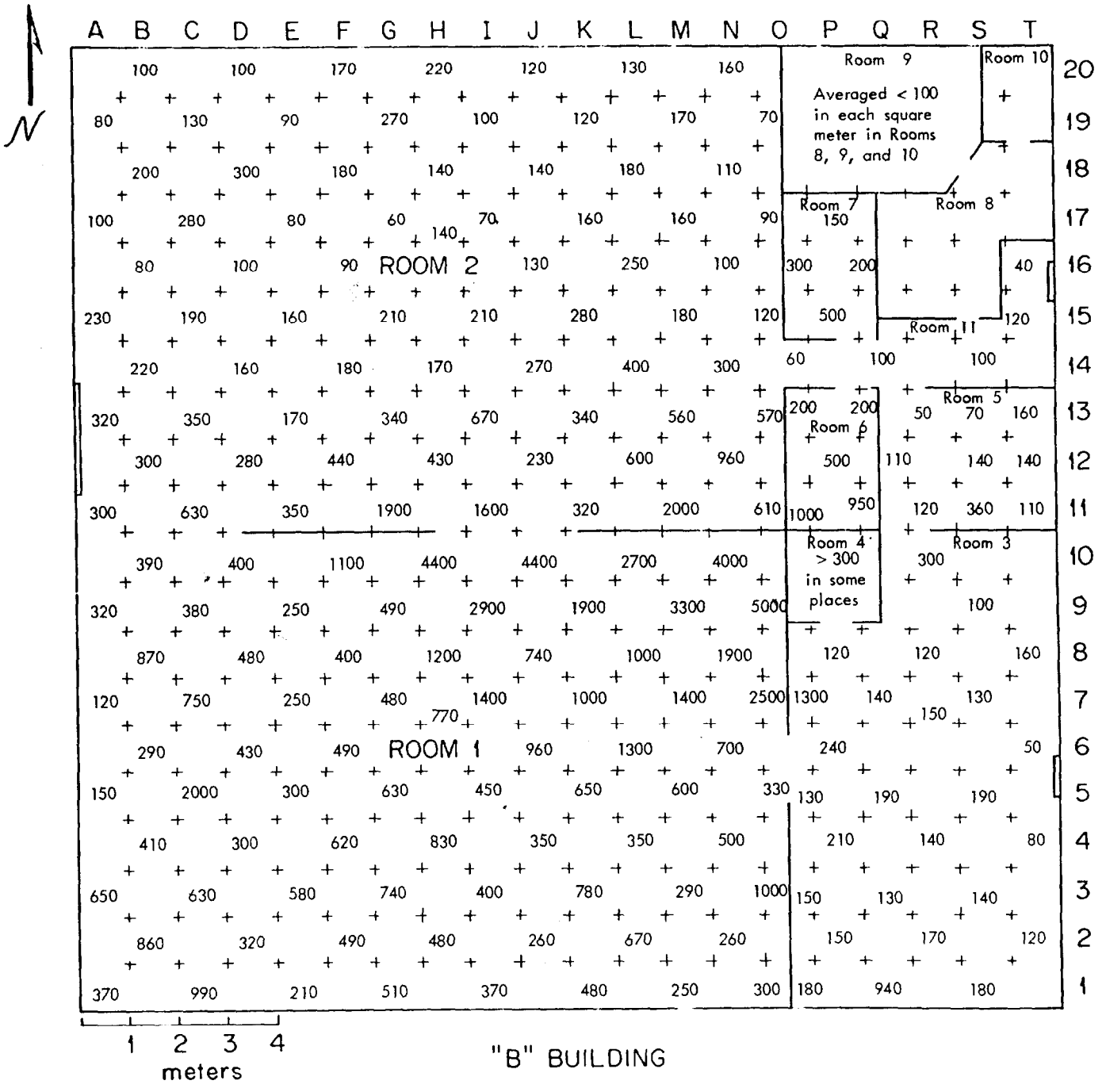

Fig. 8. Direct alpha readings (dpm/100 cm^2, averaged over 1 m^2) on the floor in Building B.

ORNL DWG. 77-10373

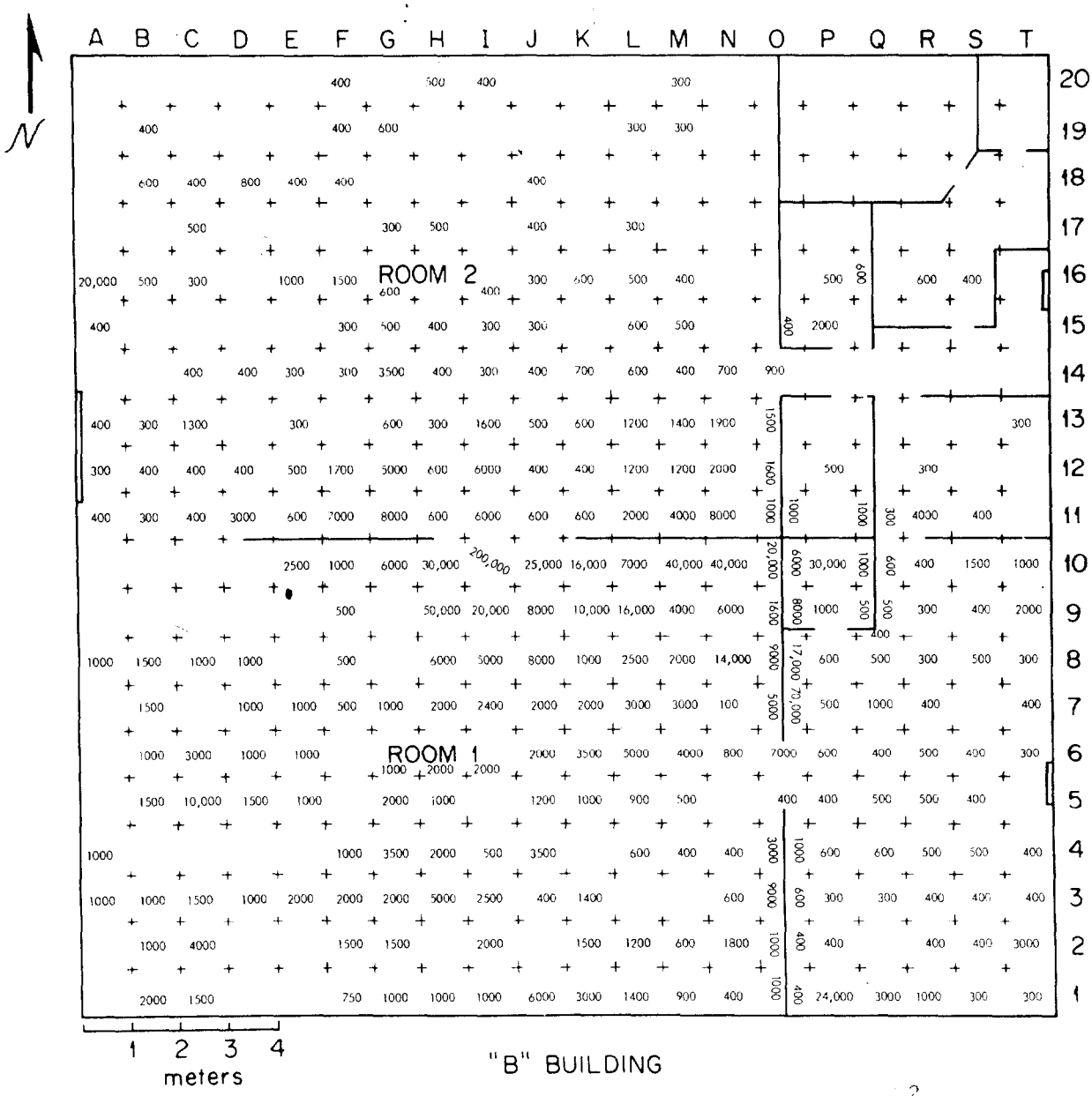

Fig. 9. Maximum direct alpha readings (dpm/100 cm^2) in survey squares on floor in Building B where readings exceeded 300 dpm/100 cm^2.

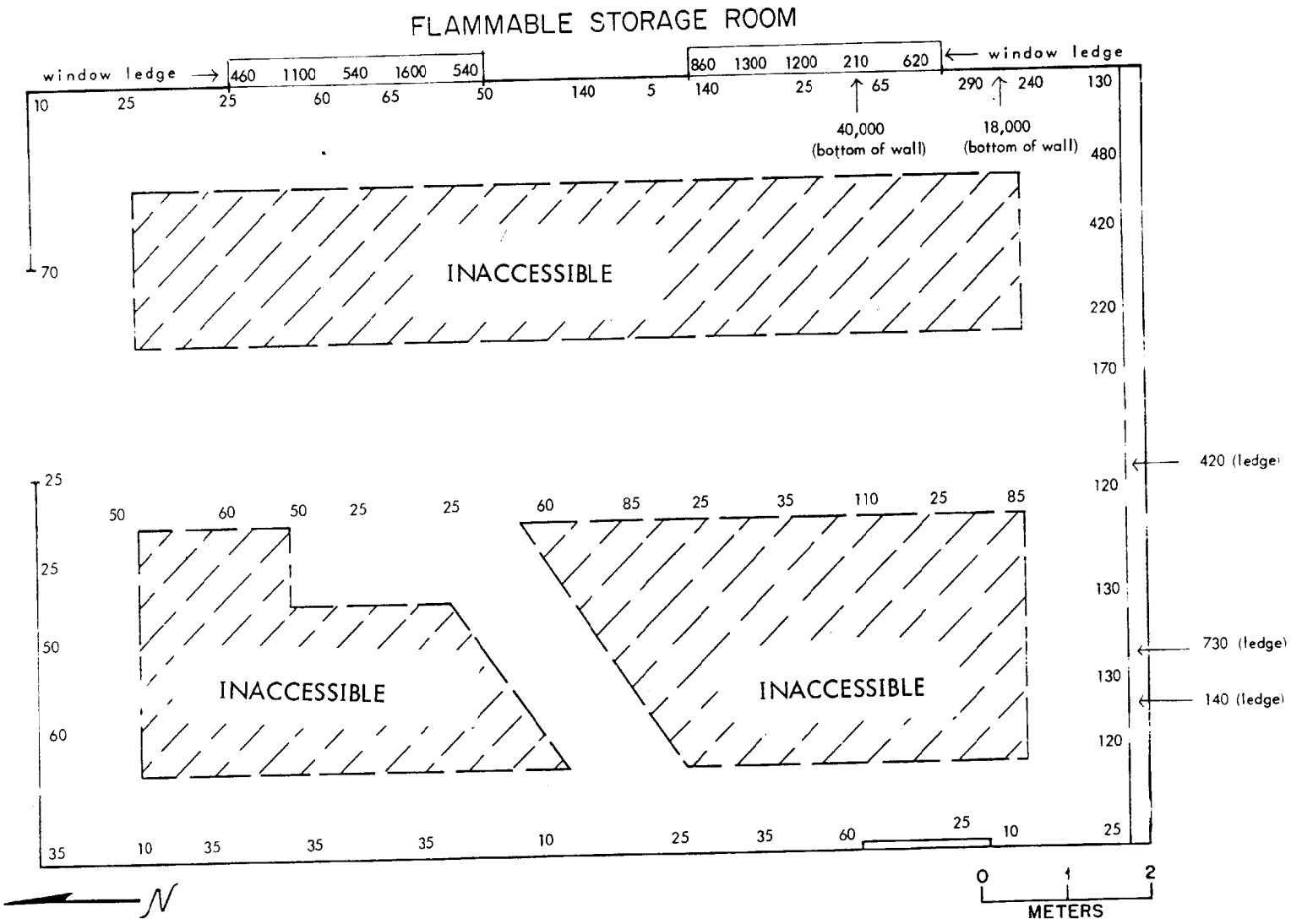

Fig. 10. Direct alpha reading (dpm/100 cm^2) on floor and lower wall in flammable storage room.

Note: Measurements are individual instrument readings rather than averages.

ORNL DWG. 77-10369

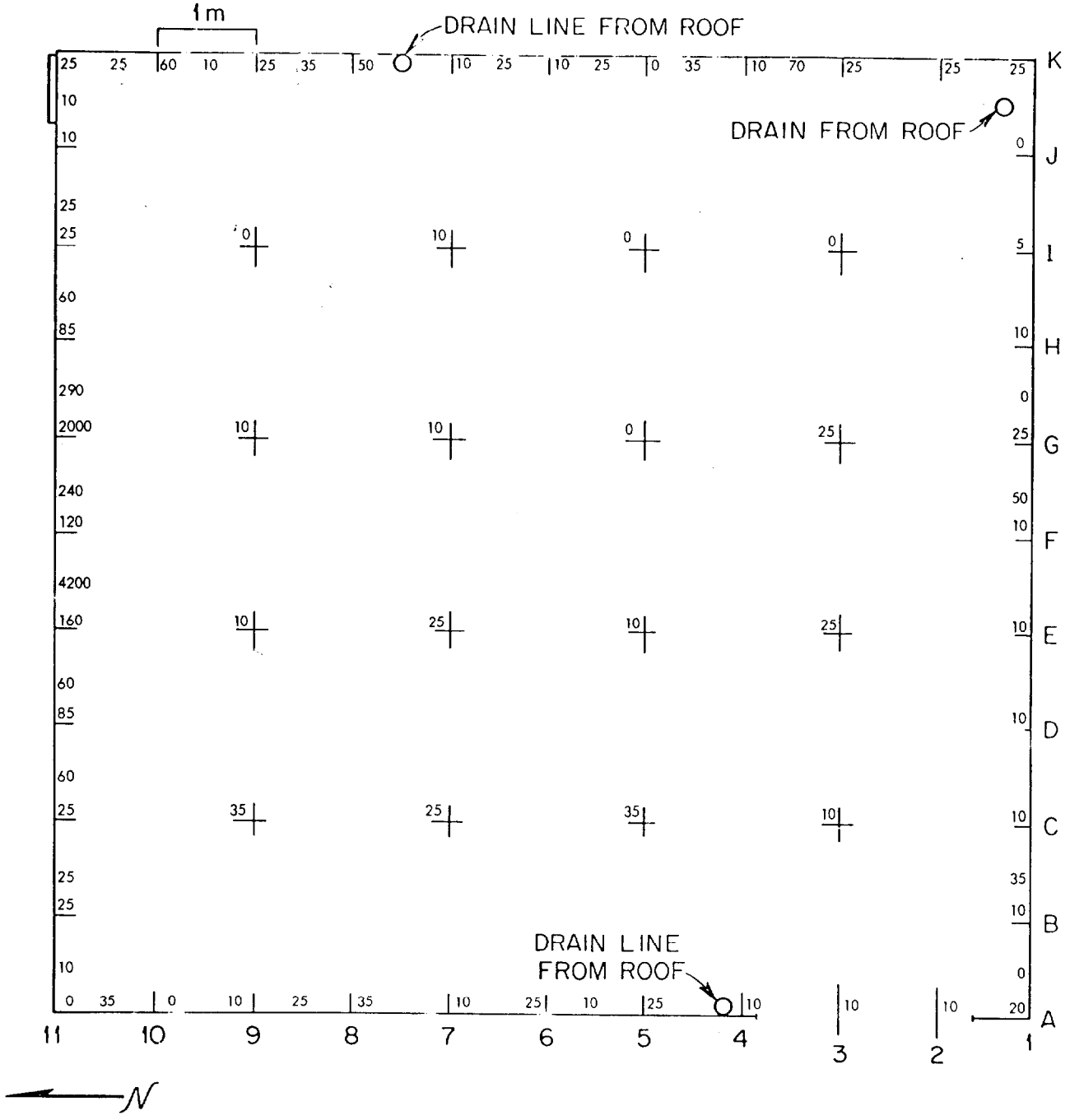

Fig. 11. Direct alpha readings (dpm/100 cm^2) on floor of old storage room in Building C.

Note: Measurements are individual instrument readings rather than averages.

ORNL DWG. 77-10371

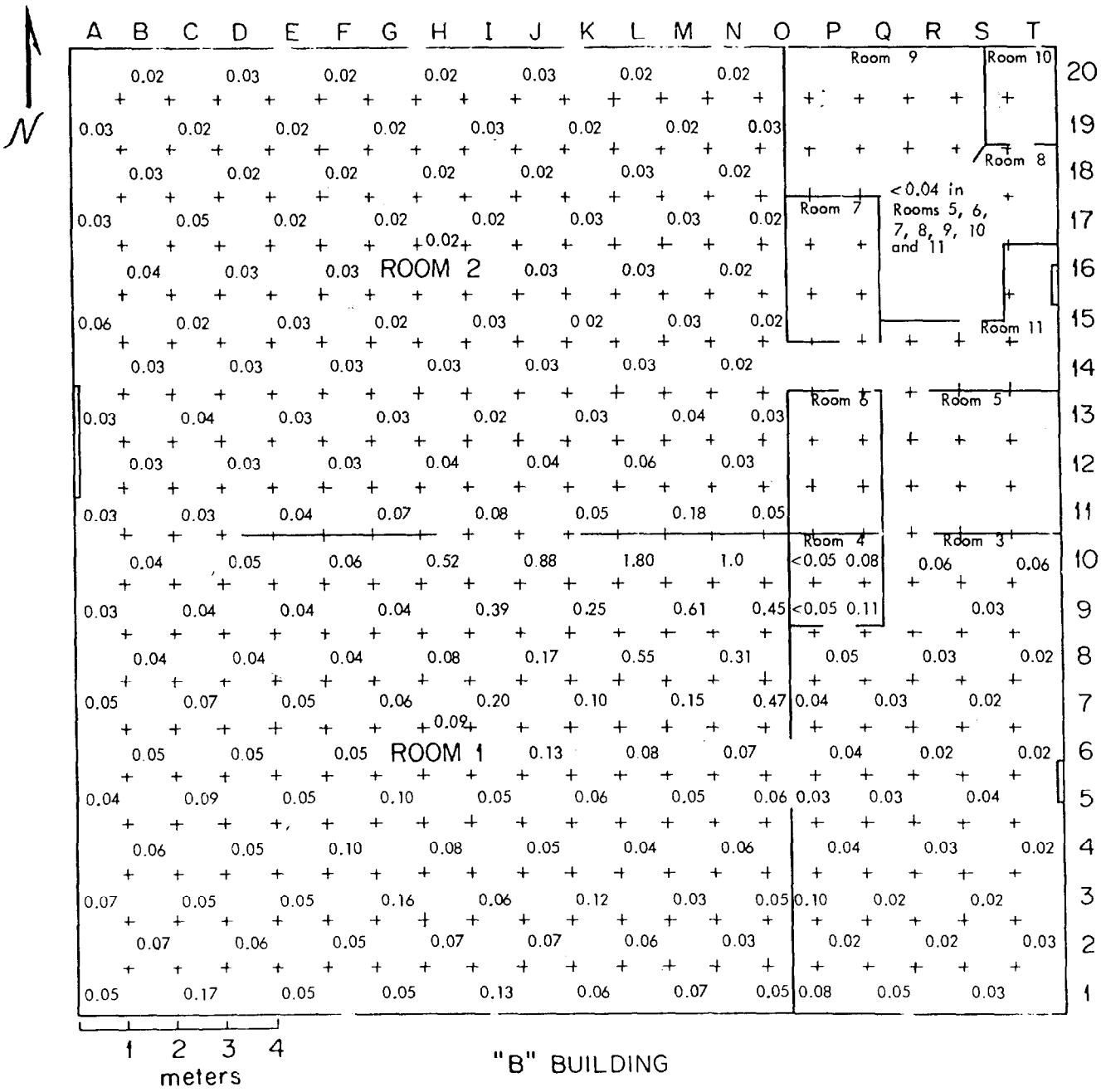

Fig. 12. Beta-gamma dose rates (mrad/hr, averaged over 1 m^2) on floor in Building B.

ORNL-DWG. 77-10374

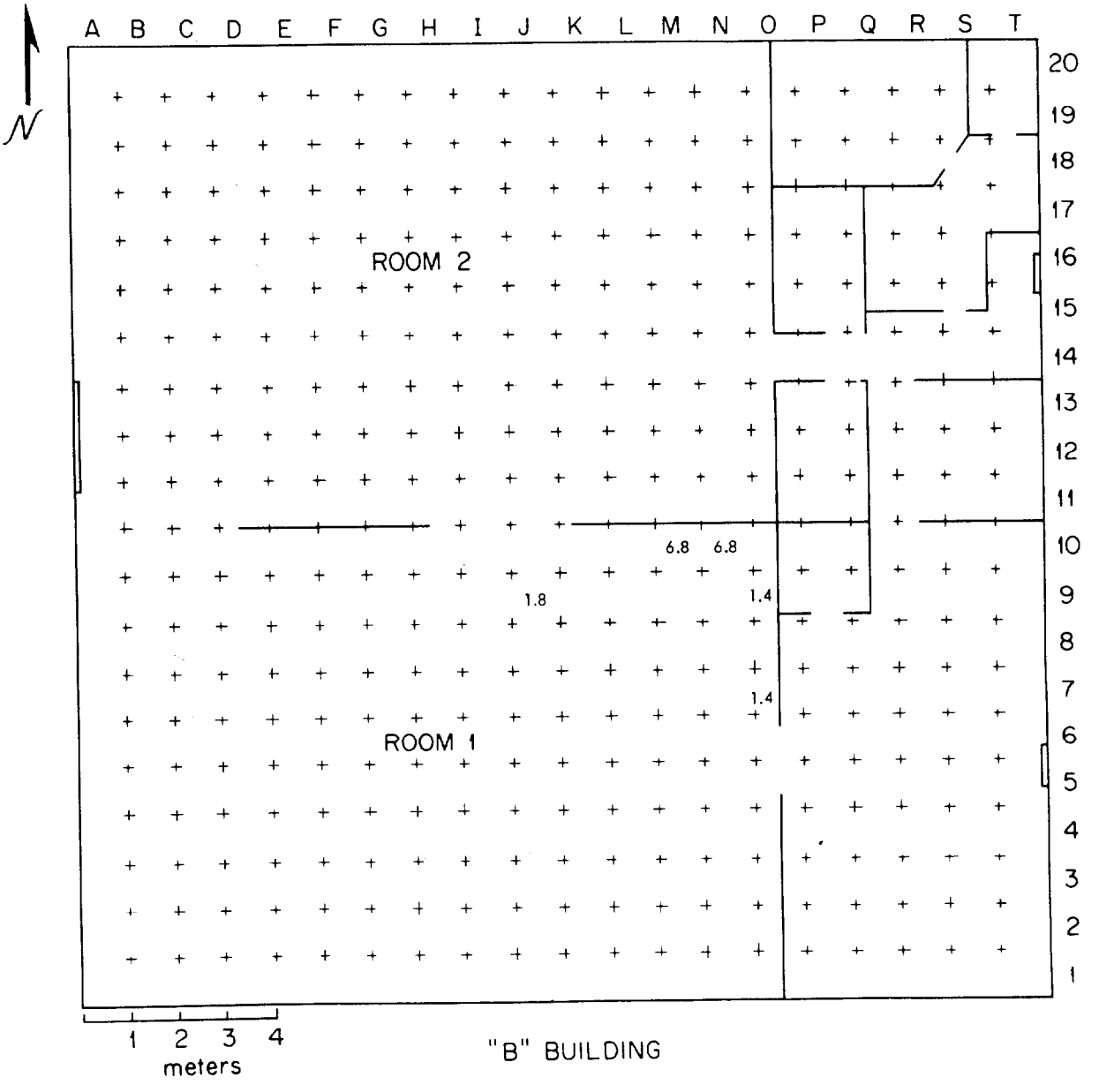

Fig. 13. Beta-gamma dose rates (mrad/hr) exceeding 1 mrad/hr on floor in Building B.

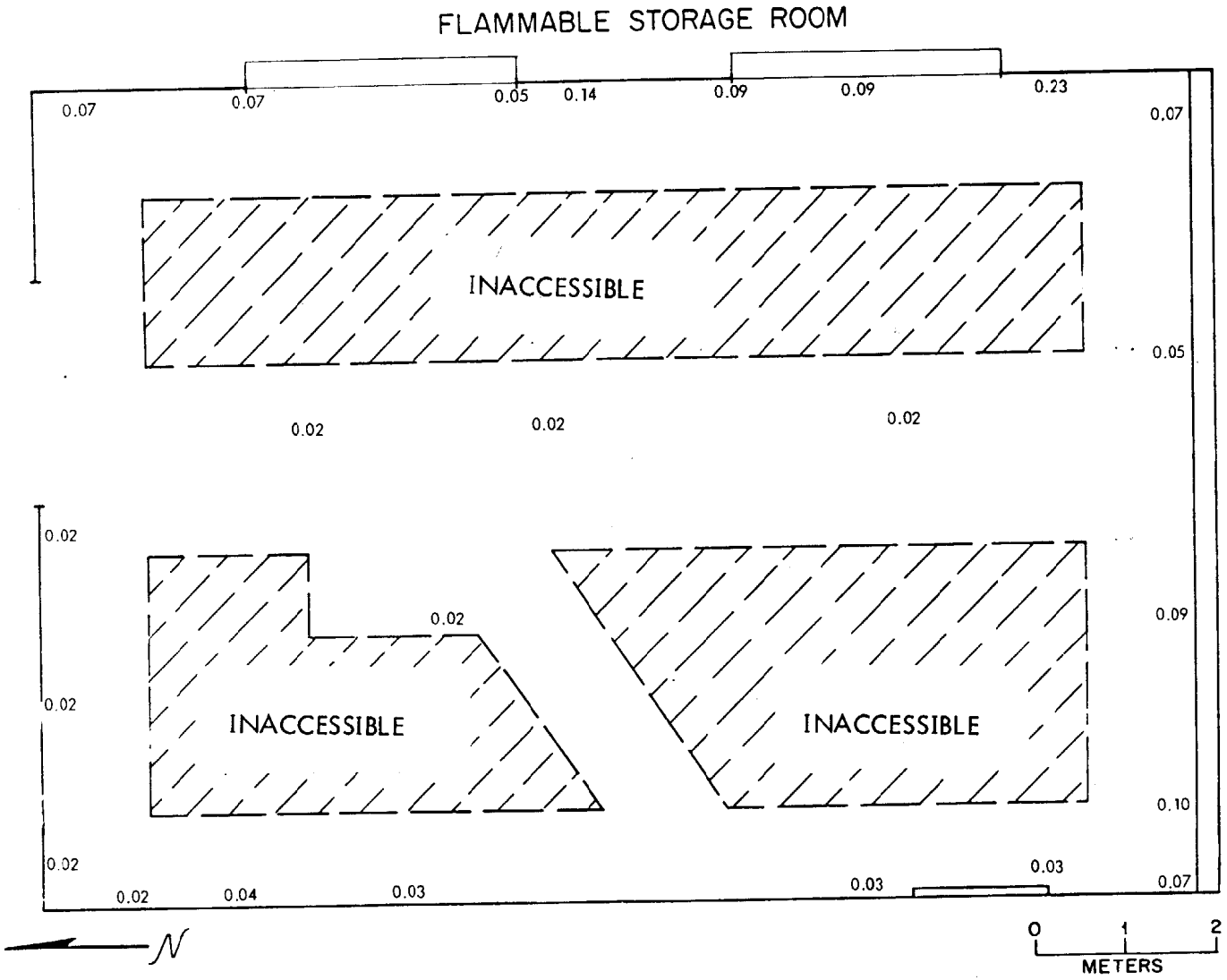

Fig. 14. Beta-gamma dose rates (mrad/hr) on floor in flammable storage room in Building C.

Note: Measurements were averaged over area no larger than 1 m^2.

ORNL-DWG. 77-10368

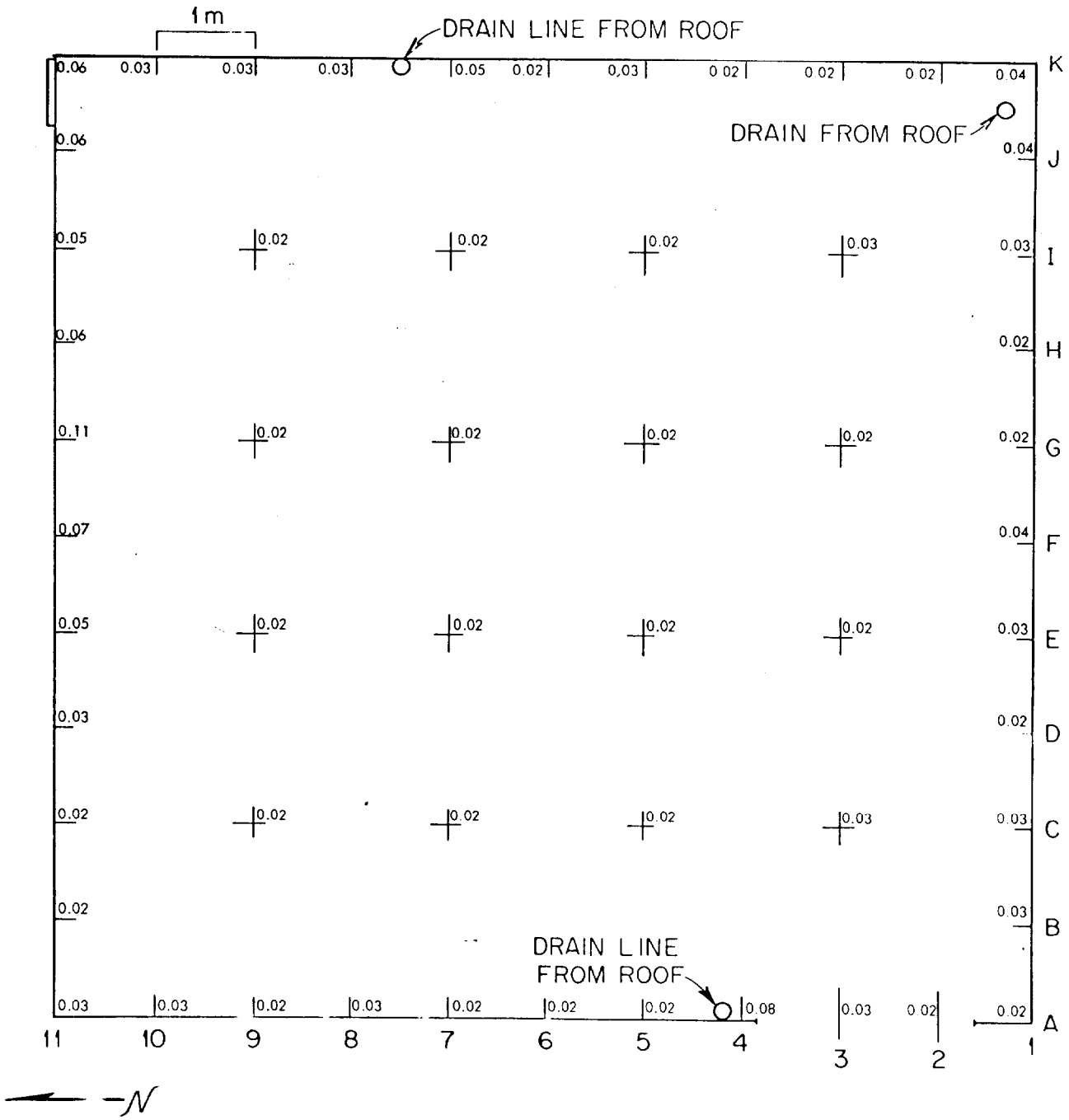

Fig. 15. Beta-gamma dose rates (mrad/hr) on floor of old storage room in Building C.

Note: Measurements were averaged over areas no larger than 1 m^2.

ORNL DWG. 77-10375

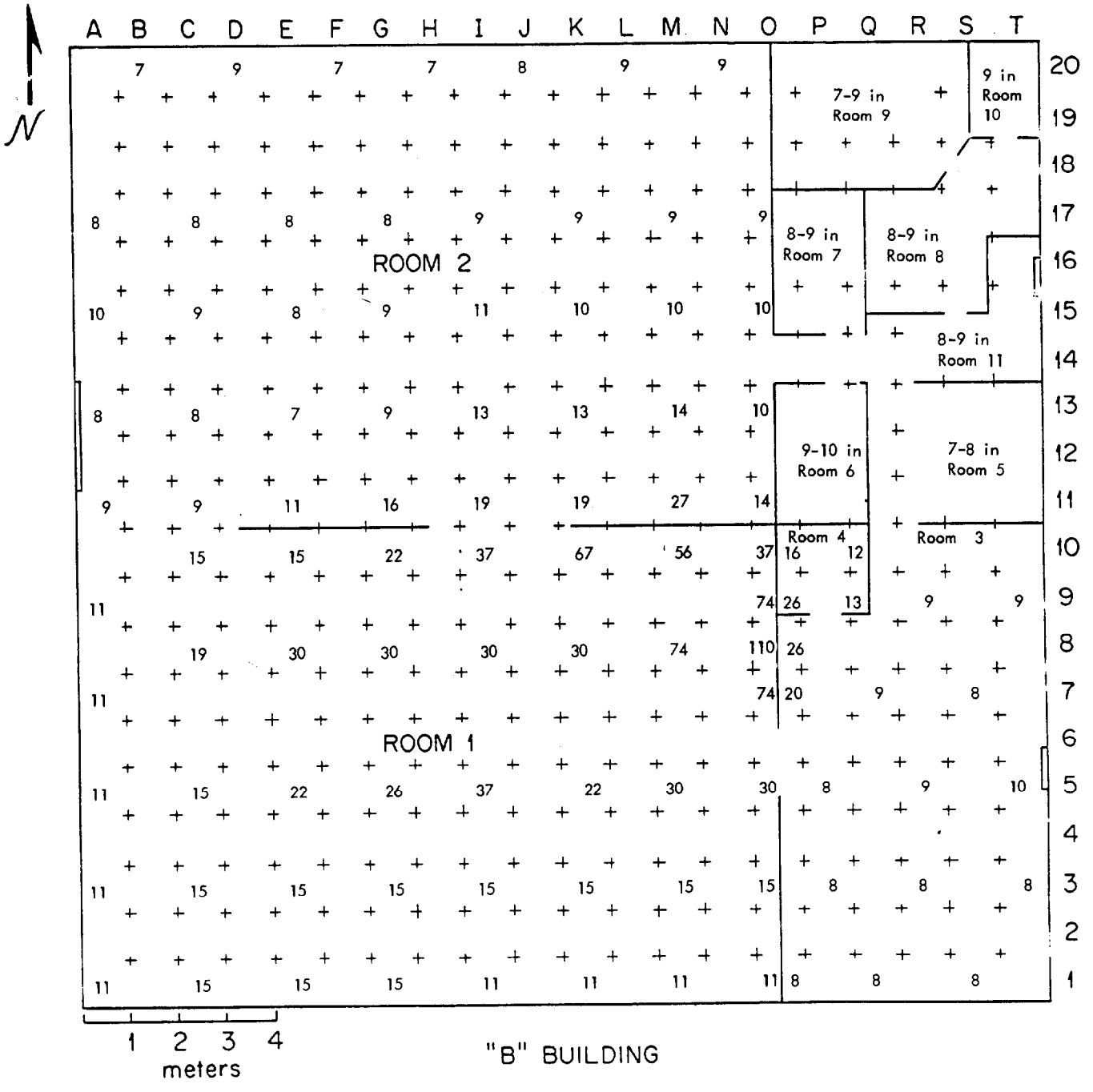

Fig. 16. External gamma radiation (μR/hr) at 1 m above floor in Building B.

ORNL DWG. 77-10376

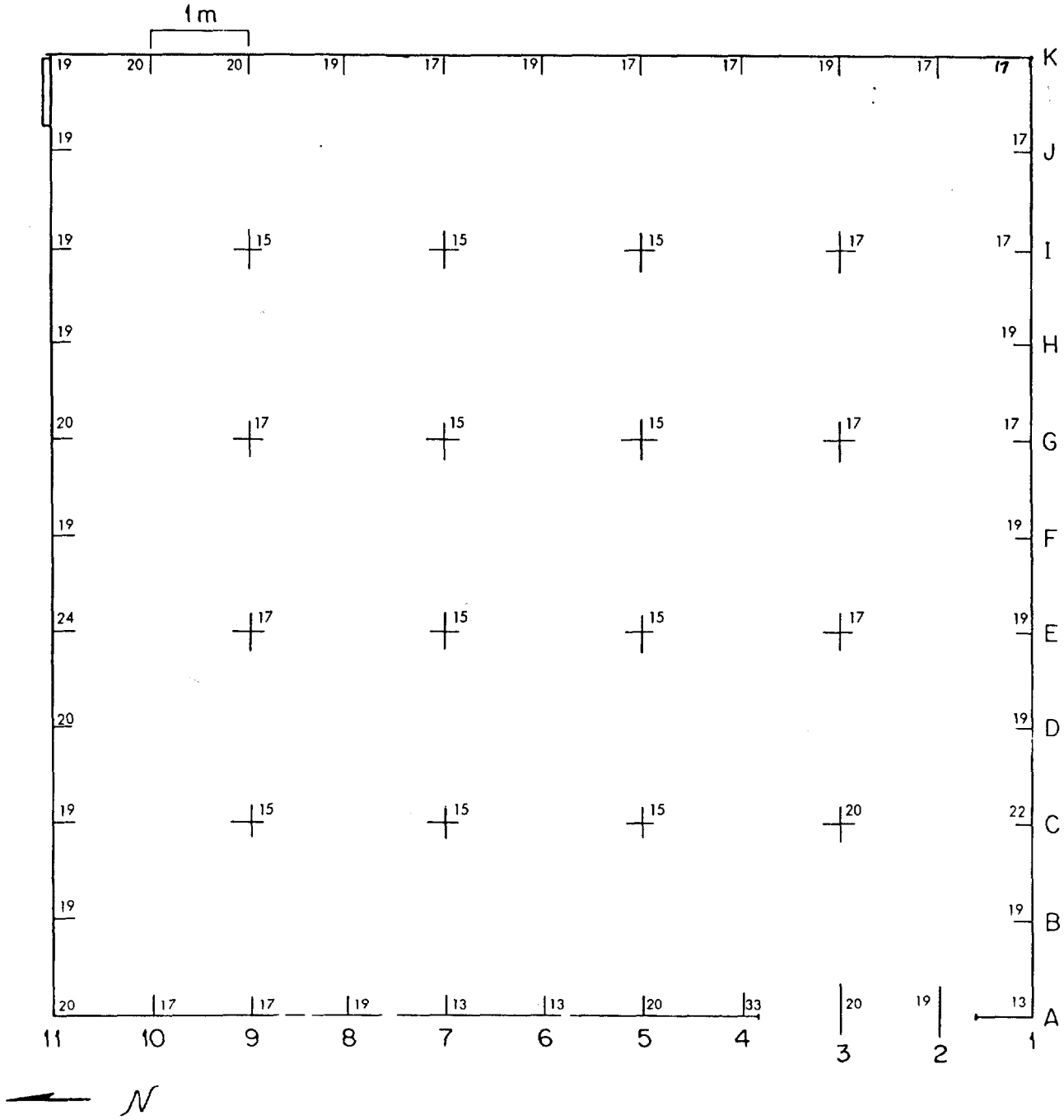

Fig. 17. External gamma radiation levels (μR/hr) at 1 m above the floor in the old storage room in Building C.

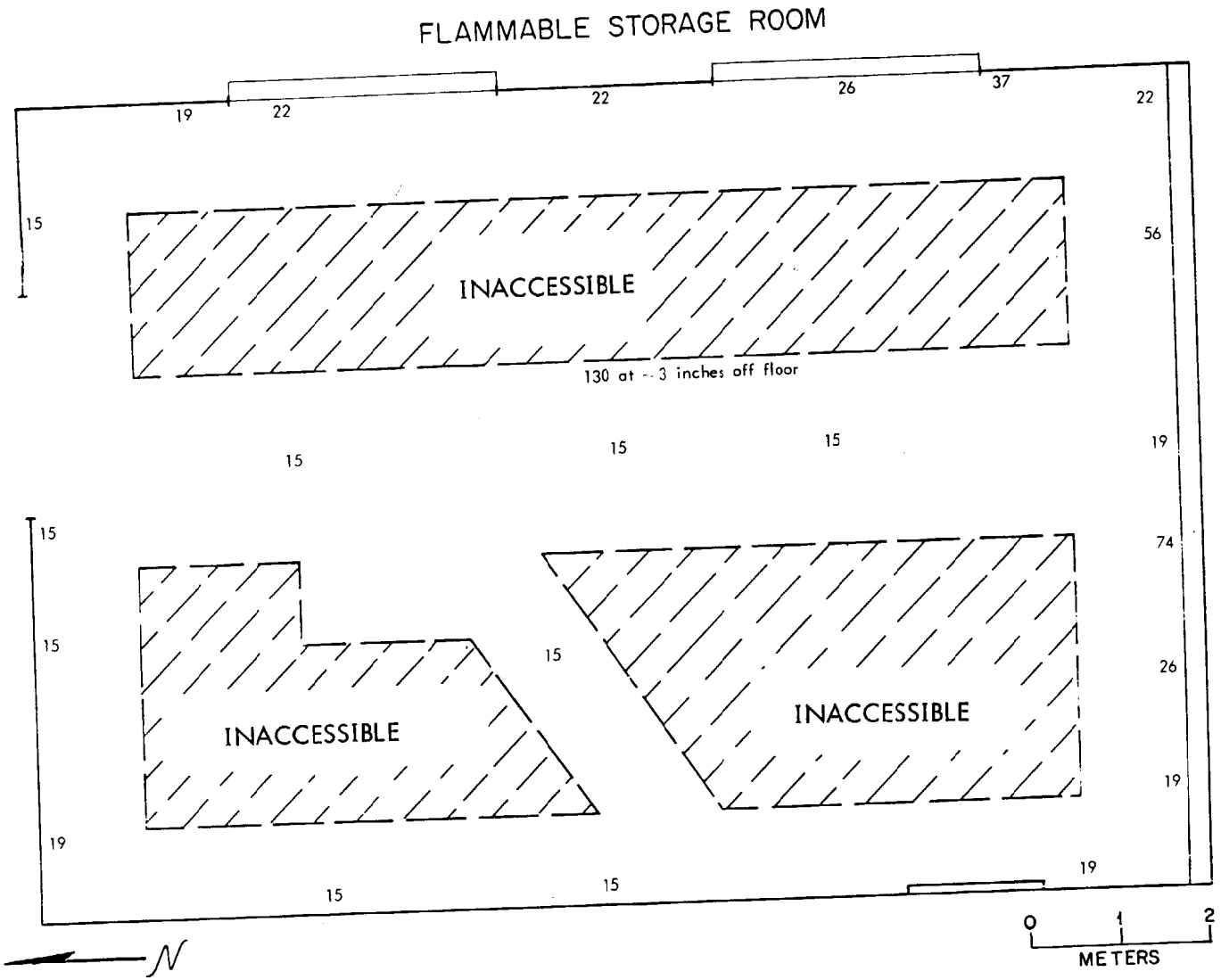

Fig. 18. External gamma radiation levels (μR/hr) at 1 m above floor in flammable storage room in Building C.

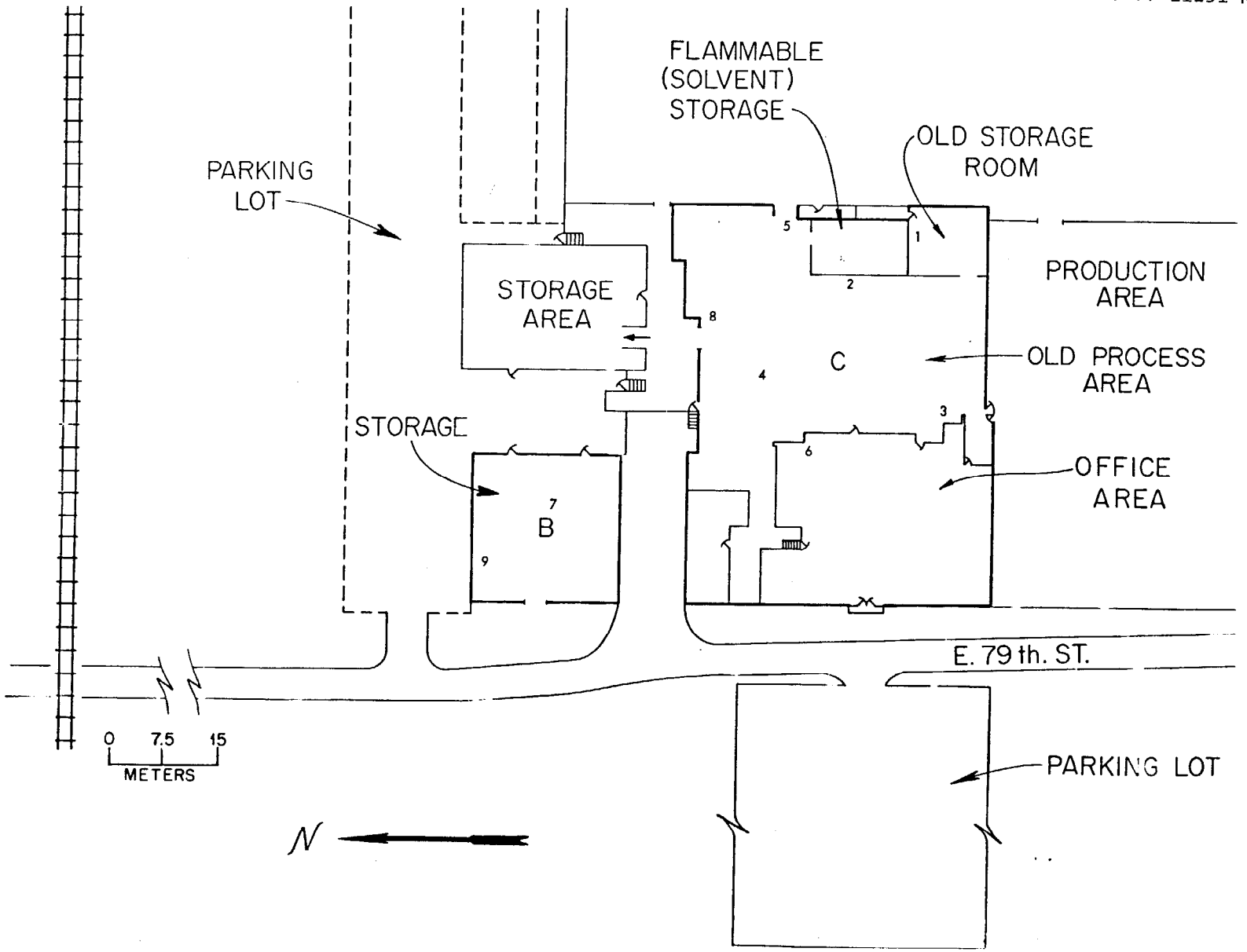

Fig. 19. Points at which thoron daughter measurements were made in Building B and C.

Table 1. Concentrations of ^{232}Th, ^{228}Ra, ^{228}Th, and ^{230}Th in surface dirt and building materials taken from most-contaminated surfaces in Building B and C

Sample	^{232}Th (pCi/g)	^{228}Ra (pCi/g)	^{228}Th (pCi/g)	^{230}Th (pCi/g)	Type Material and Location (see Fig. 7)
D-1	34	33	32	6.9	Asbestos and dirt from center overhead beam in solvent storage room, Bldg. C.
D-2	79	86	69	15	Paint and dirt from bottom of wall (under window) on east side of solvent storage room, Bldg. C.
D-3	11.8	13	12	2	Putty from window, east side of solvent storage room in Bldg. C.
D-4	100	82	68	11	Concrete from floor near middle of north wall in old storage room, Bldg. C.
D-5	10	13	12	2.5	Dirt from drain 3, Bldg. B.
D-6	13	10	11	2	Dirt from drain 5, Bldg. B.
D-7	2530	2620	2640	505	Dirt from drain 6, Bldg. B.
D-8	318	410	460	70.7	Dirt from drain 8, Bldg. B.
D-9	69.6	70	69	3	Dirt from beam and fan duct in northwest corner of Room 1, Bldg. B.
D-10	4890	5300	4960	752	Dirt from support near north wall, Room 1, Bldg. B.
D-11	36	32	33	12	Asbestos and dirt from overhead, NE corner, Room 1, Bldg. B.
D-12	795	850	853	102	Dirt and scrapings from overhead, Room 2, Bldg. B.
D-13	7.5	5.7	5.6	1.74	Dirt from manhole between high bays, Bldg. C.

Table 2. Nuclide concentrations in samples taken from beneath floor in Building C

Hole No.	Depth (in.)	^{232}Th (pCi/g)	^{228}Ra (pCi/g)	^{238}U (pCi/g)	^{226}Ra (pCi/g)
1	6-9	111	98.3	3.3	1.6
1	9-21	591	538	13.1	N.F.[a]
1	21-35	58.4	52.6	2.1	N.F.
1	35-60	45.4	39.8	2.0	N.F.
1	60-72	442	415	6.2	N.F.
1	72-81	73.3	65.1	2.5	1.4
1	81-89	N.F	3.9	1.3	1.4
2	8-20	1.4	1.7	2.4	0.3
2	20-30	0.9	0.9	N.D[b]	1.0
2	34-52	0.9	0.8	0.9	0.9
2	52-75	0.9	0.8	N.D.	1.0
3	6-10	255.	N.D.	N.D.	N.D.
3	10-18	48.1	43.3	1.8	N.F.
3	18-39	7.7	6.8	6.1	0.4
4	7-27	9.4	8.6	1.1	0.9
4	27-38	1.7	1.4	N.D.	0.7
5	7-31	2.0	1.4	N.D.	0.2
5	31-43	1.8	2.1	2.4	0.2
6	4-8	N.D.	N.D.	N.D.	1.4
6	8-20	1.2	1.0	1.5	1.0
6	20-45	1.3	1.0	N.D.	1.1

[a] N.F. = not found (by the procedure described in Appendix IV).

[b] N.D. = not determined.

Table 3. Nuclide concentrations in surface samples taken outdoors on and near Clecon property

Location (see Fig. 3)	^{232}Th (pCi/g)	^{228}Ra (pCi/g)	^{226}Ra (pCi/g)
1	1.3	1.2	1.0
3	0.9	0.9	1.5
6	0.8	1.3	1.3
13	0.9	0.7	1.5
22 [a]	54.3	49.7	2.1
22 [a]	16.2	14.2	1.5
27	1.9	1.6	1.2
28	1.4	1.1	1.0
29	0.9	0.9	1.1
30	0.9	0.8	1.1
31	0.8	0.8	0.8
32	1.0	0.9	1.5
33	0.9	0.8	2.4

[a] Two samples were taken at this location because of elevated external gamma levels.

Table 4. Direct measuremens of alpha contamination in Buildings B and C

Building and room	Location	Extent of alpha contamination as indicated by direct readings[a]
B-1	West wall	100 to 800 dpm/100 cm^2 on horizontal steel beams; rest of wall showed little alpha contamination.
B-1	South wall	100 to 400 dpm/100 cm^2 on horizontal steel beams; rest of wall showed little alpha contamination.
B-1	North wall	200 to 400 dpm/100 cm^2 uniformly at 0 to 1 ft from floor; horizontal steel beams measured uniformly higher than 100 dpm/100 cm^2, and higher than 1000 dpm/100 cm^2 in many spots; highest reading was 40,000 dpm/100 cm^2 on steel beams at 3 to 3.5 ft from floor in northeast corner Room 1.
B-1	East wall	New metal wall; alpha contamination only on switchbox — up to 1000 dpm/100 cm^2 there.
B-1	Overhead: ceiling, beams, lights, ducts, tram, heater. (Readings taken at random points).	Most readings in range of 120 to 1000 dpm/100 cm^2, three readings in northeast quarter between 5,000 and 10,000 dpm/100 cm^2; only 4 readings were less than 100 dpm/100 cm^2, these were in southern half of the room and were on vertical surface.
B-1	Floor (see Figs. 8 and 9)	Readings averaged over one square meter far exceeded 100 dpm/100 cm^2 over entire surface; individual instrument readings exceeded 5,000 dpm/100 cm^2 in several areas, particularly in northeast quarter of room; highest individual instrument reading was 200,000 dpm/100 cm^2 in grid square I-10.
B-2	North wall	200 to 400 dpm/100 cm^2 on horizontal steel beams on western two-thirds of north wall; old (western-most) rest room wall extending $\sim$6 ft into room from north wall showed 800 to 1200 dpm/100 cm^2 on end and lower 2 ft of wall; remainder of north wall showed little alpha contamination.

Table 4. (cont'd.) Direct measuremens of alpha contamination in Buildings B and C

Building and room	Location	Extent of alpha contamination as indicated by direct readings[a]
B-2	West wall	One small area between roll-up door and center of room, about 6 ft off floor, showed 400 dpm/100 cm^2; remainder of wall showed <100 dpm/100 cm^2.
B-2	East wall	All <100 dpm/100 cm^2.
B-2	South wall	Only spot exceeding 100 dpm/100 cm^2 was on horizontal steel beam about 6 ft off floor and 16 ft from southeast corner of room; reading there was 500 dpm/100 cm^2.
B-2	Overhead: ceiling, pipes, beams, lights, ducts, etc. (Readings taken at 43 randomly distributed points.)	All readings were in range of 200 to 1300 dpm/100 cm^2, averaging 350 dpm/100 cm^2 with a standard deviation of 50%.
B-2	Floor (see Figs. 8 and 9)	Readings averaged over one square meter exceeded 100 dpm/100 cm^2 on most parts of floor and were as high as 2000 dpm/100 cm^2; many individual instrument readings exceeded 5,000 dpm/100 cm^2, particularly in southeast corner of room; highest individual instrument reading was 20,000 dpm in survey square A-16.
B-2	South wall	Most areas measured less than 100 dpm/100 cm^2. Some spots on blocks at bottom of wall and on horizontal beams across wall measured 200 to 400 dpm/100 cm^2.
B-3	West wall	Horizontal 2 x 4's measured 300 to 700 dpm/100 cm^2 on "gable" part of wall; on lower part of wall horizontal wooden studs were generally near 800 dpm/100 cm^2; on remainder of wall, several large areas around sink and north of door averaged 200 dpm/100 cm^2 or greater.

Table 4. (cont'd.) Direct measuremens of alpha contamination in Buildings B and C

Building and room	Location	Extent of alpha contamination as indicated by direct readings[a]
B-3	East wall	Horizontal beams showed 200 to 1200 dpm/100 cm^2. Bottom 2 ft on south end of wall showed 400 to 800 dpm/ 100 cm^2 in many places. Area adjacent to north side showed 400 dpm/100 cm^2.
B-2	North wall	200 to 600 dpm/100 cm^2 on horizontal beams, pipes, and ledges; lower parts of walls exterior to Room 4 showed 300 to 1200 dpm/100 cm^2 and top of door to Room 4 showed 400 dpm/100 cm^2.
B-3	Overhead: beams and lights. (Readings taken at 22 randomly distributed points.)	Most readings were in the range of 500 to 15,000 dpm/100 cm^2 and averaged 2500 dpm/100 cm^2. All readings exceeded 100 dpm/100 cm^2.
B-3	Floor (see Figs. 8 and 9)	Readings averaged over one square meter exceeded 100 dpm/100 cm^2 in most areas of floor, along west wall many individual instrument readings were in the range of 5000 to 20,000 dpm/100 cm^2 and were as high as 70,000 dpm/100 cm^2.
B-4	West wall	1400 to 1800 dpm/100 cm^2.
B-4	Hood along west wall	300 to 5000 dpm/100 cm^2 inside; approx- 100 dpm/100 cm^2 outside.
B-4	West and south walls	Approximately 100 dpm/100 cm^2 (average).
B-4	North wall	Average 200 dpm/100 cm^2 on upper part of wall; averaged 400 dpm/100 cm^2 on lower part.
B-4	Ceiling	200 to 400 dpm/100 cm^2.
B-4	Floor (see Figs. 8 and 9)	Exceeded 300 dpm/100 cm^2 in many places, averaged over one square meter. Some individual instrument readings in western-most third of floor were in range of 3000 to 30,000 dpm/100 cm^2.

Table 4. (cont'd.) Direct measuremens of alpha contamination in Buildings B and C

Building and room	Location	Extent of alpha contamination as indicated by direct readings[a]
B-5	Walls and ceiling	No alpha contamination above 100 dpm/100 cm^2.
B-5	Floors (see Figs. 8 and 9)	Averaged more than 100 dpm/100 cm^2 over most of floor; individual instrument readings were as high as 4000 dpm/100 cm^2.
B-6	Walls and ceiling	No alpha contamination above 100 dpm/100 cm^2.
B-6	Floor (see Figs. 8 and 9)	Averaged from 200 to 1000 dpm/100 cm^2.
B-7	Walls and ceiling	Measured less than 100 dpm/100 cm^2 except at three spots on west wall; two spots (each <1 m^2) at 5 to 6 ft above floor above square 0-16 (see Fig. 2) averaged 200 dpm/100 cm^2 and a spot (<1 m^2) above square 0-17 averaged 300 dpm/100 cm^2.
B-7	Floor (see Figs. 8 and 9)	Roughly 80% of floor averaged greater than 100 dpm/100 cm^2; the maximum individual instrument reading was 2000 dpm/100 cm^2.
B-8	Walls, ceiling, floor	Averaged less than 100 dpm/100 cm^2 in each square meter, all individual instrument readings less than 160 dpm/100 cm^2.
B-9	Walls, ceiling floor	All individual instrument readings less than 100 dpm/100 cm^2.
B-10	Walls, ceiling, floor	All individual instrument readings less than 100 dpm/100 cm^2.
B-11	Walls, ceiling	All individual instrument readings less than 100 dpm/100 cm^2.
B-11	Floor (see Figs. 8 and 9)	Survey squares averaged 40 to 120 dpm/100 cm^2; highest individual instrument reading was 180 dpm/100 cm^2.

Table 4. (cont'd.) Direct measuremens of alpha contamination in Buildings B and C

Building and room	Location	Extent of alpha contamination as indicated by direct readings[a]
B	Area over Rooms 5, 6, 7, 8, 9, 10, and 11	Uniformly 200 to 400 dpm/100 cm^2.
C-flammable storage room	South wall	Alpha contamination found only on lower wall. From 0 to 1 ft averaged 200 to 500 dpm/100 cm^2 with maximum readings of 2000 to 6000 dpm.
C-flammable storage room	East wall	Averaged 200 to 600 dpm/100 cm^2 on lower wall; some individual instrument readings were in range 12,000 to 40,000 dpm/100 cm^2 at wall-floor intersection; no alpha contamination above 3 ft.
C-flammable storage room	North wall	All individual instrument readings were less than 100 dpm/100 cm^2.
C-flammable storage room	West wall	Averaged 100 to 200 dpm/100 cm^2 near floor, with little alpha contamination above one foot from floor.
C-flammable storage	Window ledges (see Fig. 10)	Measurements generally in range 140 to 1600 dpm/100 cm^2.
C-flammable storage room	Overhead	No alpha contamination found.
C-flammable storage room	Floor (see Fig. 10)	Survey at random points suggested that alpha contamination exceeding 100 dpm/100 cm^2 by direct reading was concentrated mainly at 0 to 1 ft from south and east walls. Much of alpha contamination was in cracks, and highest readings appeared to be from thoron emanations.
C-flammable storage room	Walls and overhead	No alpha contamination detected.

Table 4. (cont'd.) Direct measuremens of alpha contamination in Buildings B and C

Building and room	Location	Extent of alpha contamination as indicated by direct readings[a]
C-old storage room	Floor (see Fig. 11)	New concrete. Little alpha contamination except near bottom of north wall where some readings exceeded 100 dpm/100 cm^2 and were as high as 4200 dpm/100 cm^2, apparently due to outgassing of thoron.
C-old process area	Floor	No alpha contamination except directly above open drains, where readings up to 4000 dpm/100 cm^2 were recorded, and in an area of less than 1 m^2 around a crack near the southwest corner of the solvent storage room, where readings of approximately 800 dpm/100 cm^2 were recorded.
C-old process area	Walls and overhead	All individual instrument readings were less than 100 dpm/100 cm^2.

[a]Unless stated otherwise, measurements represent averages over areas no larger than 1 m^2.

Table 5. Transferable alpha and beta contamination levels

Building and Room	Area	No. of smear samples taken	No. of samples exceeding NRC limits (α or β)	Av & max transferable α levels for samples exceeding α limits (dpm/100 cm^2)	Av & max. transferable β levels for samples exceeding β limits (dpm/100 cm^2)	General location of smear samples exceeding NRC limits
B-1	Floor	75	19	av 60 max 200	av 115 max 440	In northeast corner of floor; also in survey blocks D8, D10, and K3 (see Fig. 2).
B-1	South wall	43	23	av 35 max 35	av 85 max 280	Principally on horizontal steel and concrete ledges; also on some vertical surfaces near ceiling.
B-1	East wall	17	10	av 25 max 30	av 80 max 130	Uniformly on northern half of upper wall.
B-1	West wall	28	0			
B-1	North wall	26	19	av 115 max 340	av 75 max 150	On eastern two-thirds of wall, principally on horizontal steel beams; also scattered spots on vertical surfaces.
B-1	Over-head	46	34	av 145 max 500	av 175 max 900	On all metal surfaces.
B-2	Floor	75	24	av 50 max 110	av 60 max 140	Some contamination in south end of room, within 10 ft of Room 1.
B-2	West wall	14	6	av 25 max. 30	av 55 max 100	On horizontal ledges and at scattered spots on vertical surfaces.
B-2	South wall	14	5	av 40 max 55	av 50 max 80	On concrete supports near floor.

Table 5. (cont'd.) Transferable alpha and beta contamination levels

Building and Room	Area	No. of smear samples taken	No. of samples exceeding NRC limits (α or β)	Av & max transferable α levels for samples exceeding α limits (dpm/100 cm^2)	Av & max. transferable β levels for samples exceeding β limits (dpm/100 cm^2)	General location of smear samples exceeding NRC limits
B-2	East wall	13	0			
B-2	North wall	21	10	below limits	av 70 max 120	Principally on horizontal blocks and beams; also in scattered spots on vertical surfaces of western half of wall.
B-2	Overhead	22	13	av 30 max 40	av 50 max 120	Metal surfaces.
B-2	Drains	8	3	av 50 max 110	av 100 max 100	Drains No. 21, 24 and 25 (see Fig. 6).
B-2	Area over Rooms 5, 6 7, 8, 9, 10 and 11	21	5	av 30 max 35	av 35 max 50	
B-3	Floor	28	18	av 35 max 70	av 60 max 110	Scattered throughout room.
B-3	South wall	4	1	av 25 max 25	below limits	Horizontal steel beam.
B-3	East wall	4	3	below limits	av 65 max 110	Pipes and beams.
B-3	West wall	8	8	av 50 max 95	av 95 max 200	Entire wall appears to be contaminated.
B-3	North wall	4	0			
B-3	Overhead	12	12	av 95 max 240	av 180 max 530	All metal surfaces.

Table 5. (cont'd.) Transferable alpha and beta contamination levels

Building and Room	Area	No. of smear samples taken	No. of samples exceeding NRC limits (α or β)	Av & max transferable α levels for samples exceeding α limits (dpm/100 cm^2)	Av & max. transferable β levels for samples exceeding β limits (dpm/100 cm^2)	General location of smear samples exceeding NRC limits
B-4	All surfaces	4	4	av 80 max 90	av 65 max 70	Smears were taken on floor, one wall, ceiling, and a duct.
B-5	All surfaces	7	5	below limits	av 65 max 80	Floor, east wall, south wall, west wall, and overhead.
B-6	All surfaces	10	3	av 110 max 135	av 145 max 160	Floor and south wall.
B-7	All surfaces	8	3	av 25 max 25	av 85 max 140	Floor.
B-8	All surfaces	8	0			
B-9	All surfaces	10	2	av 25 max 30	under limit	Floor.
B-10	Floor, wall overhead	3	0			
B-11	All surfaces	10	1	av 25 max 25	under limit	Floor.
Bldg. C flammable storage room	Floor and walls	51	10	avg 35 max 40	av 60 max 90	All on lower walls, mainly under windows on east and north walls; also in northwest corner of room. No smear samples taken on ceiling, which was covered with asbestos insulation.

Table 5. (cont'd.) Transferable alpha beta contamination levels

Building and Room	Area	No. of smear samples taken	No. of samples exceeding NRC limits (α or β)	Av & max transferable α levels for samples exceeding α limits (dpm/100 cm^2)	Av & max. transferable β levels for samples exceeding β limits (dpm/100 cm^2)	General location of smear samples exceeding NRC limits
Bldg. C old storage area	All surfaces including drains	65	0			
Bldg. C [large open area referred to as] **old** process area (see Fig. 1)	Overhead	38	0			

Table 6. Direct alpha and beta-gamma readings[a] on roofs of Buildings B and C

Location (See Fig. 3)	Alpha contamination (dpm/100 cm^2)	Beta-gamma dose rate (mrad/hr)	Approximate percentage of beta-gamma reading resulting from beta radiation[b]
R1	480	0.03	14
R2	80	0.03	17
R3	50	0.02	20
R4	420	0.03	17
R5	220	0.03	17
R6	360	0.02	0
R7	60	0.02	0
R8	540	0.03	17
R9	560	0.03	17
R10	600	0.03	17
R11	480	0.03	17
R12	280	0.04	25
R13	300	0.03	17
R14	2940	0.03	14
R15	50	0.02	20
R16	240	0.03	17
R17	780	0.03	33
R18	480	0.03	33

[a]These measurements represent individual instrument readings at 18 randomly selected locations.

[b]The percentage P is estimated from the formula:

$$P = 100 \times \frac{\text{open-window G-M reading - closed-widow G-M reading}}{\text{open-window G-M reading}}$$

Table 7. Direct measurement of beta-gamma contamination in Buildings B and C

Building and room	Location	Extent of beta-gamma contamination as indicated by direct readings
B-1	Walls	Less than 0.05 mrad/hr at all points.
B-1	Overhead: ceiling beams, pipes, ducts, insulation	Generally 0.25 to 1.35 mrad/hr on horizontal surfaces of beams and lights and less than 0.10 mrad/hr elsewhere.
B-1	Floor (see Figs. 12 and 13)	Readings averaged over 1 m^2 exceeded 0.20 mrad/hr in northeast corner; individual instrument readings exceeded 1 mrad/hr at many points in northeast corner and were as high as 6.8 mrad/hr.
B-2	Walls and overhead	Less than 0.05 mrad/hr at all points.
B-2	Floor (see Fig. 12)	Readings averaged over 1 m^2 did not exceed 0.07 mrad/hr except in the southeast corner, where an average of 0.18 mrad/hr was recorded.
B-3 and B-4	Walls and overhead	Readings were less than 0.10 mrad/hr at all points.
B-3 and B-4	Floor (see Fig. 12)	No readings exceeded 0.05 mrad/hr.
B, rooms 5, 6, 7, 8, 9, 10, and 11	All areas	No readings exceeded 0.05 mrad/hr.
B	Area over rooms 5, 6, 7, 8, 9, 10, and 11	All readings less than 0.05 mrad/hr.
C-flammable storage room	Walls and overhead	Less than 0.05 mrad/hr at all points.
C-flammable storage room	Floor (see Fig. 14)	Average over area of no more than 1 m^2 exceeded 0.20 in area near wall in southeast corner.
C-old storage room	Walls and overhead	Less than 0.05 mrad/hr at all points.
C-old storage	Floor (see Fig. 15)	Individual instrument readings did not exceed 0.11 mrad/hr.
C	Remainder of building	No reading above background.

Table 8. Gamma and beta-gamma readings outdoors on and near the site

Location (See Fig. 3)	Gamma radiation at 1 m (μR/hr)	Gamma radiation at surface (μR/hr)	Beta-gamma dose rates at 1 cm (mrad/hr)
1	12	16	0.02
2	12	12	0.02
3	13	13	0.02
4	10	10	0.02
5	18	18	0.02
6	12	12	0.02
7	10	10	0.01
8	11	11	0.01
9	12	12	0.02
10	13	13	0.02
11	11	11	0.02
12	13	13	0.02
13	12	12	0.02
14	12	12	0.03
15	10	10	0.03
16	10	10	0.03
17	12	12	0.02
18	13	13	0.02
19	12	12	0.03
20	12	12	0.03
21	12	12	0.02
22	28	70	0.07
23	12	12	0.02
24	14	24	0.04
25	14	14	0.04
26	Inaccessible	90	0.09
27	14	14	0.02
28	12	12	
29	12	12	
30	14	14	
31	11	11	
32	16		
33	14		
34	14		

Table 9. Radioactivity in drains[a]

Building and Drain No.	Alpha activity at 3-5 cm above drain (dpm/100 cm^2)	Gamma radiation level inside drain (μR/hr)	Nuclide concentrations in samples taken from drain	
			^{232}Th (pCi/g)	^{230}Th (pCi/g)
B1	1000	28		
B2	3000	100		
B3	800	-		
B4	600	22		
B5	1600	80	13	2
B6	5000	1000	2530	505
B7	160,000	2000		
B8	1,000,000	2200	318	70.7
B9	120,000	800		
B10	10,000	200		
B11	50,000	3000		
B12	150,000	-		
B13	0	100		
B14	1200	300		
B15	500	24		
B16	500	60		
B17	500	200		
B18	400	400		
B19	300	16		
B20	400	22		
B21	600	20		
B22	Plugged	Plugged		
B23	100	20		
B24	600	16		
B25	3500	18		
B26	400	14		
B27	300	17		
C1	0	60		
C2	40	28		
C3	4000	60	10	2.5
C4	1200	32		
C5	600	24		
C6	200	24		
C7	20	24		

[a] See Figs. 5 and 6 for locations.

Table 10. Concentrations of soluble and suspended ^{232}Th and ^{228}Th in water samples

Sample location	Water (pCi/liter)		Solids suspended in water (pCi/g)		
	^{232}Th	^{228}Th	^{232}Th	^{228}Th	^{230}Th
Bldg. C, Drain 1 (Fig. 5)	$<5 \times 10^{-5}$	$<5 \times 10^{-5}$	<0.2	<0.2	<0.2
Bldg. C, Drain 2 (Fig. 5)	$<5 \times 10^{-5}$	$<10^{-4}$	N.D.[a]	0.3	N.D.
Tap-water sample from Cleveland water system	N.D.	$<5 \times 10^{-4}$			
RCG_W	2	7			

[a] N.D. = not detected.

Table 11. Concentrations of thoron (^{220}Rn) daughter radionuclides in air

Location[a]	Date	Starting time	Sampling period (min)	Th-B (pCi/liter)	Th-C (pCi/liter)
1	2-10-77	3:00 pm	60	1.4×10^{-2}	<MDA[b]
2	2-10-77	5:20 pm	926	8.4×10^{-3}	<MDA
3	2-11-77	9:40 am	60	1.4×10^{-2}	4.3×10^{-3}
4	2-11-77	11:20 am	240	7.6×10^{-3}	<MDA
5	2-12-77	9:30 am	60	1.7×10^{-2}	1.5×10^{-3}
6	2-12-77	11:01 am	60	5.0×10^{-3}	4.6×10^{-3}
7	2-12-77	4:10 pm	65	3.6×10^{-1}	1.9×10^{-1}
8	2-15-77	12:10 pm	1265	1.3×10^{-2}	<MDA
9	2-16-77	10:00 am	240	4.9×10^{-1}	1.8×10^{-1}
CG_a				6×10^{-1}	3

[a]See Fig. 19.

[b]MDA = minimum detectable activity.

APPENDIX I

PHOTOGRAPHS OF CLECON METALS, INC., SITE

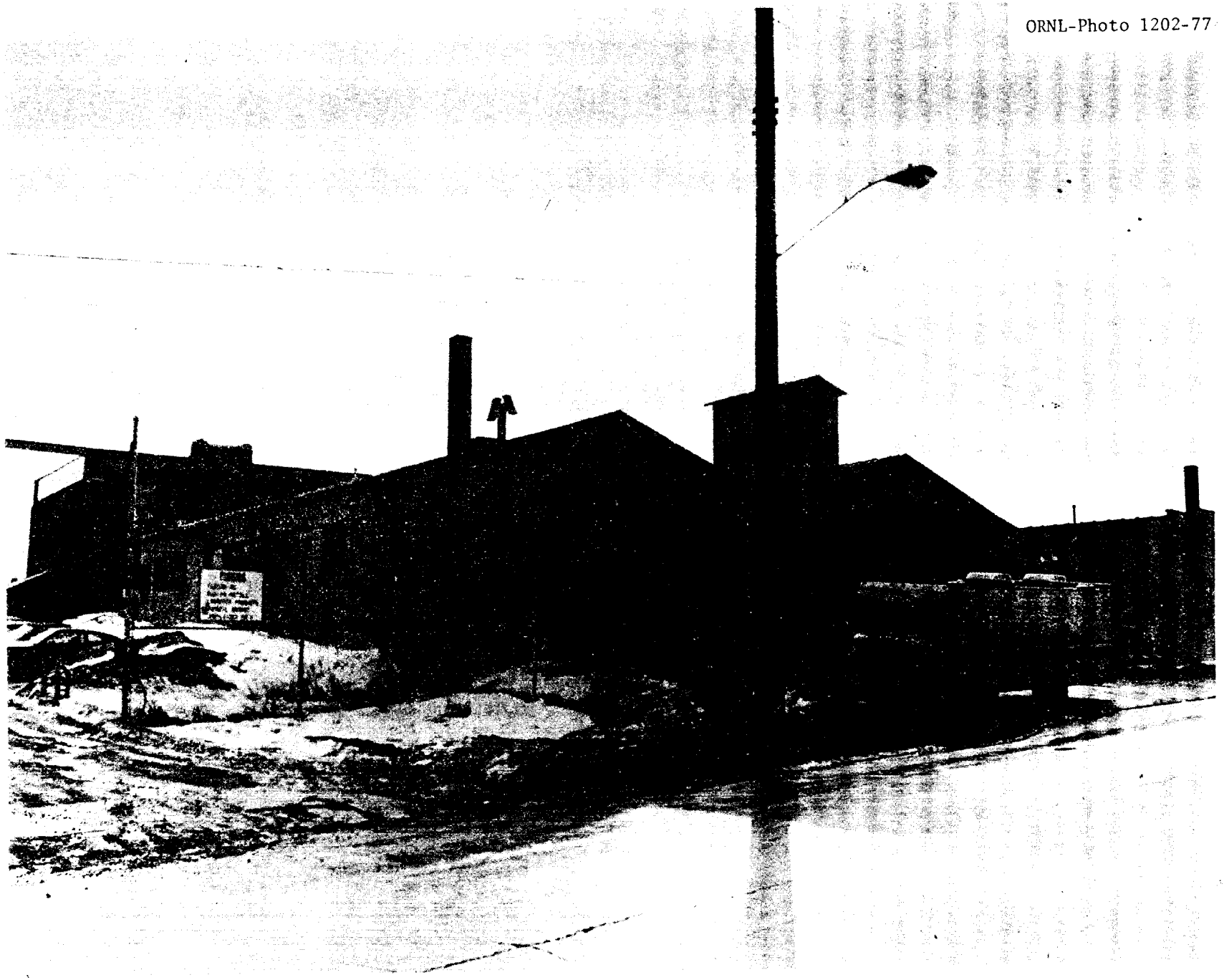

Fig. I-A. Northwest corner of Building B.

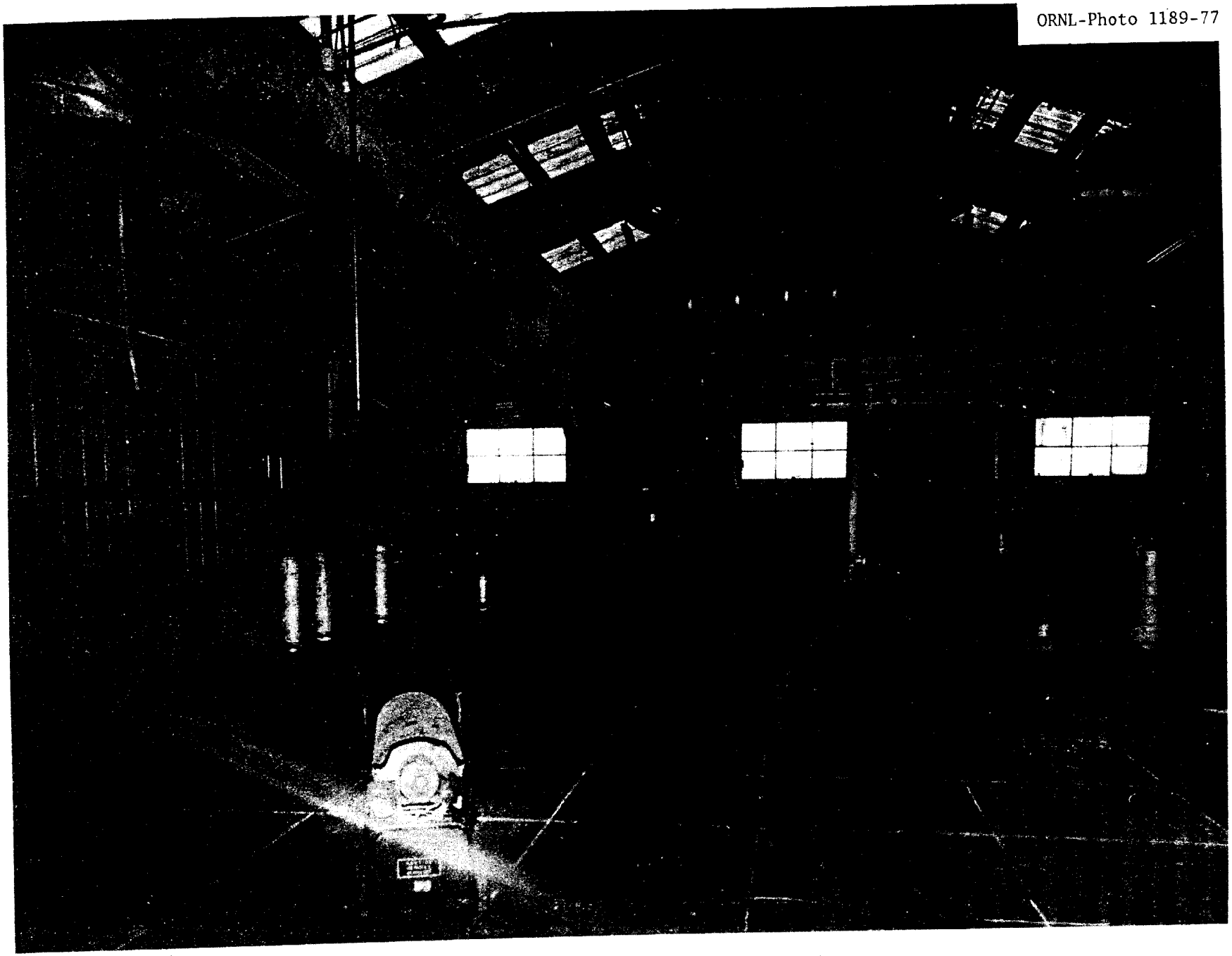

Fig. I-B. View east to west in Room 1 Building B.

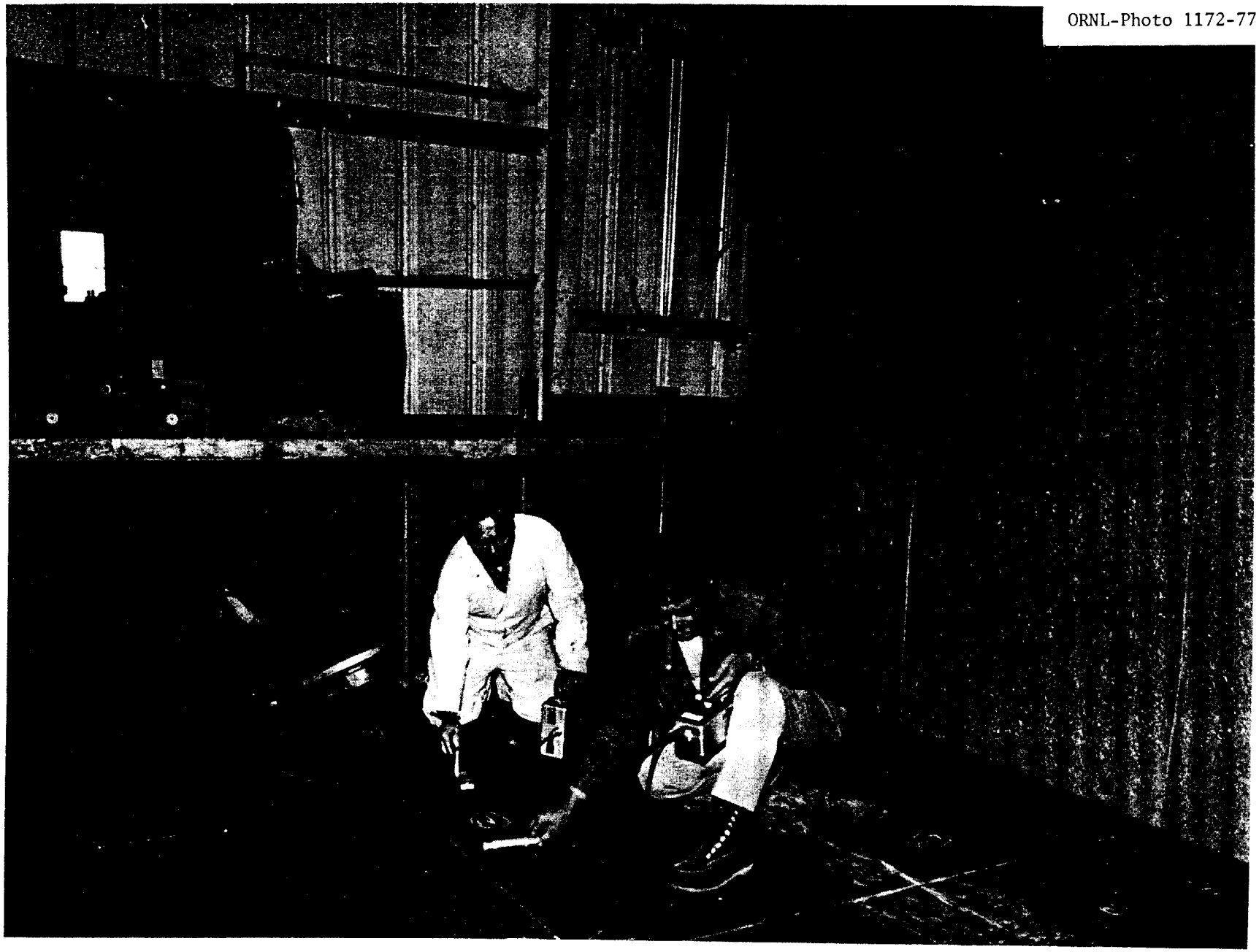

Fig. I-C. Northeast corner of Room 1 in Building B (most-contaminated surfaces on the site).

ORNL-Photo 1167-77

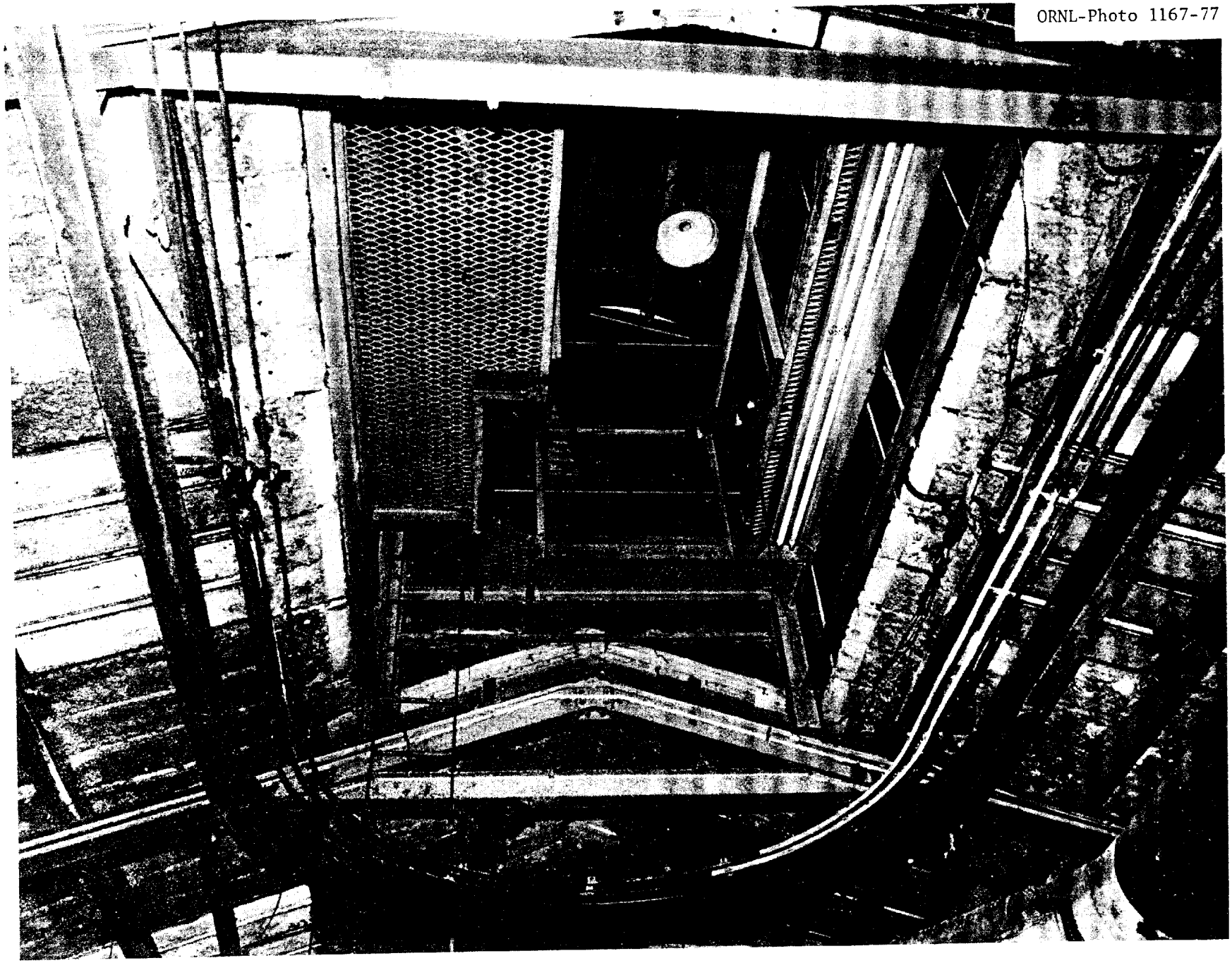

Fig. I-D. Overhead view in Room 1 of Building B.

ORNL-Photo 1203-77

Fig. I-E. Entrance to Clecon, Inc., built over old alley.

ORNL-Photo 1161-77

Fig. I-F. Old process area in Building C.

ORNL-Photo 1166-77

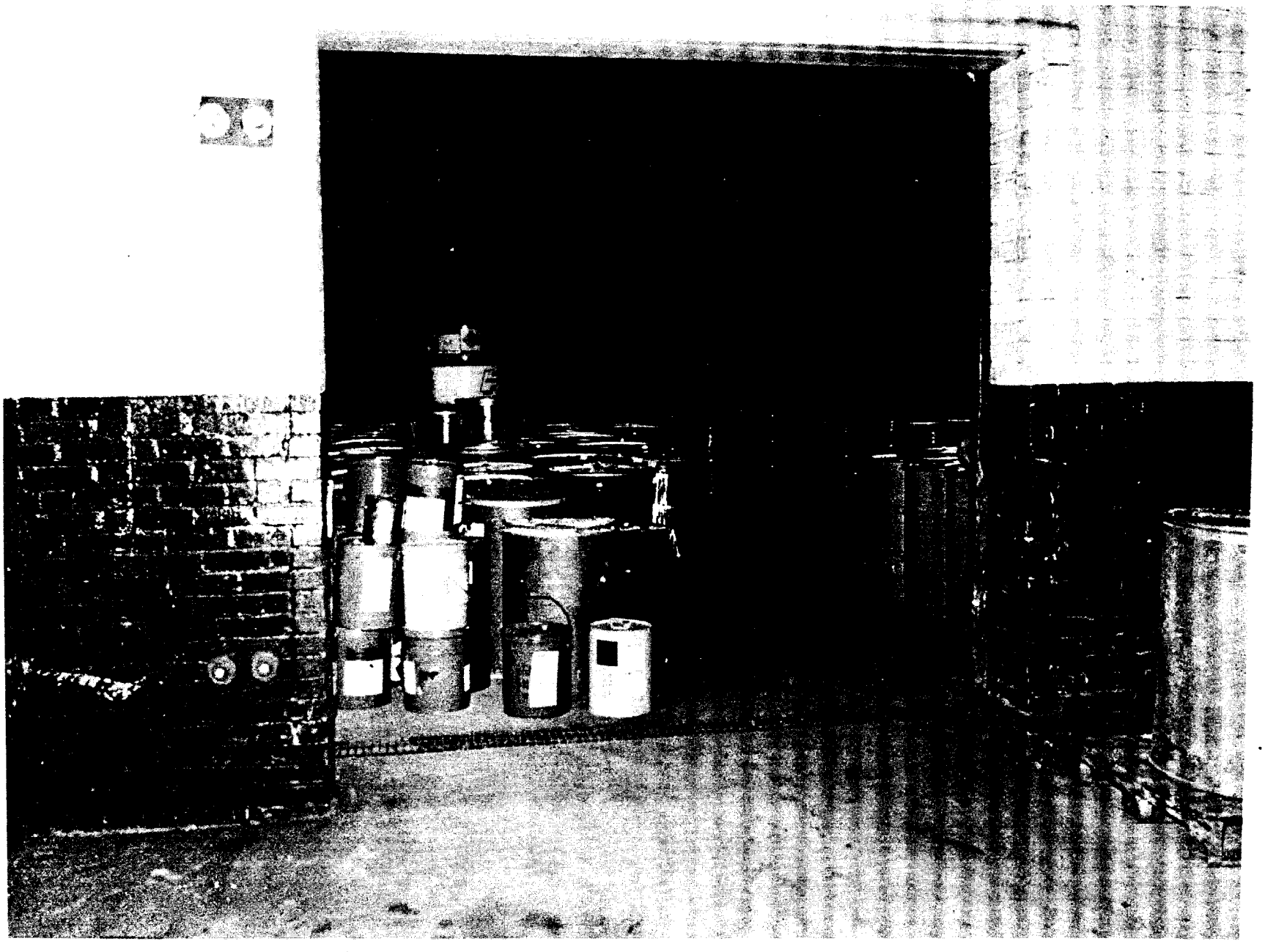

Fig. I-G. View north to south of solvent storate room in Building C.

ORNL-Photo 1182-77

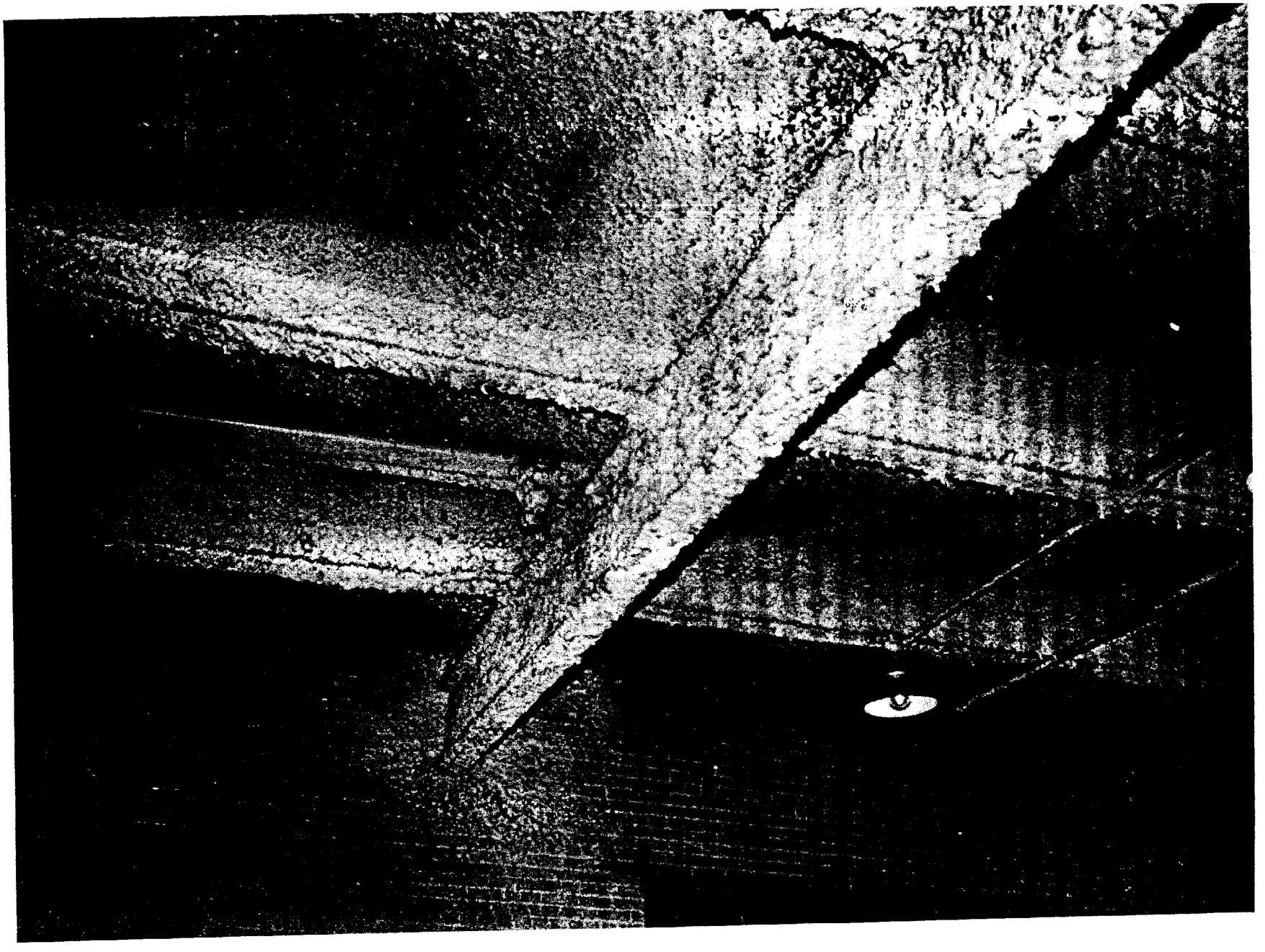

Fig. I-H. Asbestos ceiling of solvent storage room in Building C.

ORNL-Photo 1185-77

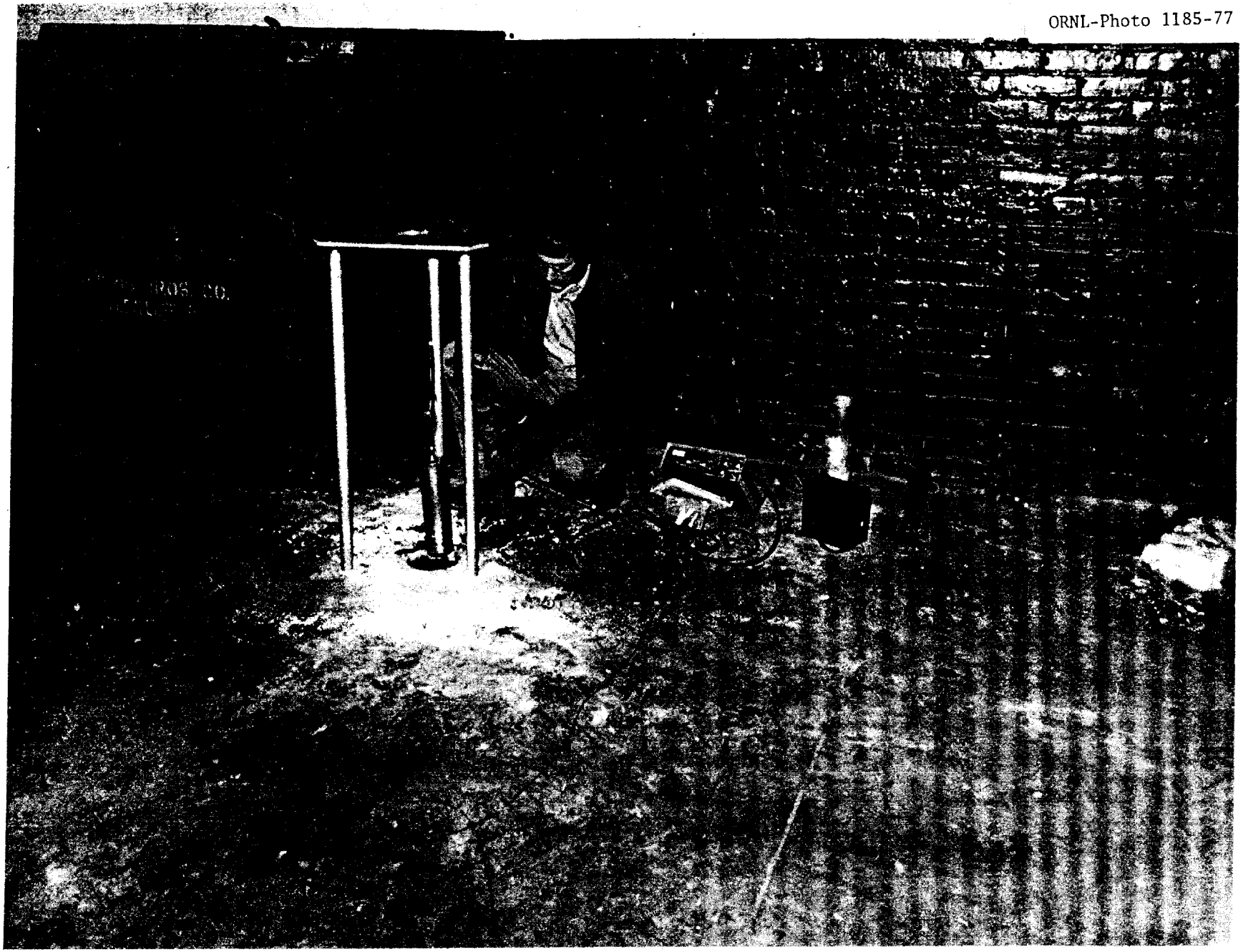

Fig. I-I. South side of old storage area in Building C.

ORNL-Photo 1180-77

Fig. I-J. View southwest to northeast in old storage area in Building C, showing workmen at a core drilling site.

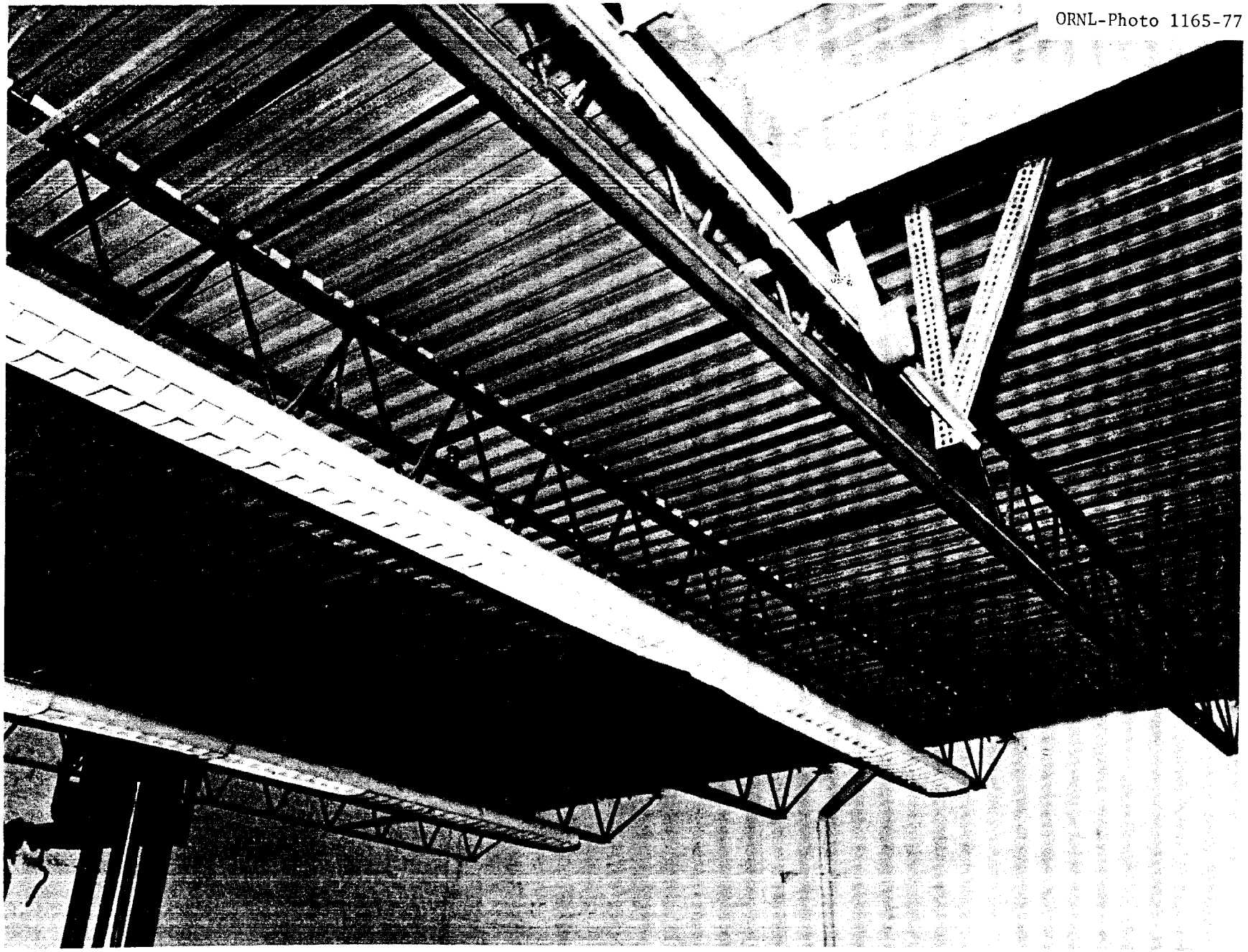

Fig. I-K. New ceiling of old storage area in Building C.

ORNL-Photo 1201-77

Fig. I-L. Parking area at north end of Clecon property.

APPENDIX II

DESCRIPTION OF RADIATION SURVEY METERS AND SMEAR COUNTERS

RADIATION SURVEY METERS

Alpha Survey Meters

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

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

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

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

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

Beta Survey Meter

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

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

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

Gamma Scintillation Survey Meter

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

SMEAR COUNTERS

Alpha Smear Counter

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

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

Beta Smear Counter

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

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

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

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

ORNL-Photo 6705-76

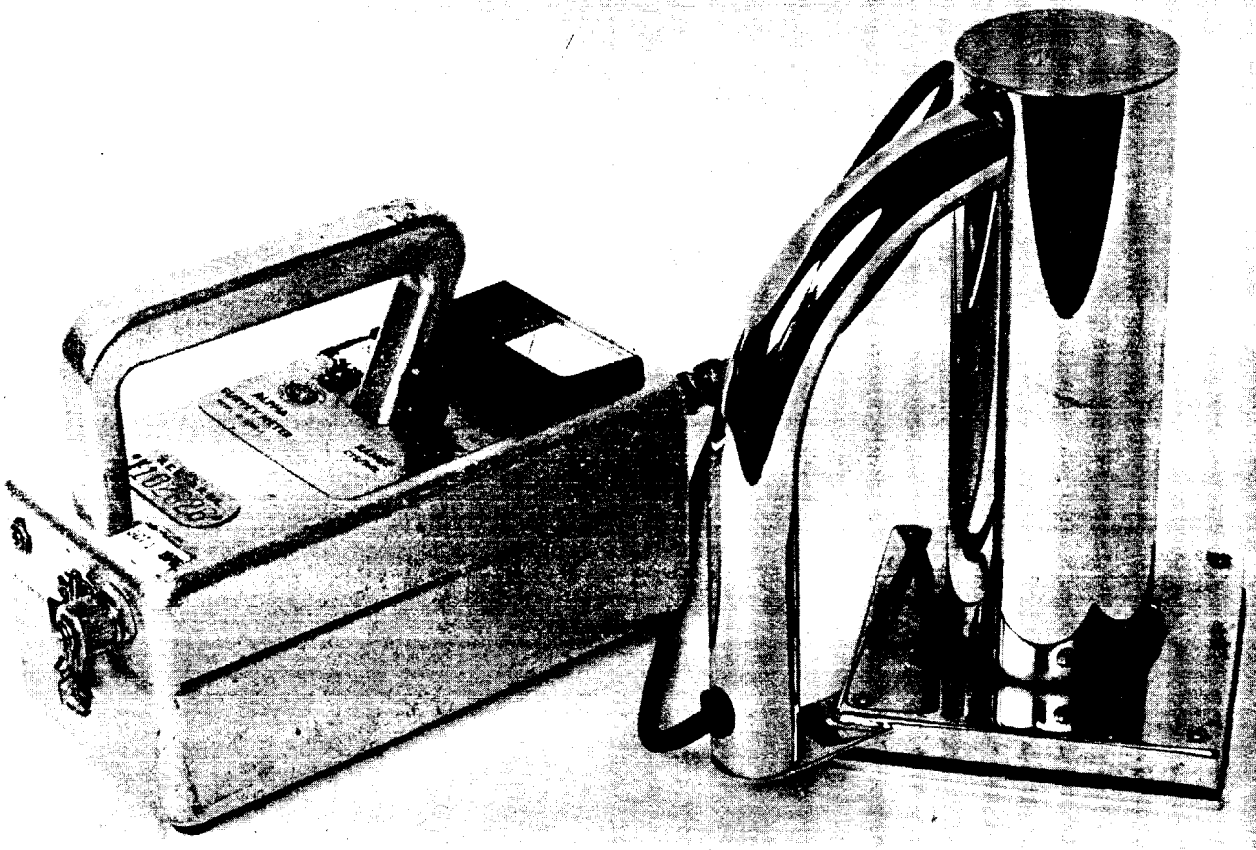

Fig. II-A. Alpha scintillation survey meter.

ORNL-Photo 6715-76

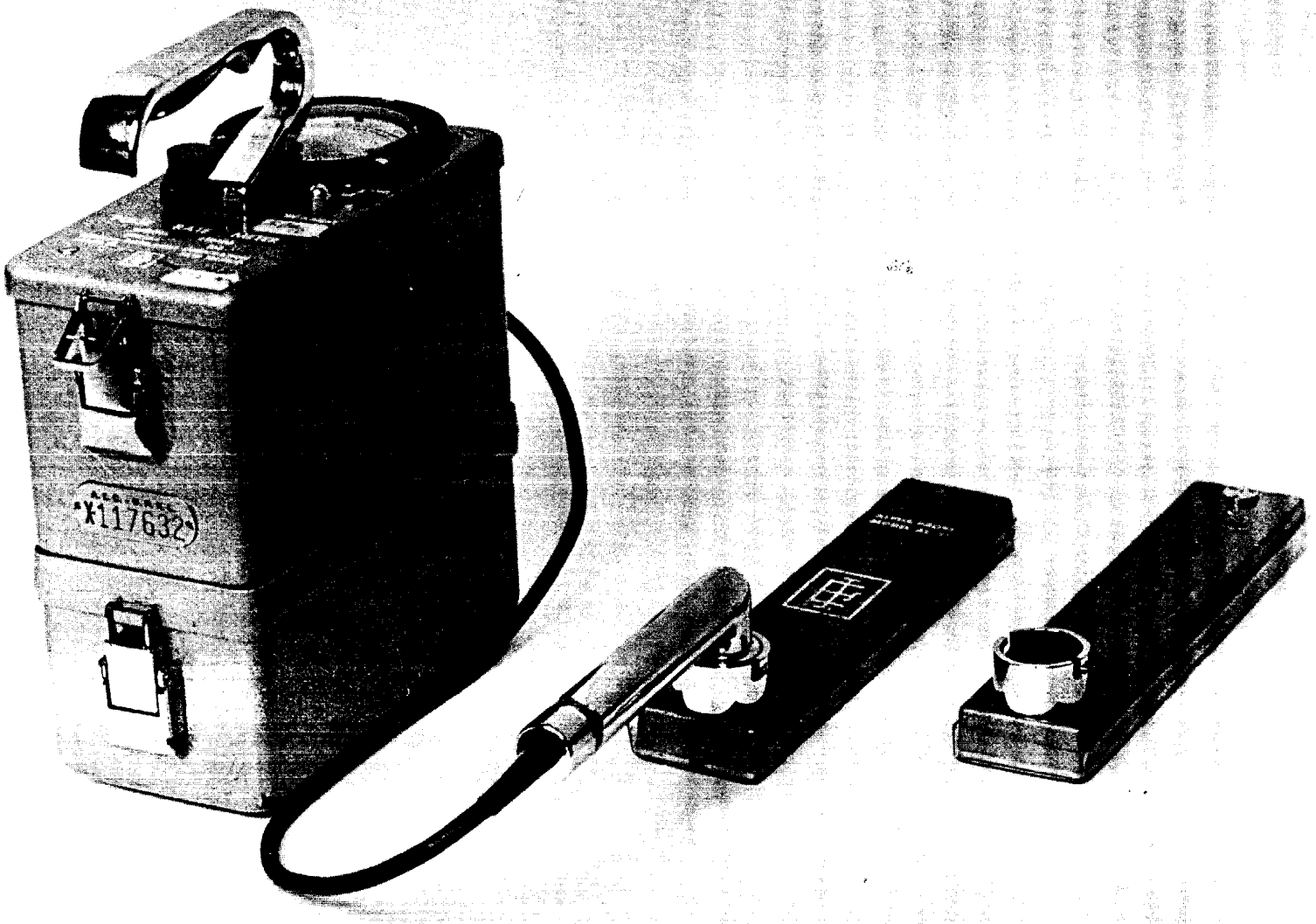

Fig. II-B. Gas-flow proportional alpha survey meter.

ORNL-Photo 6704-76

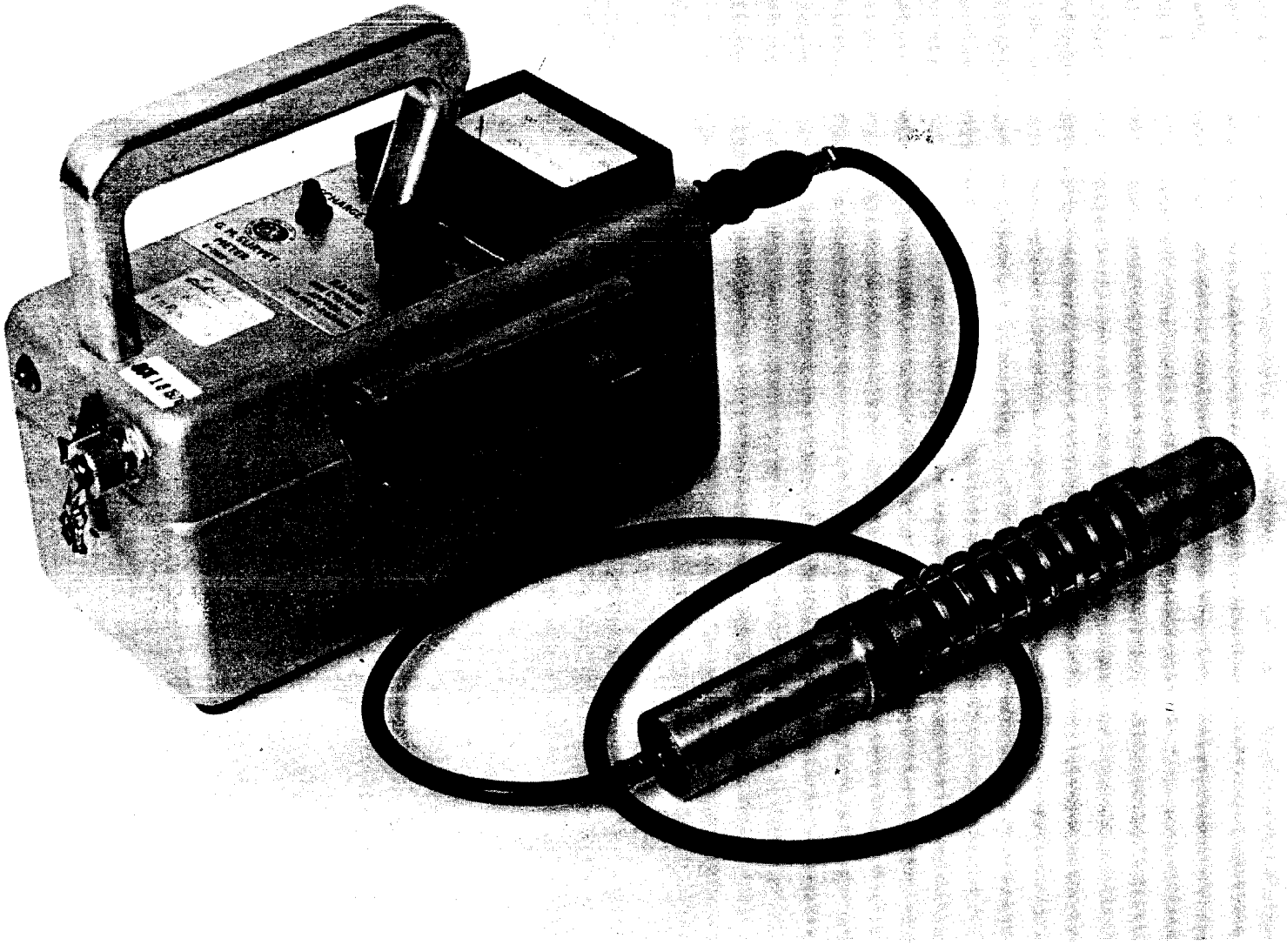

Fig. II-C. Geiger-Muller survey meter.

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

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

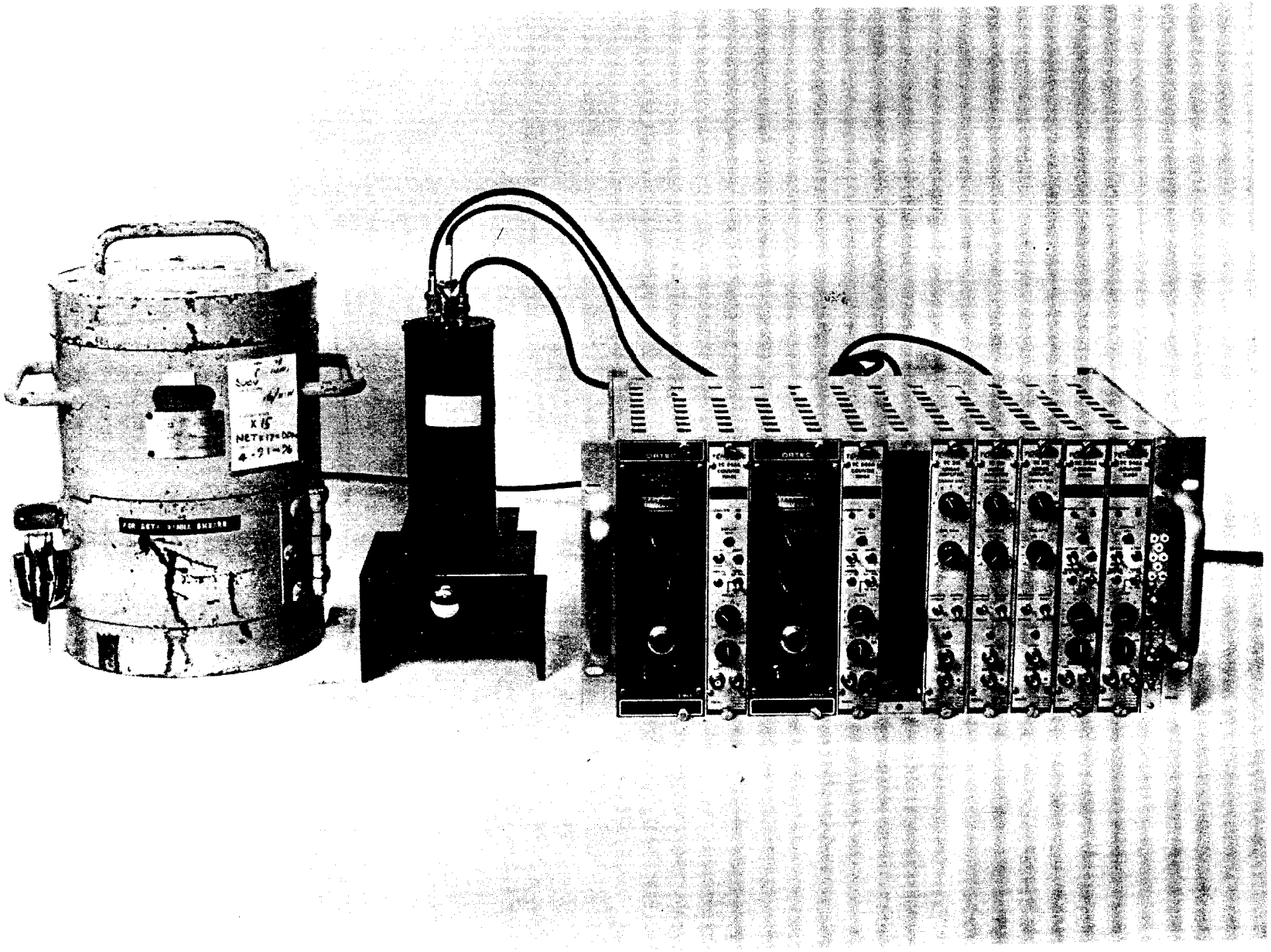

Fig. II-F. Alpha and beta smear counters.

Fig. II-G. Mobile laboratory.

APPENDIX III

TECHNIQUE FOR THE MEASUREMENT OF THORON PROGENY CONCENTRATIONS IN AIR

TECHNIQUE FOR THE MEASUREMENT OF ^{220}Rn THORON PROGENY CONCENTRATIONS IN AIR

An alpha spectrometry technique has been developed for the measurement of ^{220}Rn progeny concentrations in air. From two integral counts of the ^{212}Po alpha peaks, the concentrations in air of ^{212}Pb (Thorium B) and ^{212}Bi (Thorium C) may be calculated.

Particulate ^{220}Rn daughters attached to airborne dust are collected on a membrane filter with a pore size of 0.4 microns. A sampling time of 1 to 15 hr and a flow rate of 12 liters/min are used. The filter sample is then placed under a silicon surface barrier detector and counted. The detector and counting system used for thoron daughter measurements are shown in Fig. III-A. Usually, counting of this kind is performed with a vacuum between the sample and the detector which requires a complicated sample holder and time-consuming sample changing methods. Experiments at this laboratory have shown that ease in sample handling is obtained with little loss in resolution when helium is used to fill the chamber. In this counter, helium flows between the diode and the filter sample, which are 0.5 cm apart. One integral count of the ^{212}Po alpha peak is obtained during the period 60 to 90 min after sampling and a second integral count of the ^{212}Po peak is obtained during the 240- to 295-min post-sampling period.

The equations describing the ^{220}Rn progeny atoms collection rates on the filter are of the form

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

where

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

λ_i = radioactive decay constant of the i^{th} species (min^{-1}),

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

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

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

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

From the general form of the solution, specific equations can be obtained describing the number of each ^{220}Rn decay product collected on the filter as a function of time. Also by letting $v = 0$ in Eq. (1), a set of equations describing the decay on the filter of each ^{220}Rn progeny can be obtained. The equations describing the decay of ^{220}Rn progeny on the filter can be integrated and related to the integral counts obtained experimentally. Values for the total activities of ^{212}Pb and ^{212}Bi on the filter at the end of sampling are obtained by applying matrix techniques. The airborne concentrations are obtained by solving the equations describing the atom collection rates on the filter. A computer program has been written to perform these matrix operations, to calculate the air concentrations of the thoron progeny, and to estimate the accuracy of the calculated concentrations.

ORNL-Photo 6708-76

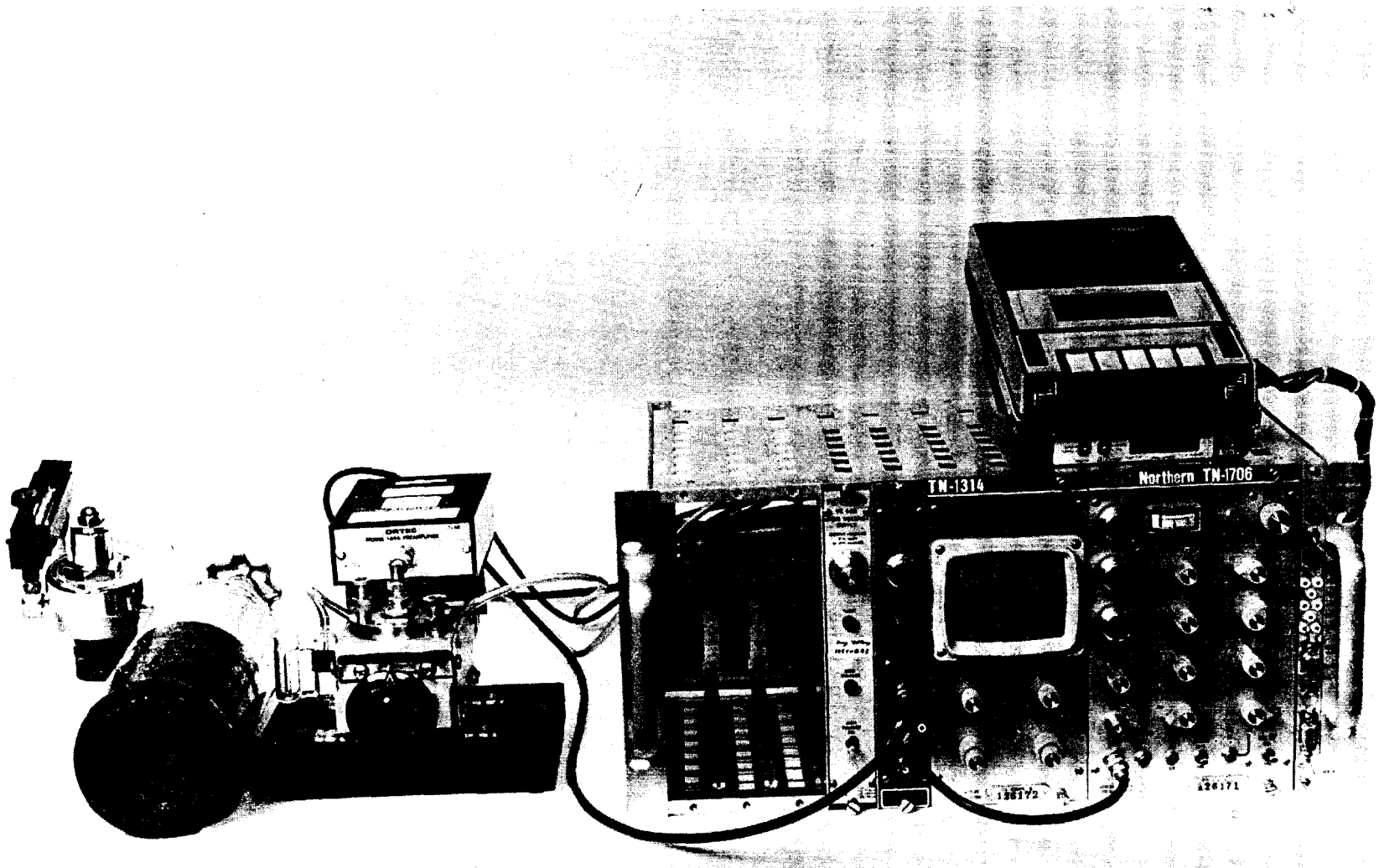

Fig. III-A. System used for measurements of thoron daughter concentrations.

APPENDIX IV

DESCRIPTION OF Ge(Li) DETECTOR AND SOIL COUNTING PROCEDURES

DESCRIPTION OF Ge(Li) DETECTOR SYSTEM

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

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

ORNL-Photo 2172-75

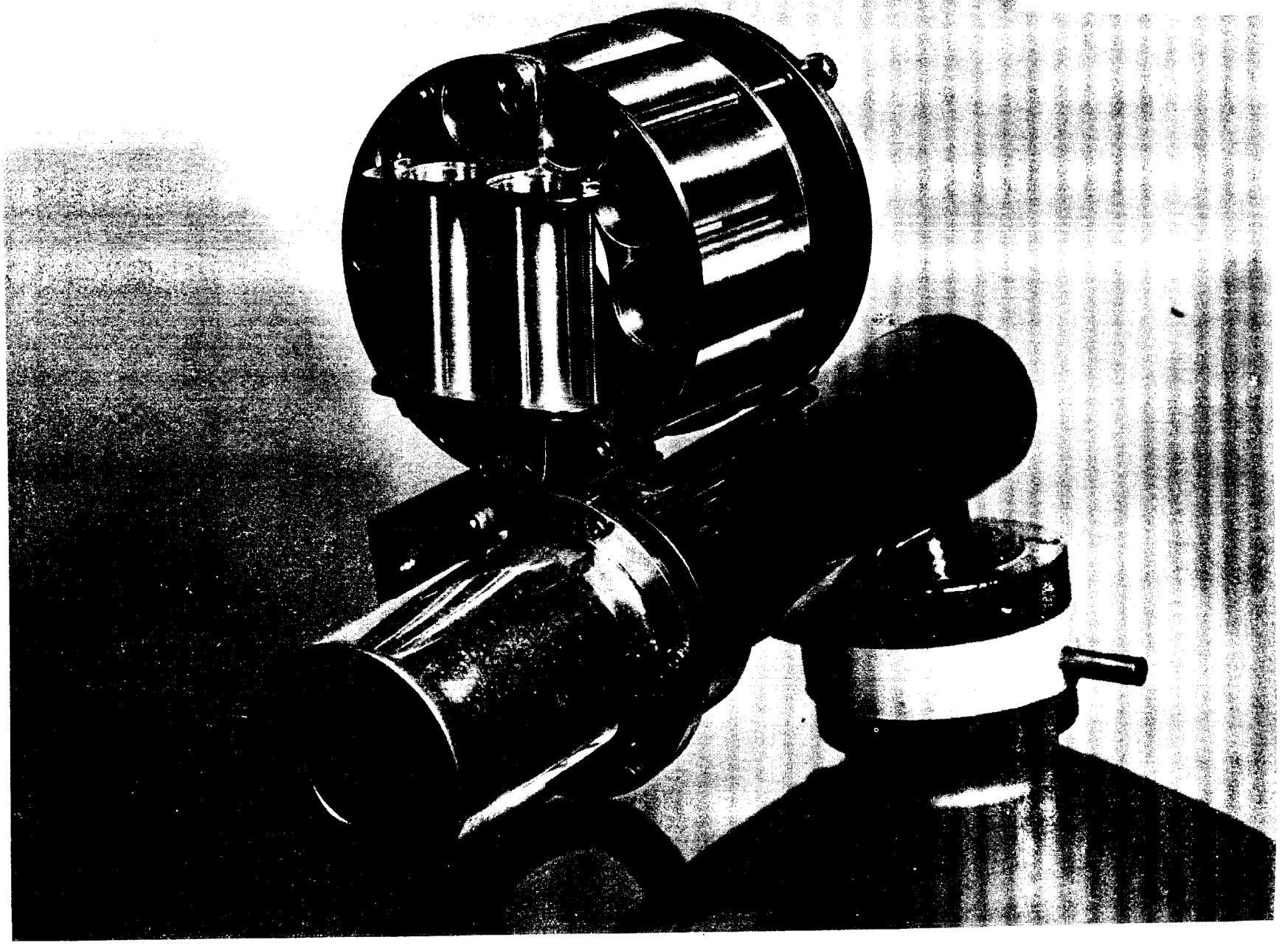

Fig. IV-A. Holder for Ge(Li) detector system.

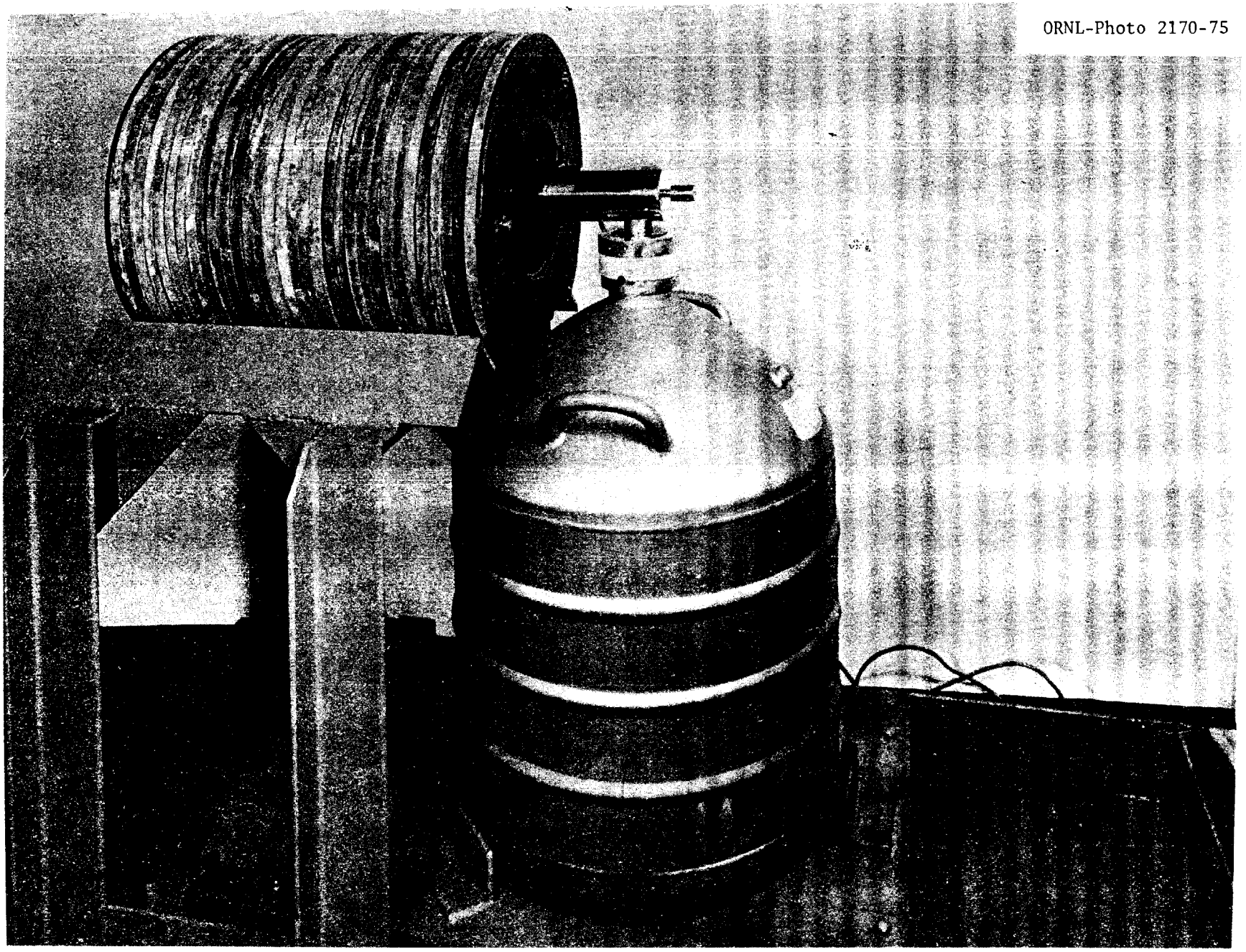

Fig. IV-B. Ge(Li) detector system.

ORNL-Photo 6711-76

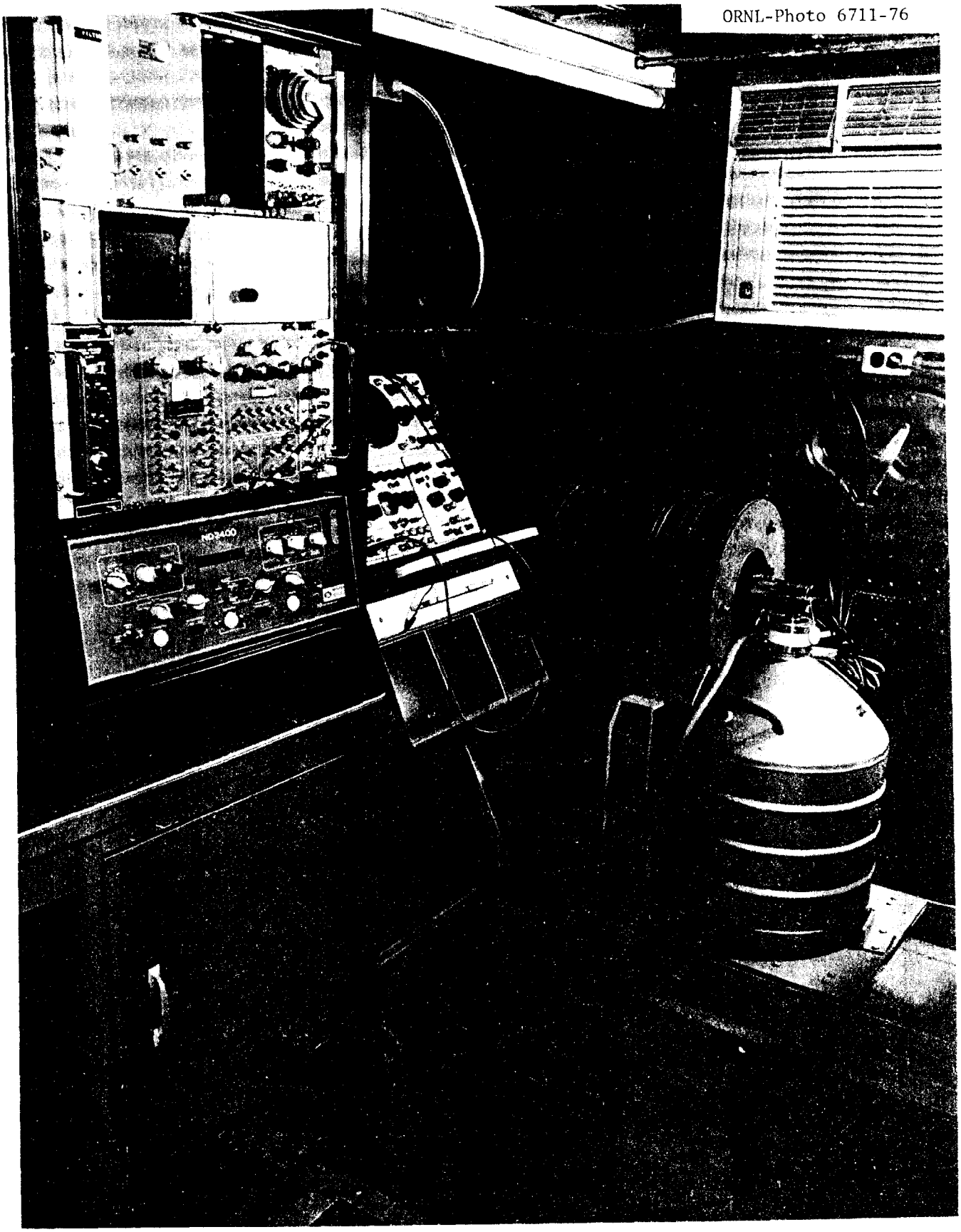

Fig. IV-C. 4096-channel analyzer.

APPENDIX V

PERTINENT RADIOLOGICAL REGULATIONS,

STANDARDS AND GUIDELINES

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

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

November 1976

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

1. The licensee shall make a reasonable effort to eliminate residual contamination.

2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table I prior to applying the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.

3. The radioactivity on the interior surfaces of pipes, drain lines, or ductwork shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces of premises, equipment, or scrap which are likely to be contaminated but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement shall be presumed to be contaminated in excess of the limits.

4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with materials in excess of the limits specified. This may include, but would not be limited to, special circumstances such as razing of buildings, transfer or premises to another organization continuing work with radioactive materials, or conversion of facilities to a long-term storage or standby status. Such request must:

    a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.

    b. Provide a detailed health and safety analysis which reflects that the residual amounts of materials on surface areas, together with other considerations such as prospective use of the premises, equipment or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table I. A copy of the survey report shall be filed with the Division of Fuel Cycle and Material Safety, USNRC, Washington, D.C. 20555, and also the Director of the Regional Office of the Office of Inspection and Enforcement, USNRC, having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:

    a. Identify the premises.

    b. Show that reasonable effort has been made to eliminate residual contamination.

    c. Describe the scope of the survey and general procedures followed.

    d. State the findings of the survey in units specified in the instruction.

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

Table V-1

ACCEPTABLE SURFACE CONTAMINATION LEVELS

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

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

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

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

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

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

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

Excerpts from

Proposed

ANSI N328-197

Proposed American National Standard

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

Secretariat

Health Physics Society

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

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

TABLE V-2

SURFACE CONTAMINATION LIMITS

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

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

*See note following Table 2 on application of limits.

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

‡MPC_w: Maximum Permissible Concentration in Water applicable to members of the public.

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

TABLE V-3

ALTERNATE SURFACE CONTAMINATION LIMITS

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

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

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

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

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

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

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

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

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

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

PART 712 - GRAND JUNCTION REMEDIAL ACTION CRITERIA

712. 1 Purpose

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

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

713.2 Scope

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

712.3 Definitions

As used in this part:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

712.4 Interpretations

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

712.5 Communications

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

712.6 General radiation exposure level criteria for remedial action

The basis for undertaking remedial action shall be the applicable

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

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

712.7 Criteria for determination of possible need for remedial action

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

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

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

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

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

(1) For dwellings and schoolrooms:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

712.10 Selection of appropriate remedial action

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

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

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

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

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

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

(a) Combined ^{226}Ra and ^{228}Ra - 5 pCi/liter.

(b) Gross alpha particle activity (including ^{226}Ra but excluding radon and uranium) - 15 pCi/liter.

APPENDIX VI

EVALUATION OF RADIATION EXPOSURES

EVALUATION OF RADIATION EXPOSURES AT THE FORMER HORIZONS, INC., METAL HANDLING FACILITY, CLEVELAND, OHIO

The U. S. Department of Energy has determined that the former Horizons, Inc., Metal Handling Facility in Cleveland, Ohio, is presently contaminated with naturally occurring radioactive residues from previous uses of the property. Under current conditions of use, this contamination is causing employees working at the site to receive radiation exposures which are slightly higher than those due to naturally occurring environmental radioactivity. However, increased occupancy of a building currently used for storage (Building B) could lead to radiation exposures approaching the guidelines used for limiting exposures to individuals. For that reason, the Department of Energy (DOE) will conduct further evaluations to identify actions deemed appropriate to preclude any future concerns for radioactivity at this site.

During the 1940's and early 1950's, two buildings at the Horizons facility were used for the production of granular thorium metal under government contracts with the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC). Using thorium nitrate tetrahydrate as a feed material, ammonium thorium chloride was produced in the wet plant (Building C). In the dry plant (Building B), thorium metal was formed in a dry electrolytic process; the metal was then crushed, washed, dried, and packaged for shipment from the plant. Building B is presently used for storage of nonradioactive equipment and materials, and Building C is used for receiving and storage of materials used in the present operation and for the housing of several offices.

It appears that much of the potentially contaminated material has been removed or covered by substantial construction modifications since

the thorium operations. In particular, Building C has been extended on the south side to take in an old alley; also an area which is known to have been contaminated in the past (an outside storage area) has a new built up concrete floor. Also, several sections of walls, floors, and ceilings in Building B and C have been repaired or replaced since the thorium operations. Clecon Metals, Inc., the present occupant, employs approximately 60 workers (mostly in Building C). The site is in an industrial area which is sparsely populated; however, there are a few dwellings on adjacent property.

Contamination at the former Horizons site is due primarily to deposits of naturally occurring thorium and its daughters on building surfaces, in floor drain sediments, and in soil beneath that portion of the floor of Building C which was constructed over contaminated soil. This contamination is yielding slightly elevated radiation exposures to employees working at this site, primarily from the emission of beta and gamma radiations. Additional exposures can be attained by inhalation of airborne radionuclides. Other exposures by ingestion (e.g., eating or drinking in the single occupied building) are relatively small as compared with direct beta-gamma radiation and inhalation. These exposures are summarized and compared numerically with guidelines and background radiation in Table VI-1.

The naturally occurring radionuclides which comprise the contamination at the Horizons site are present in minute quantities throughout our environment. Concentrations of these radionuclides in normal soils, air, water, food, etc., are referred to as background concentrations. Radiation exposures resulting from this environmental radioactivity are

referred to as background exposures. These background exposures are not caused by any human activity and, to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

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

Thorium-232 is believed to have been created during the formation of the earth. The fact that it is still present in measurable quantities is due primarily to its extremely long half-life. The half-life is the time required for an initial activity of a radionuclide to decay to one-half of that activity. In the case of thorium-232, this half-life is approximately 14 billion years. Thus, if you begin with one curie[a] of thorium-232, one-half curie will remain after a period of 14 billion years; in 28 billion years you will have one-quarter of a curie of thorium-232. As thorium-232 decays, it transforms into another substance; in this case, radium-228, which is called the "daughter" of thorium-232. In turn, radium-228 is the "parent" of actinium-228. This successive decay from parent to daughter continues until stable lead is formed, as

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[a]The curie is a unit used to measure the amount of radioactivity in a substance; one curie represents 37 billion radioactive disintegrations per second.

shown in Table VI-2. The "decay product" listed in Table VI-2 is the radiation released during the decay of the parent radionuclide.

Thorium Contamination of Soils and Surfaces

Elevated concentrations of thorium-232 and radium-228 were found in surface soils located immediately east of Building B. This soil contains up to 54 picocuries[b] per gram of thorium-232 and 50 picocuries per gram (pCi/g) of radium-228. Average surface soil contamination for each of these two materials is about 6 picocuries per gram when averaged over the entire site. Auger holes drilled through the floor of Building C show subsurface contamination extending to seven feet and averaging 220 picocuries per gram for thorium-232 and 173 picocuries per gram for radium-228. Normal soils in the Cleveland area contain a background concentration of approximately 0.5 to 1.0 picocurie per gram of thorium-232 with an approximately equal concentration of radium-228.

Samples of surface dirt and building materials were taken in Buildings B and C. These samples were removed from drains, support columns, windows, walls, and floors. The samples from Building B show concentrations of thorium-232 which range to 4890 picocuries per gram. This value was obtained from a sample taken in a drain which also showed 5300 picocuries of radium-228 per gram of material.

Direct Beta-Gamma and External Gamma Exposures

As may be seen in Table VI-2, the thorium-232 decay chain contains several radionuclides which emit beta and gamma radiation. Due to the short half-lives of these radionuclides with respect to thorium-232, their concentrations will quickly approach the concentration of initially

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[b] A picocurie is one million-millionth of a curie, previously defined.

pure thorium-232. As a result, surfaces contaminated with pure thorium-232 twenty five years ago can now produce both beta and gamma radiation exposures. This exposure appears to be significant in Building B.

Nuclear Regulatory Commission (NRC) requirements applicable to its licenses state that the combined dose rate from weakly penetrating beta particles and from gamma-rays, measured at a distance of one centimeter above surfaces should not exceed 0.2 millirad[c] per hour when averaged over an area of one square meter. The combined dose rate should not exceed 1.0 millirad per hour in small areas of 100 cm^2. In room B-1 of Building B, beta-gamma readings were found which exceed these guidelines, with individual measurements ranging up to 6.8 millirad per hour on floors and 1.3 millirad per hour on the ceiling surfaces. For comparison, the skin dose which would be expected from a normal year's watching of color television by an adult is 1.6 millirads; for a child less than 15 years of age, the comparable dose is 3.6 millirad per year (according to the United Nations Scientific Committee on the Effects of Atomic Radiation). Thus, an adult resting on the most contaminated portion of the floor of Building B would receive the same skin dose in about fifteen minutes as would be expected from watching color television for a year.

The primary concern of the NRC guideline for beta-gamma radiation is for exposure to skin surfaces. The thickness of ordinary shoe soles is sufficient to protect the skin of the feet from beta radiation. Other areas of body skin are adequately protected from these exposures if they remain away from these surfaces. In most cases, radiation exposure from contamination on a surface is negligible at a distance of one foot away from the surface. Although potential exists for exposures

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[c]The millirad is a unit for measuring the amount of radiation energy absorbed by human tissues.

far in excess of the guidelines, beta and gamma surface exposures are believed to be inconsequential to employees at this site due principally to a low frequency of occupancy (about 8 man-hours per month in Building B).

As may be seen in Table 2, several of the daughters of thorium-232 emit gamma radiation (gamma-rays are penetrating radiation like X-rays). Hence, contaminated areas of soil on this site are sources of external gamma radiation. External gamma exposure rates measured at one meter above the ground averaged 13 microRoentgens[d] per hour over the site. Exposures ranged from 5 to 110 microRoentgens per hour in Building B. Background levels in the Cleveland area average approximately 10 micro-Roentgens per hour. A single typical chest X-ray (according to Department of Health, Education, and Welfare data) might yield an exposure of about 27,000 microRoentgens, which is equivalent to 2700 hours of exposure to the average background level in Cleveland.

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

Exposure from Inhalation of Radionuclides in Air

As may be seen in Table VI-2, radon-220 is the daughter of radium-224. Radon-220 is an inert gas which can seep from contaminated areas and

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

surfaces and move freely in the air inside buildings. Within a few minutes after entering the building air, radon-220 decays to polonium-216 which decays quickly into lead-212. Elevated levels of lead-212 (up to 0.5 picocurie per liter) were found in the air of Building B. These levels approach the concentration recommended as an upper limit for continuous exposure to members of the general public (0.6 picocurie per liter). The normal occupancy of Building B is approximately 100 hours per year by one or two employees. Consequently, exposure to employees to airborne lead-212 is limited by the infrequent occupancy of Building B. Increased occupancy of Building B would lead to increased employee exposure.

The primary source of this airborne contamination in Building B is high levels of radioactive residue in drains from which radon-220 escapes. Cleaning and sealing these drains would greatly reduce actual and potential exposures to lead-212.

Other Considerations of Exposure

If the contaminated soil on the site were used for growing crops, some minor human exposures could result from the consumption of food contaminated with thorium-232 and its daughters. In addition, actions which involve considerable abrasion of dry contaminated surfaces in both buildings should be avoided because airborne radioactive dust could be created and produce human exposures through inhalation of the airborne material.

If future uses of this site were to involve demolition of the south addition of Building C, care should be taken to avoid problems which might be associated with the contamination beneath the concrete floors.

Risk and Radiation Exposures

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

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

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

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

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

The annual death rate[e] from all types of cancer among all population groups in Cuyahoga County (as of 1970) was 178 deaths per 100,000 population. At the same time, the death rate from all types of cancer for all population groups in the United States and in the state of Ohio were 151 and 157 per 100,000 population, respectively. A one-year exposure to penetrating gamma radiation of 500,000 microRoentgens might increase the risk of death due to all types of cancer by about one-tenth of a percent. Furthermore, a one-year exposure to the guideline value for airborne lead-212 (0.6 picocurie per liter) might be expected to increase the risk of death due to all types of cancer by about an additional one-tenth of a percent. Exposures in excess of guideline values mentioned in this evaluation would be expected to result in proportionately higher increases in risk. Consequently, any action

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[e]Mortality statistics were obtained from data in *U.S. Cancer Mortality by County: 1950-1969*, prepared by the National Cancer Institute, 1973, available from the U.S. Government Printing Office.

taken to reduce either the rate or the duration of radiation exposures would also reduce the risk attendant to that exposure.

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

Remedial Measures

Employees working in Building B are currently receiving small radiation exposures to the skin, gamma exposures to the total body, and internal exposure resulting from inhalation of airborne lead-212. The risk associated with these present exposures is small. However, exposures and risks would be increased by increased occupancy of Building B. Furthermore, the potential exists for more serious exposures by inhalation of radioactive dusts should the contamination become airborne. Exposures to employees at this site are unrelated to their normal jobs; no discernable benefits can be attributed to these exposures. Removal of the thorium-232 residues on building surfaces and from drains would reduce the actual and potential exposures. Small areas of soil surrounding Building B contain relatively high levels of thorium-232 and daughters and act as a potential source of exposure should the soil be used to grow crops. Removal of the contaminated soil, along with proper disposal, would afford maximum protection both to present employees and future occupants of the site. The DOE is now actively evaluating alternatives under a priority program designed to assure adequate protection against current and potential exposure.

SUMMARY

The former Horizons site is contaminated with residues containing naturally occurring thorium and its daughters. Current radiation exposures to employees working at this site are slightly greater than background exposures. However, contamination inside both buildings has the potential for producing appreciable human exposures should it become dislodged from the building surfaces. In addition, increased occupancy of Building B could lead to significant exposures to airborne lead-212. Consequently, remedial measures are in order. The DOE has developed a coordinated plan which addresses the specific problems at the Horizons site. Currently, work is underway to implement the elements of this plan.

TABLE VI-1

SUMMARY OF EXPOSURE DATA AT FORMER HORIZONS SITE
CLEVELAND, OHIO

Exposure Source	Background Levels	Guideline Value for General Public	Guideline Value for Radiation Workers	Average Levels at Horizons Site
Thoron daughters (lead-212) in air	Less than 0.1 picocurie[a] per liter of air	0.6 picocurie per liter of air	20 picocuries per liter of air	Daytime concentrations ranged from 0.005 to 0.5 picocurie per liter of air
Gamma radiation from daughters of thorium contamination	10 micro-Roentgens[b] per hour in the Cleveland area	250 microRoentgens per hour above natural background for 40 hours per week and 50 weeks per year for an individual in the general public. This is equivalent to 0.5 Roentgen per year	2500 microRoentgens per hour for 40 hours per week and 50 weeks per year. This is equivalent to 5 Roentgens per year	Average gamma radiation levels one meter above the floor or ground ranged from 5 to 110 microRoentgens per hour

[a]The picocurie is a unit used to measure the amount of radioactivity present in a substance.

[b]The Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microRoentgen is one-millionth of a Roentgen.

TABLE VI-2

THORIUM DECAY SERIES

PARENT	HALF-LIFE	DECAY PRODUCTS	DAUGHTER
thorium-232	14 billion years	alpha	radium-228
radium-228	7 years	beta	actinium-228
actinium-228	6 hours	beta, gamma	thorium-228
thorium-228	2 years	alpha	radium-224
radon-220	55 seconds	alpha	polonium-216
polonium-216	0.15 second	alpha	lead-212
lead-212	10.6 hours	beta, gamma	bismuth-212
bismuth-212	1 hour	beta, gamma alpha	polonium-212 thallium-208
polonium-212	$\frac{3}{10,000,000}$ second	alpha	lead-208
thallium-208	3 minutes	beta, gamma	lead-208
lead-208	stable	none	none

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