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# RESULTS OF THE RADIOLOGICAL SURVEY AT 467 LATHAM STREET, MAYWOOD, NEW JERSEY

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# RESULTS OF THE RADIOLOGICAL SURVEY AT 467 LATHAM STREET, MAYWOOD, NEW JERSEY*

## INTRODUCTION

A comprehensive radiological survey at 467 Latham Street, Maywood, New Jersey, was conducted by Oak Ridge National Laboratory (ORNL) from June 3 to 10, 1981 with assistance from Oak Ridge Associated Universities (ORAU). Contaminated material was discovered in the area during an EG&G aerial radiological survey,[1] and confirmed by a ground-level radiological survey by the Nuclear Regulatory Commission.[2] This contaminated material is believed to have been transported from the former Maywood Chemical Company (now the Stepan Chemical Company) during the period from 1944-1946.

The Maywood Chemical Company was founded in 1895. From about 1916 until 1957, the Company processed thorium for use in the manufacture of gas mantles for various lighting devices.[1] Apparently the Company allowed removal of processing waste by-products from their operations, charging only a minimal fee for transportation. Much of the by-product material from non-thorium operations was in the form of tea and cocoa leaves mixed with other fill material. This material was suitable for use as an organic mulch for gardens, flowers, and shrubbery and as general fill material for lawns. It probably was the source of the contamination at 467 Latham Street in that it included wastes from the thorium processing operations.

The present owners of the 467 Latham Street, the Joe Hughes family, have lived there all their lives. The house was constructed in 1925 and has been in the same family since that time. Front and rear views of the property are provided in Figs. 1 and 2, respectively. The layout of the property, depicting the survey grid pattern and approximate property boundaries, is shown in Fig. 3. The dimensions of the lot are approximately 15 m wide by 37.5 m deep.

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*The survey was performed by members of the Off-Site Pollutant Measurements Group of the Health and Safety Research Division at Oak Ridge National Laboratory, under DOE contract W-7405-eng-26.

## SURVEY METHODS

The survey of 467 Latham Street was performed in accordance with the action and survey plan for Maywood, New Jersey (Appendix I). A comprehensive description of the survey methods and instrumentation is also given in Appendix I.

## SURVEY RESULTS

Applicable federal guidelines have been summarized in Table 1. The normal background levels for the northern New Jersey area are presented in Table 2. These data are provided for comparison with the survey results presented in this section.

With the exception of measurements of transferable activity which represent net count rates, all direct measurement results presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations measured in environmental samples.

### Outdoor Survey Results

External gamma-ray and beta-gamma measurements. The results of the grid point measurements and grid block scans are presented in Table 3. Analysis of this data indicates that only two small isolated areas of contaminated soil are present on the property. These areas have been highlighted with shading on Fig. 4. The larger area located behind the garage is part of a garden plot, where the contaminated mulch material was probably placed in the past. The contamination in the front yard was placed there as fill for a low area.

The average external gamma-ray exposure rate at 1 m above the surface on this property was determined to be 16 μR/h, a value twice the normal background for the Maywood area. These elevated gamma radiation levels are due primarily to direct and scattered radiation from the contamination on bordering properties (461 Latham and 464 Davison). Grid point readings on the property ranged from 7 μR/h to 110 μR/h, with

the highest level being recorded at the rear of the lot, nearest to the adjacent properties.

In the two contaminated areas on the property, the maximum measured surface external gamma-ray exposure rate was 86 μR/h, with an associated 1 m exposure rate of 23 μR/h. The maximum measured beta-gamma dose rate on the surface of the contaminated areas was 0.08 mrad/h.

Surface soil samples. Surface soil samples were collected at fourteen systematic locations (MJ samples) and six biased locations (MJB samples) on the property (a biased soil sample is one which is collected at a location exhibiting elevated gamma radiation levels). These sample locations are depicted in Fig. 5. Results of the laboratory analysis for $^{232}$Th, $^{238}$U, and $^{226}$Ra in these samples are presented in Table 4.

The average concentrations of $^{232}$Th, $^{238}$U, and $^{226}$Ra in surface soil from across the yard were approximately 1.1, 0.76, and 0.78 pCi/g, respectively. These values are within the normal background range for the Maywood area. In the two contaminated areas on the property, $^{232}$Th concentrations were measured ranging from 10 pCi/g (MJB36) to 26 pCi/g (MJB32). The maximum level is approximately thirty times the normal background concentration for the area. No other biased soil samples contained radionuclide concentrations significantly above background.

## Indoor Survey Results

Alpha, beta-gamma, and gamma-ray measurements. The results of the indoor measurements made at 467 Latham Street are provided in Table 5. Schematic views of the floor plans of the house are given in Figs. 6-9 for use in correlation with the data presented in the table.

The average gamma-ray exposure rate at 1 m above the floor surface in the house was determined to be 10 μR/h, a value only slightly above the normal background level for the area. Based on the results of the scan survey of the house and garage, there is no indication of the presence of contaminated materials inside either structure. The maximum surface gamma-ray exposure rate was found to be 18 μR/h, and the maximum observed beta-gamma dose rate was 0.04 mrad/h. Surface alpha activity throughout both structures was found to be negligible (<60 dpm/100 cm$^2$). No radiation levels in the house or garage exceeded the applicable radiation guidelines.

Radon and radon daughter sampling. Preliminary radon and radon daughter measurements were made in the basement of the house to determine the approximate magnitude of the exposure pathway. The measurements are indicative of radon levels only at the instant of sampling and do not represent daily or annual averages. Further sampling would be required to determine the levels in the house for comparison with applicable guidelines.

The results of the radon and radon daughter measurements are presented in Table 6. Concentrations of radon in air were measured at 0.68 pCi/L with an associated radon daughter concentration of 0.00017 WL. Both measured levels are in the normal range of background for the Maywood area.

## SIGNIFICANCE OF FINDINGS

Summaries of the outdoor and indoor measurement results of the radiological survey conducted at 467 Latham Street are provided in Tables 7 and 8, respectively. These results indicate that at only two locations on the property were contaminated materials found (see Fig. 4). Both locations were outdoors and were found to contain soil primarily contaminated with radionuclides of the $^{232}$Th decay chain. The total estimated volume of the contaminated material on the property is approximately 1 $m^3$, based on an average assumed depth of 15 cm in the suspect areas. A breakdown of this volume by area is provided in Table 9.

Outdoors on the property, the average external gamma-ray exposure rate at 1 m above the surface was approximately two times the normal background for the Maywood area. This increased activity is due to direct and scattered radiation from adjacent contaminated properties, not from the small areas of contamination on this lot. However, in the areas of contamination, surface external gamma-ray exposure rates approached or exceeded the NRC guidelines for continuous exposure (10 CFR 20). Surface soil in these areas contained $^{232}$Th in concentrations up to thirty times background.

Inside the house, radiation levels were found to be in the normal background range for homes in the Maywood area. There was no evidence

of the presence of contaminated materials present inside either structure on this property. No measured radiation levels approached the applicable guidelines for exposure to the general population.

Using the results of this radiological survey, a preliminary evaluation of the potential exposure pathways for radiation exposures to residents at this location has been conducted. The four primary pathways from the type of contaminated materials found on the property are: (1) direct radiation exposure, (2) inhalation of radon and radon daughter products, (3) inhalation of resuspended radioactive particles, and (4) ingestion of radionuclides through food pathways. An evaluation of the first two pathways is provided in Appendix II. The latter two pathways are not considered to be significant at this property, under present conditions of property use. These pathways could only become significant if major changes in land use occur in the future. Based on conservative assumptions, preliminary estimates of the total risk of cancer mortality from radiological conditions at this property are given in Appendix II. The estimated total increased risk due to radiation induced cancer for residents at 467 Latham Street was calculated to be 0.01%.[4] Thus, for a person living a lifetime at 467 Latham, the hypothetical average chance of dying from cancer would increase from 24.4% (the average for Bergan County, New Jersey in 1975[5]) to 24.41%.

## REFERENCES


1. EG&G, An Aerial Radiological Survey of the Stepan Chemical Company and Surrounding Area, Maywood, New Jersey, EG&G Survey Report NRC-8109, April 1981.
2. Nuclear Regulatory Commission, memorandum from M. Campbell to J. D. Kinnerman, re: Records of Surveys of Private Homes in Maywood, New Jersey, Docket No. 40-8610, May 15, 1981.
3. A. C. George and A. J. Breslin, "The Distribution of Ambient Radon and Radon Daughters in Residential Buildings in the New Jersey - New York Area," Proceedings of the Natural Radiation Environment III, pp. 1272-93, CONF-780422 (Vol. 2), NTIS, 1980.
4. J. W. Healy and W. J. Bair, "Preliminary Report - Radiological Appraisal of Houses in Maywood, New Jersey." Attachment to letter from W. J. Bair, Battelle Pacific Northwest Laboratories to W. E. Mott, Department of Energy, Washington, D. C., July 17, 1981.
5. U. S. Department of Health, Education and Welfare, Vital Statistics of the United States – 1975, Volume II – Mortality, Part B, Public Health Service, National Center for Health Statistics, (PHS) 78-1102, 1977.

Fig. 1. Front view of property at 467 Latham Street in Maywood, NJ

Fig. 2. Rear view of property at 467 Latham Street in Maywood, NJ

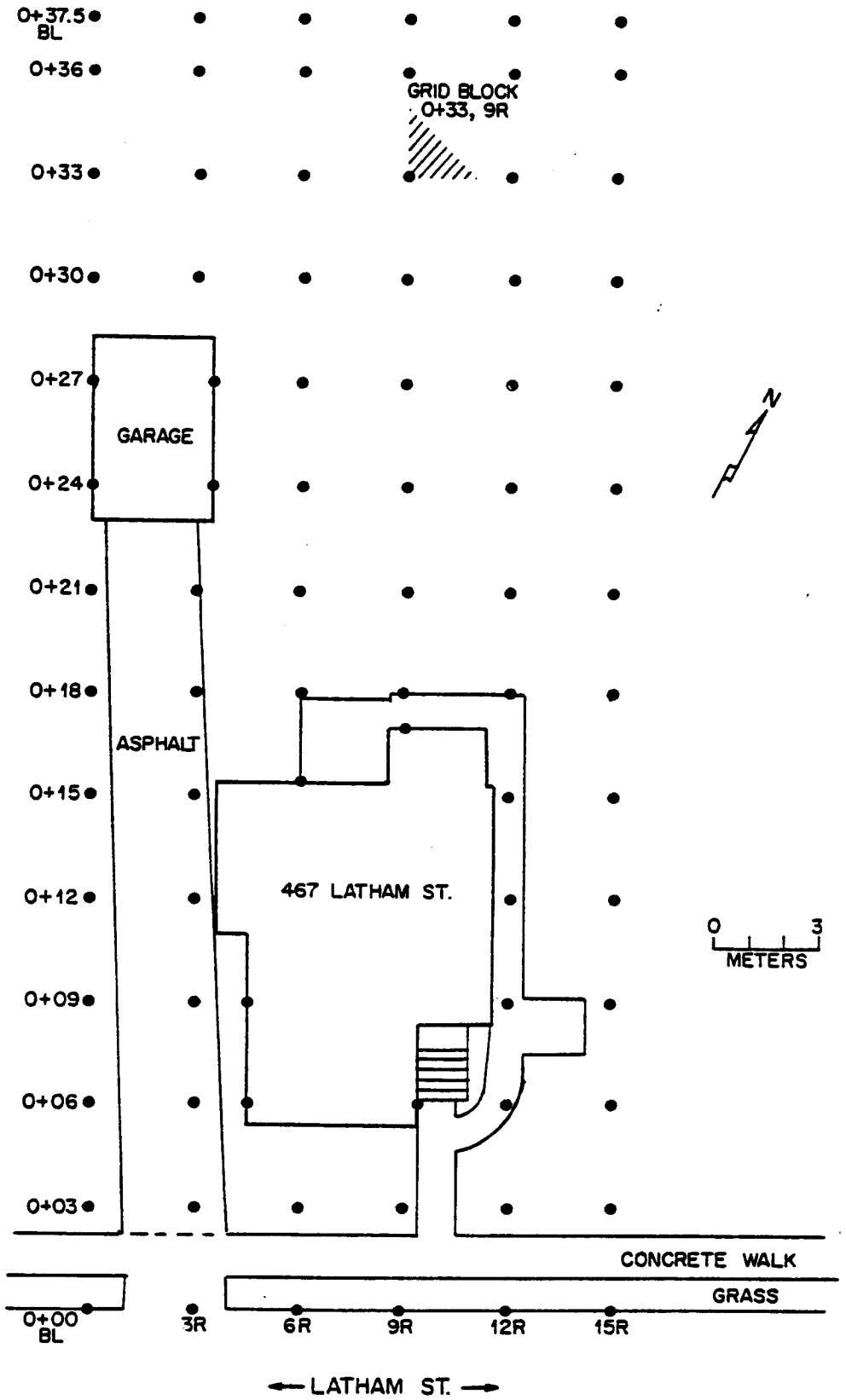



Fig. 3. Grid point and grid block locations at 467 Latham Street.

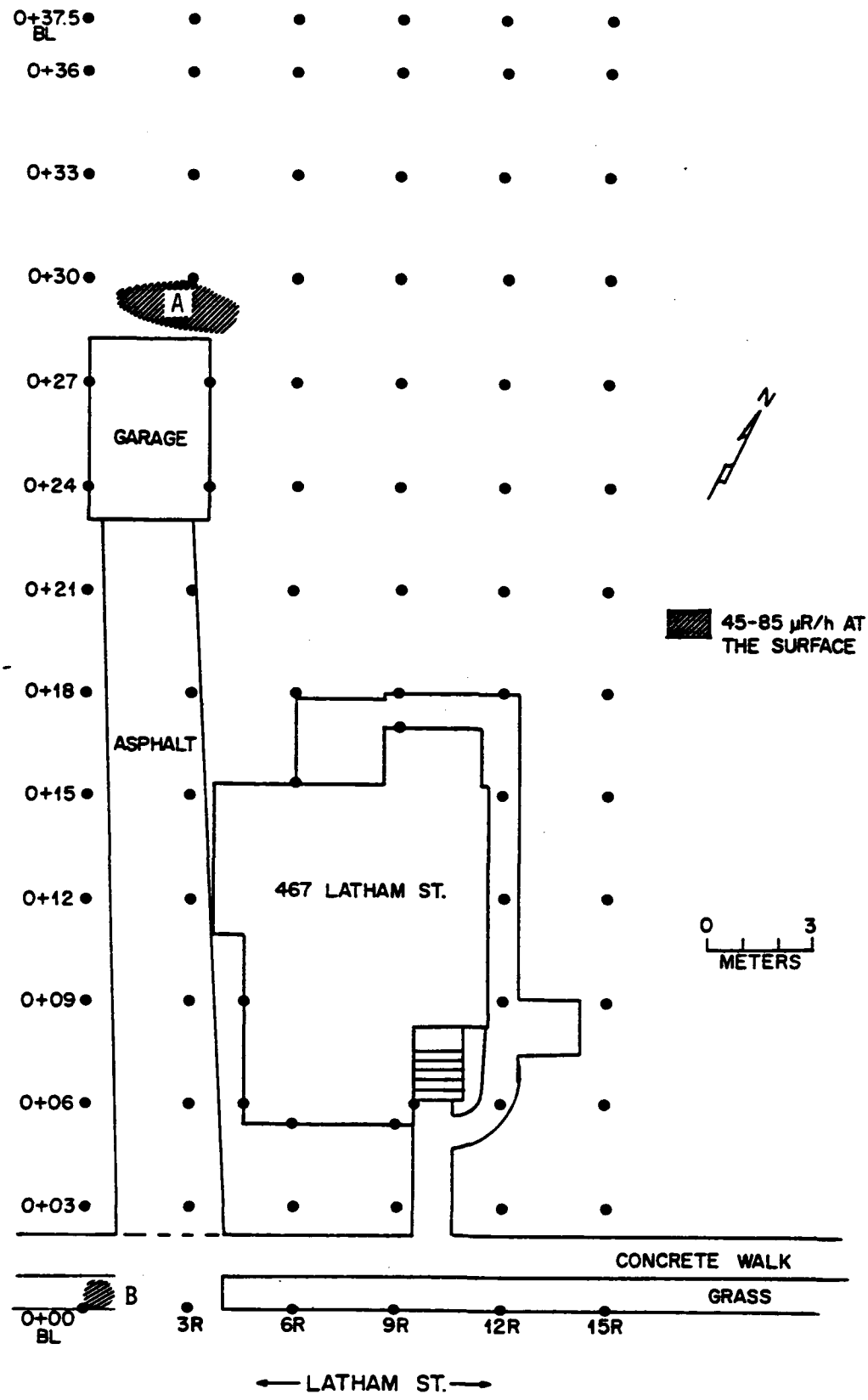



Fig. 4. Estimated extent of contamination at 467 Latham Street, based on the results of the surface gamma-ray scan.

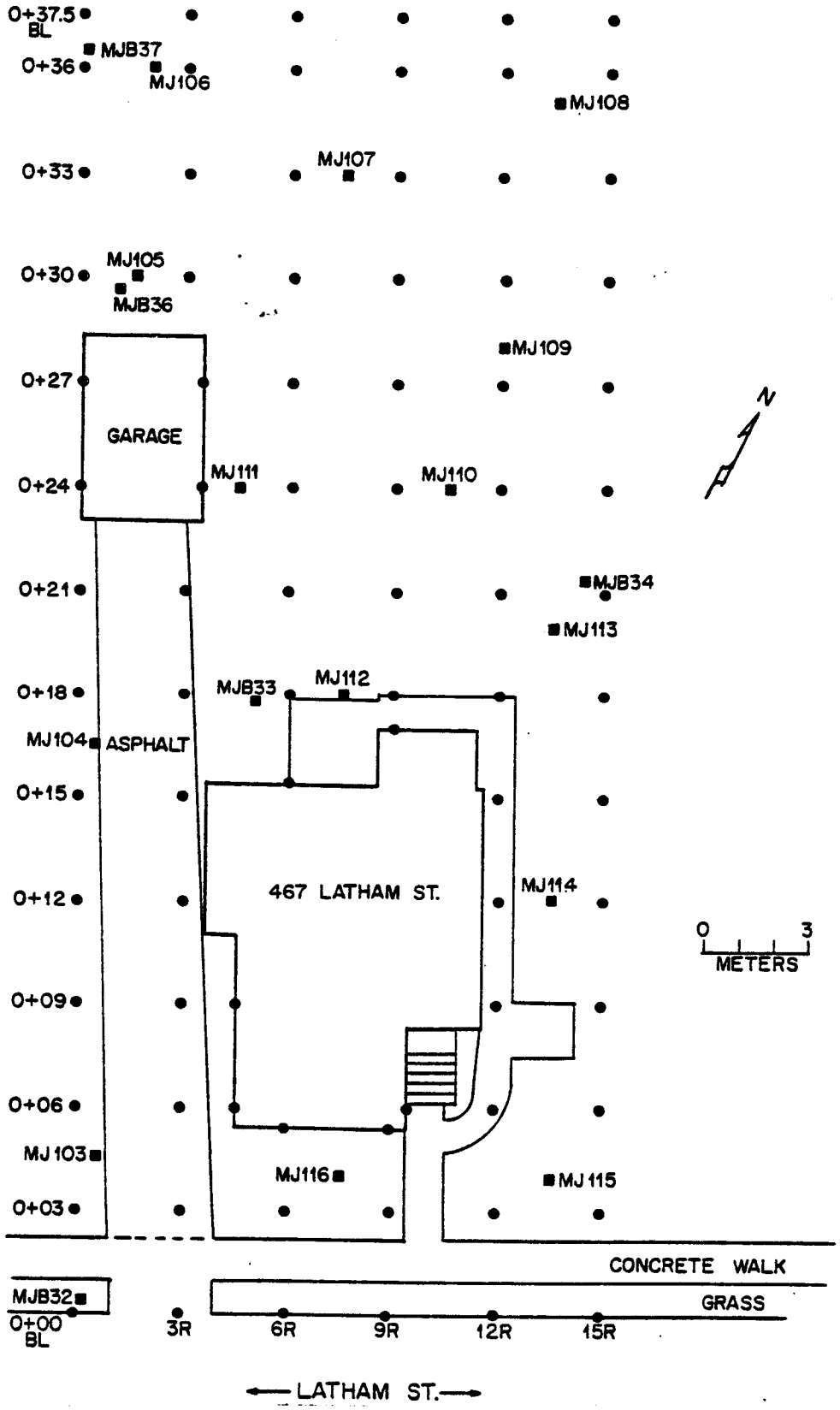
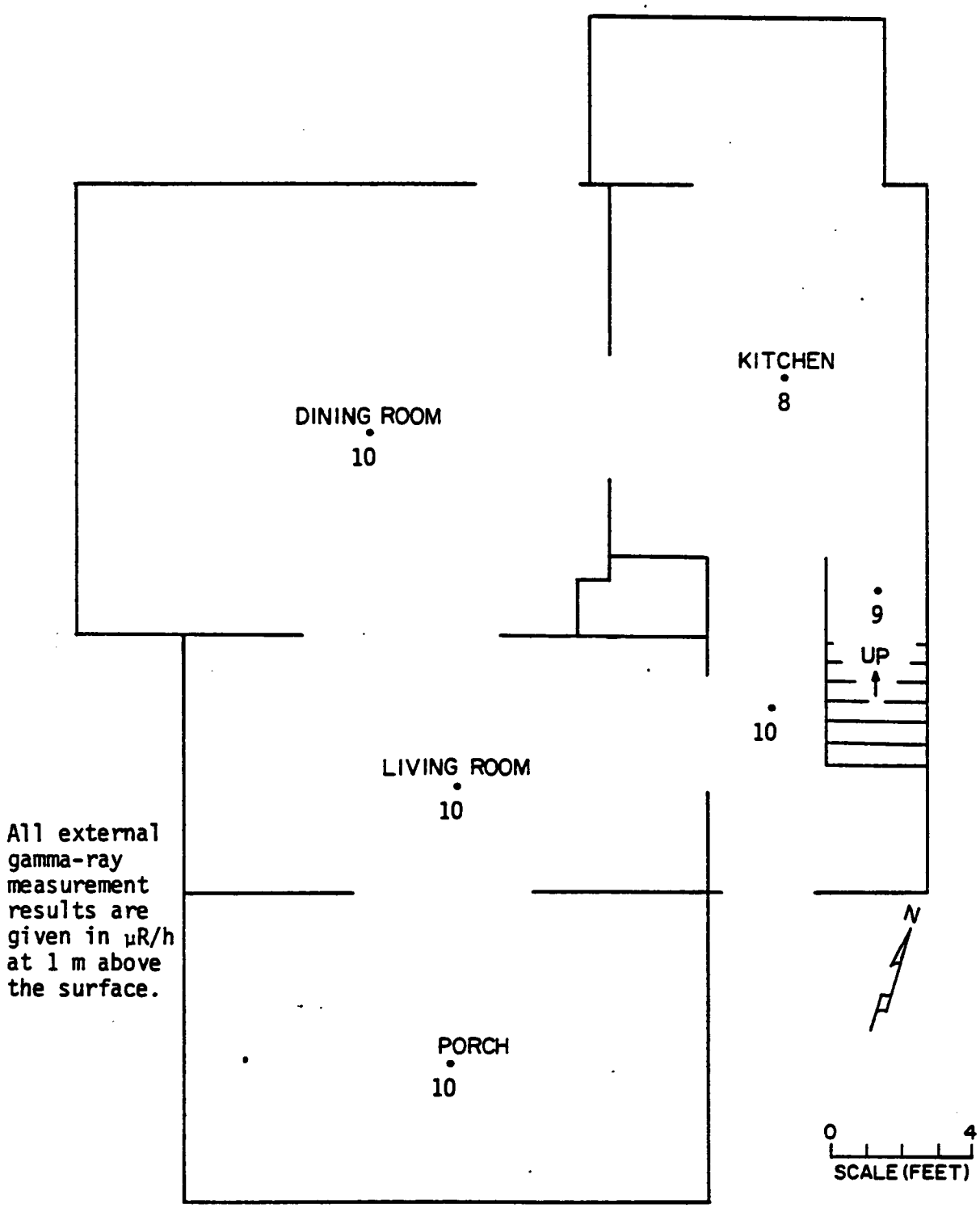



Fig. 5. Location of systematic and biased surface soil samples at 467 Latham Street.




FIRST LEVEL

467 LATHAM ST.

Fig. 6. Schematic of the first level floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.

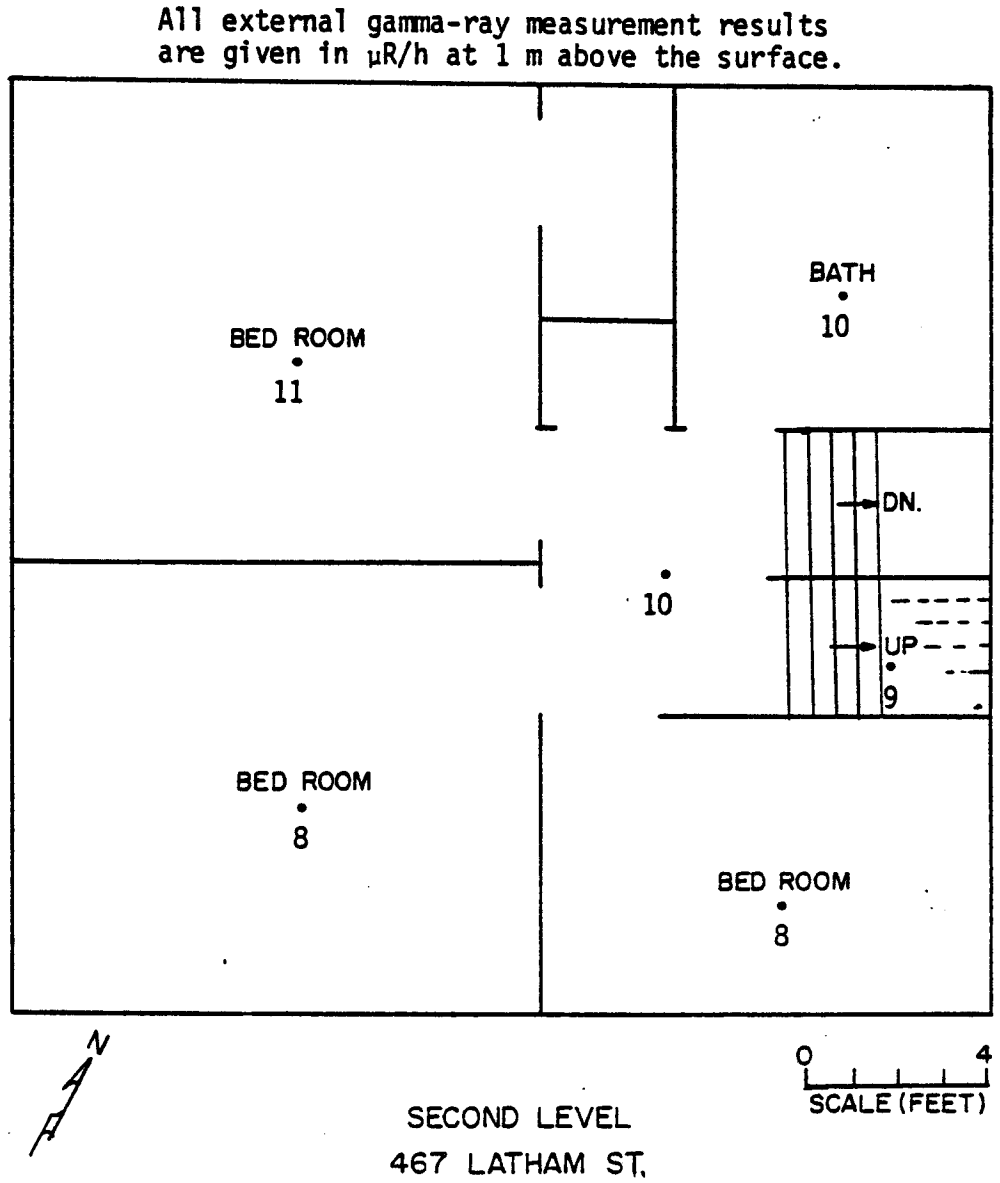
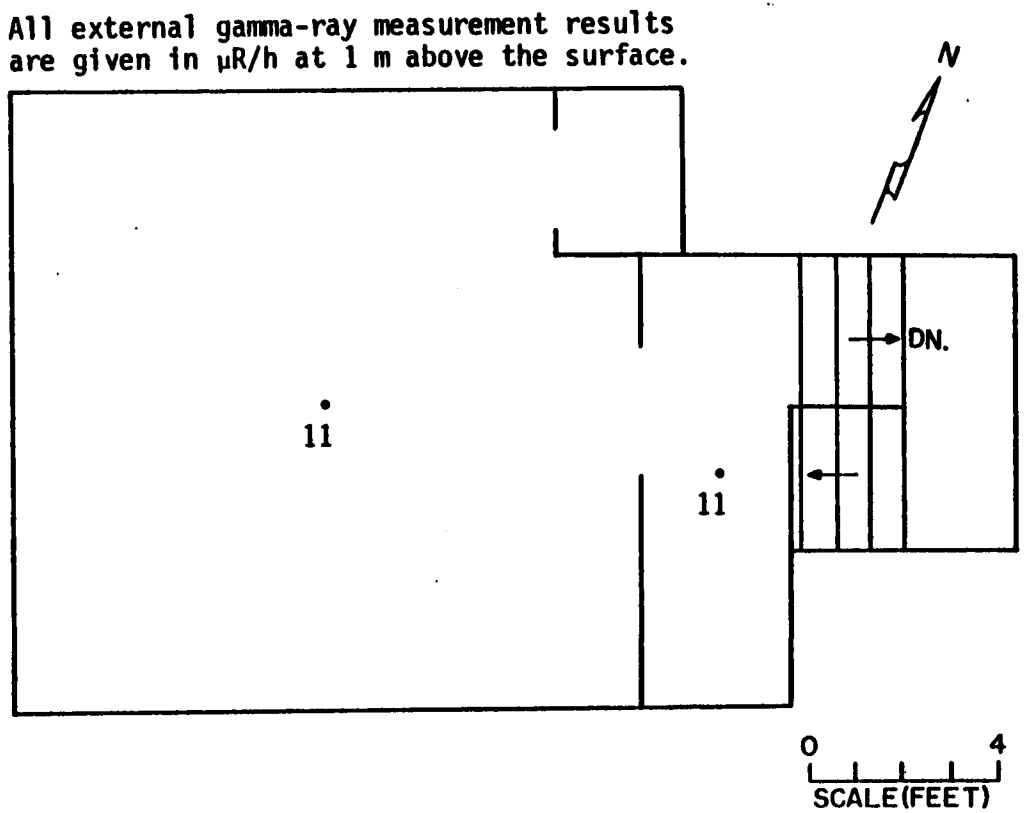



Fig. 7. Schematic of the second level floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.




THIRD LEVEL

467 LATHAM ST.

Fig. 8. Schematic of the third level floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.

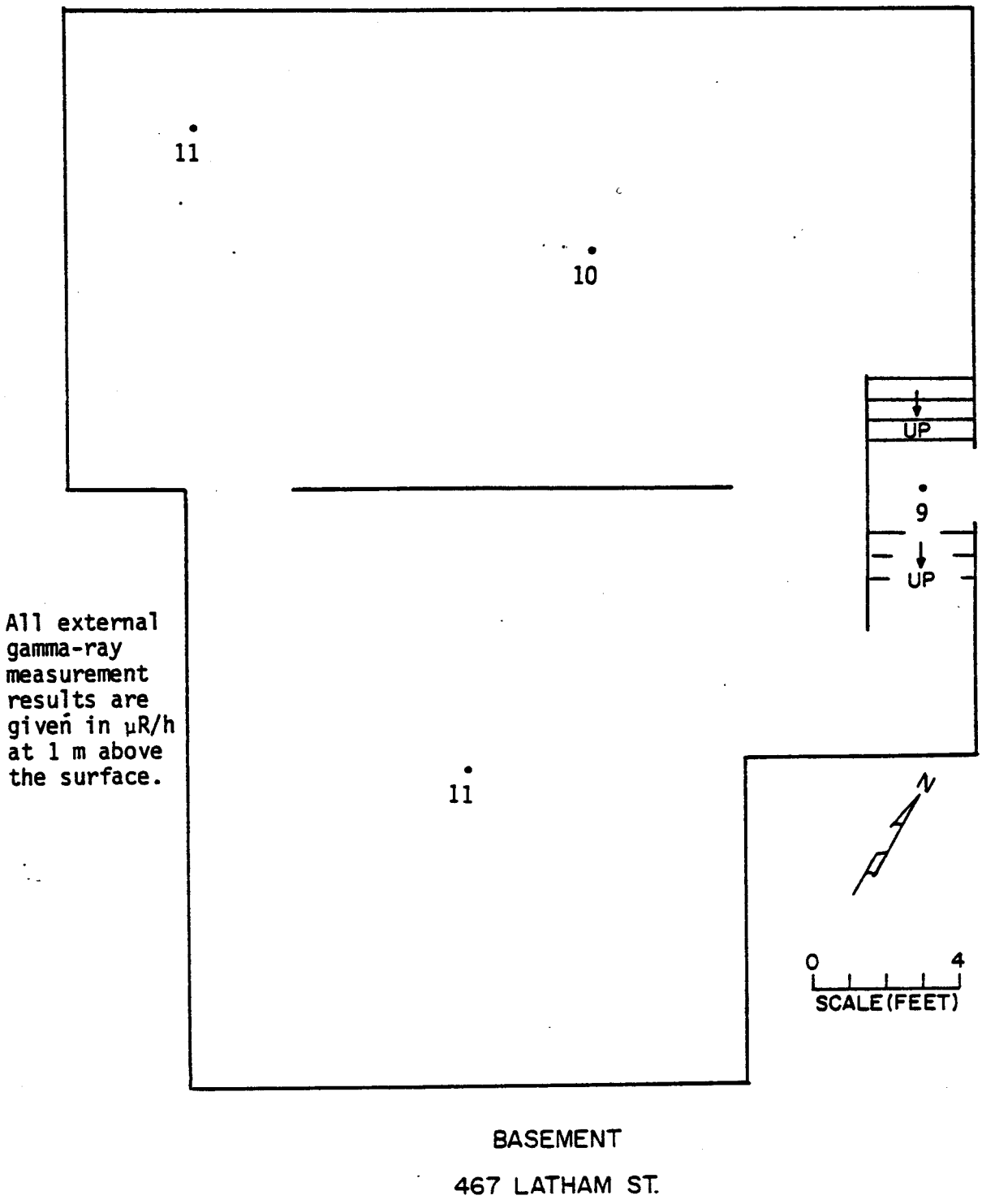



Fig. 9. Schematic of the basement floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.

Table 1. A summary of applicable radiation guidelines

| Mode of exposure | Exposure conditions | Guideline value | Guideline source |
|---|---|---|---|
| 1. External gamma radiation | Continuous exposure to individual in general population (whole body) | 60 μR/h | Nuclear Regulatory Commission (NRC) - Standards for Protection Against Radiation (10 CFR 20.105) |
| 2. Surface alpha contamination | $^{226}Ra$ contamination fixed on surfaces | 100 dpm/100 $cm^2$ | NRC Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-product, Source, or Special Nuclear Material (Adapted from NRC Reg. Guide 1.86 |
| | Removable $^{226}Ra$ contamination | 20 dpm/100 $cm^2$ | |
| 3. Surface beta contamination | Removable beta-gamma emitters | 1000 dpm/100 $cm^2$ | Same as number 2 |
| 4. Beta-gamma dose rates | Average dose rate on an area no greater than 1 $m^2$ | 0.20 mrad/h | Same as number 2 |
| | Maximum dose rate in any 100 $cm^2$ area | 1.0 mrad/h | Same as number 2 |
| 5. Exposure to radon | Maximum permissible concentration of $^{222}Rn$ in air in unrestricted areas | 3.0 pCi/L | NRC 10 CFR 20.103, Appendix B, Table II |
| 6. Radionuclides in water | Maximum contaminant level for combined $^{226}Ra$ and $^{228}Ra$ in drinking water | 5 pCi/L | EPA Interim Standards 40 CFR 141.15 |
| | Maximum permissible concentration of the following radionuclides in water for unrestricted areas | | NRC 10 CFR 20.103 Appendix B, Table II |
| | $^{226}Ra$ | 30 pCi/L | |
| | $^{238}U$ | 40,000 pCi/L | |
| | $^{230}Th$ | 2,000 pCi/L | |
| | $^{210}Pb$ | 100 pCi/L | |
| 7. Airborne $^{222}Rn$ progeny | Remedial action indicated if $^{222}Rn$ progeny exceed this concentration because of uranium mill tailings under or around the structure | 0.01 WL | 10 CFR 712.7 |

Table 2. Background radiation levels for the northern New Jersey area.

| Type of radiation measurement or sample | Radiation level or radionuclide concentration |
|---|---|
| Gamma-ray exposure rate at 1 m above floor or ground surface (μR/h) | 8 |
| Direct alpha activity on indoor floor or wall surface (dpm/100 $cm^2$) | 26 |
| Transferable alpha activity on indoor floor or wall surface (dpm/100 $cm^2$) | 10 |
| Transferable beta-gamma activity on indoor floor or wall surface (dpm/100 $cm^2$) | 20 |
| Beta-gamma dose rate activity on ground, floor and wall surfaces (mrad/h) | 0.01 - 0.03 |
| Indoor radon concentration (pCi/L)[a] | |
| Basement | 1.7 |
| Upstairs | 0.8 |
| Indoor radon daughter concentration (WL)[a] | |
| Basement | 0.008 |
| Upstairs | 0.004 |
| Concentration of radionuclides in soil (pCi/g) | |
| $^{232}Th$ | 0.9 |
| $^{238}U$ | 0.9 |
| $^{226}Ra$ | 0.9 |

[a]Reference 3.

Table 3. Outdoor measurements at 467 Latham Street

| Grid[a] location | Grid point measurements[b] | | | Grid block measurements[c] | | |
|---|---|---|---|---|---|---|
| | Gamma exposure at 1 m (μR/h) | Gamma exposure at the surface (μR/h) | Beta-gamma dose rate at 1 cm above the surface[d] (mrad/h) | Maximum gamma exposure at 1 m[d] (μR/h) | Maximum gamma exposure at the surface[d] (μR/h) | Beta-gamma dose rate at maximum 1 cm above the surface[d] (mrad/h) |
| 0+00, BL | 15 | 10 | | 11 | 47 | 0.08 |
| 0+03, BL | 9 | 9 | | | 13 | |
| 0+06, BL | 12 | 12 | | | 14 | |
| 0+09, BL | 14 | 13 | | | 14 | |
| 0+12, BL | 14 | 13 | | | 14 | |
| 0+15, BL | 13 | 13 | | | 14 | |
| 0+18, BL | 13 | 16 | | 23 | 19 | |
| 0+21, BL | 20 | 17 | | 35 | 21 | |
| 0+24, BL | 49 | 47 | 0.05 | | | |
| 0+27, BL | 47 | 58 | 0.08 | 33 | 56 | 0.05 |
| 0+30, BL | 40 | 28 | | 51 | 35 | |
| 0+33, BL | 35 | 30 | | | 35 | |
| 0+36, BL | 56 | 30 | | 86 | 51 | 0.04 |
| 0+37.5, BL | 110 | 47 | 0.04 | | 11 | |
| 0+00, 3R | 7 | 7 | | | 11 | |
| 0+03, 3R | 8 | 9 | | | 11 | |
| 0+06, 3R | 8 | 8 | | | 12 | |
| 0+09, 3R | 9 | 11 | | | 12 | |
| 0+12, 3R | 11 | 11 | | | 15 | |
| 0+15, 3R | 9 | 10 | | 14 | 23 | |
| 0+18, 3R | 9 | 10 | | | 15 | |
| 0+21, 3R | 11 | 11 | | | 12 | |
| 0+24, 3R | 9 | 9 | | | 14 | |
| 0+27, 3R | 11 | 9 | | 23 | 86 | 0.03 |
| 0+30, 3R | 18 | 16 | | | 11 | |
| 0+33, 3R | 23 | 17 | | | 28 | |
| 0+36, 3R | 35 | 28 | 0.04 | | 28 | |
| 0+37.5, 3R | 47 | 26 | | | | |
| 0+06, 4.5R | 11 | 8 | | | | |
| 0+09, 4.5R | 11 | 9 | | | | |
| 0+12, 3.5R | 11 | 10 | | | | |
| 0+15, 3.5R | 10 | 9 | | | | |

Table 3. (continued)

| Grid[a] location | Grid point measurements[b] | | | Grid block measurements[c] | | |
|---|---|---|---|---|---|---|
| | Gamma exposure at 1 m (μR/h) | Gamma exposure at the surface (μR/h) | Beta-gamma dose rate at 1 cm above the surface[d] (mrad/h) | Maximum gamma exposure at 1 m[d] (μR/h) | Maximum gamma exposure at the surface[d] (μR/h) | Beta-gamma dose rate at maximum 1 cm above the surface[d] (mrad/h) |
| 0+00, 6R | 8 | 7 | | | 10 | |
| 0+03, 6R | 8 | 8 | | | 11 | |
| 0+5.5, 6R | 10 | 9 | | | | |
| 0+15.5, 6R | 10 | 12 | | | 13 | |
| 0+18, 6R | 11 | 12 | | | 13 | |
| 0+21, 6R | 11 | 11 | | | 14 | |
| 0+24, 6R | 12 | 11 | | | 15 | |
| 0+27, 6R | 15 | 13 | | | 18 | |
| 0+30, 6R | 16 | 15 | | | 19 | |
| 0+33, 6R | 19 | 16 | | | 23 | |
| 0+36, 6R | 26 | 23 | 0.03 | | 23 | |
| 0+37.5, 6R | 30 | 23 | | | | |
| 0+00, 9R | 7 | 7 | | | 10 | |
| 0+03, 9R | 8 | 8 | | | 10 | |
| 0+5.5, 9R | 9 | 8 | | | 14 | |
| 0+17, 9R | 11 | 9 | | | 12 | |
| 0+18, 9R | 10 | 9 | | | 12 | |
| 0+21, 9R | 11 | 11 | | | 14 | |
| 0+24, 9R | 12 | 11 | | | 16 | |
| 0+27, 9R | 15 | 12 | | | 17 | |
| 0+30, 9R | 13 | 13 | | | 18 | |
| 0+33, 9R | 15 | 14 | | | 18 | |
| 0+36, 9R | 19 | 17 | | | 19 | |
| 0+37.5, 9R | 21 | 15 | | | 19 | |
| 0+00, 12R | 7 | 6 | | | 11 | |
| 0+03, 12R | 8 | 8 | | | 12 | |
| 0+06, 12R | 9 | 9 | | | 14 | |
| 0+09, 12R | 10 | 11 | | | 12 | |
| 0+12, 12R | 8 | 9 | | | 12 | |
| 0+15, 12R | 9 | 9 | | | 13 | |
| 0+18, 12R | 12 | 11 | | | 13 | |
| 0+21, 12R | 11 | 11 | | 12 | 23 | 0.02 |

Table 3. (continued)

| Grid[a] location | Grid point measurements[b] | | | Grid block measurements[c] | | |
|---|---|---|---|---|---|---|
| | Gamma exposure at 1 m (μR/h) | Gamma exposure at the surface (μR/h) | Beta-gamma dose rate at 1 cm above the surface[d] (mrad/h) | Maximum gamma exposure at 1 m[d] (μR/h) | Maximum gamma exposure at the surface[d] (μR/h) | Beta-gamma dose rate at maximum 1 cm above the surface[d] (mrad/h) |
| 0+24, 12R | 12 | 12 | | | 15 | |
| 0+27, 12R | 14 | 12 | | | 18 | |
| 0+30, 12R | 15 | 15 | | | 18 | |
| 0+33, 12R | 16 | 14 | | | 18 | |
| 0+36, 12R | 19 | 16 | | | 19 | |
| 0+37.5, 12R | 23 | 14 | | | 21 | |
| 0+00, 15R | 8 | 7 | | | | |
| 0+03, 15R | 8 | 9 | | | | |
| 0+06, 15R | 8 | 8 | | | | |
| 0+09, 15R | 8 | 9 | | | | |
| 0+12, 15R | 8 | 10 | | | | |
| 0+15, 15R | 9 | 10 | | | | |
| 0+18, 15R | 9 | 10 | | | | |
| 0+21, 15R | 11 | 11 | | | | |
| 0+24, 15R | 12 | 11 | | | | |
| 0+27, 15R | 11 | 12 | | | | |
| 0+30, 15R | 12 | 13 | | | | |
| 0+33, 15R | 12 | 14 | | | | |
| 0+36, 15R | 14 | 14 | | | | |
| 0+37.5, 15R | 18 | 12 | | | | |

[a]Grid location is shown in Fig. 3.

[b]Grid point measurements are discrete measurements at each grid point.

[c]Grid block measurements are obtained by gamma-ray scan of entire block.

[d]Absence of a value indicates no measurement was taken.

Table 4. Results of radionuclide analyses of surface soil samples from 467 Latham Street

| Sample[a] | Location[b] | Radionuclide concentration (pCi/g) | | |
|---|---|---|---|---|
| | | $^{232}Th$[c] | $^{238}U$[d] | $^{226}Ra$[c] |
| MJ103 | 0+4.5, 0.5R | 0.96 ± 0.04 | 0.71 | 0.77 ± 0.02 |
| MJ104 | 0+16.5, 0.5R | 1.6 ± 0.2 | 0.73 | 0.90 ± 0.05 |
| MJ105 | 0+30, 1.5R | 1.1 ± 0.2 | 0.68 | 0.70 ± 0.09 |
| MJ106 | 0+36, 2R | 1.5 ± 0.03 | 0.68 | 0.90 ± 0.04 |
| MJ107 | 0+33, 7.5R | 1.1 ± 0.02 | 0.79 | 0.83 ± 0.03 |
| MJ108 | 0+35, 13.5R | 1.9 ± 0.06 | 0.89 | 1.0 ± 0.04 |
| MJ109 | 0+28, 12R | 1.0 ± 0.2 | 0.77 | 0.70 ± 0.05 |
| MJ110 | 0+24, 10.5R | 0.83 ± 0.04 | 0.72 | 0.67 ± 0.02 |
| MJ111 | 0+24, 4.5R | 0.95 ± 0.04 | 0.71 | 0.71 ± 0.03 |
| MJ112 | 0+18, 7.5R | 1.1 ± 0.2 | 0.77 | 0.80 ± 0.02 |
| MJ113 | 0+20, 13.5R | 0.90 ± 0.04 | 0.77 | 0.70 ± 0.04 |
| MJ114 | 0+12, 13.5R | 1.3 ± 0.04 | 0.79 | 0.75 ± 0.04 |
| MJ115 | 0+04, 13.5R | 0.77 ± 0.02 | 0.85 | 0.76 ± 0.02 |
| MJ116 | 0+04, 7.5R | 0.90 ± 0.04 | 0.76 | 0.66 ± 0.03 |
| MJB32 | 0+0.2, 0.2R | 26 ± 2 | 2.3 | 3.7 ± 0.2 |
| MJB33 | 0+17.8, 5R | 1.9 ± 0.03 | 1.1 | 1.3 ± 0.03 |
| MJB34 | 0+21.5, 14.5R | 0.95 ± 0.06 | 0.68 | 0.63 ± 0.04 |
| MJB36 | 0+29.5, 1R | 10 ± 0.2 | 0.72 | 2.4 ± 1.0 |
| MJB37A | 0+36.5, BL | 3.6 ± 0.08 | 0.95 | 1.2 ± 0.05 |
| MJB37B[e] | 0+36.5, BL | 1.5 ± 0.05 | 0.90 | 0.85 ± 0.03 |

[a]MJ is a systematic surface soil sample; MJB is a biased surface soil sample. All samples are taken from the top 15 cm of soil surface.

[b]Location is shown on Fig. 5.

[c]Indicated error is at the 95% confidence interval (±2σ).

[d]Total error on measurement results is less than ±3% error (95% confidence level).

[e]Sample was obtained at a depth of 41-46 cm.

Table 5. Indoor measurements at 467 Latham Street

| Location[a] | External gamma exposure rate (μR/h) | | Beta-gamma dose rate at 1 cm in the center of room (mrad/h) | Average direct alpha activity on surface (dpm/100 cm²) | Transferable alpha activity/Transferable beta-gamma activity (dpm/100 cm²) |
|---|---|---|---|---|---|
| | Center of room at 1 m | Surface maximum | | | |
| **Street level** | | | | | |
| Porch | 10 | 12 | 0.02 | <26 | b |
| Living room | 10 | 11 | 0.02 | <26 | b |
| Dining room | 10 | 12 | 0.03 | <26 | b |
| Kitchen | 8 | 11 | 0.02 | <26 | <10/<20 |
| Hallway | 10 | 11 | 0.02 | <26 | b |
| Stairway to second level | 9 | 11 | 0.02 | <26 | b |
| **Second level** | | | | | |
| Hall | 10 | 10 | 0.01 | <26 | <10/<20 |
| Southeast bedroom | 8 | 9 | 0.01 | <26 | b |
| Southwest bedroom | 8 | 9 | 0.01 | <26 | b |
| Northwest bedroom | 11 | 12 | 0.02 | <26 | b |
| Bathroom | 10 | 10 | 0.01 | <26 | b |
| Stairway to third level | 9 | 9 | 0.02 | <26 | b |
| **Third level** | | | | | |
| Hallway | 11 | 10 | 0.02 | <26 | b |
| Bedroom | 11 | 11 | 0.01 | <26 | <10/<20 |
| **Basement** | | | | | |
| Stairway to basement | 9 | 11 | 0.01 | <26 | b |
| Furnace room | 11 | 14 | 0.02 | <26 | b |
| Study | 10 | 13 | 0.04 | <26 | <10/<20 |
| South room | 11 | 13 | 0.02 | <26 | b |
| **Unattached garage** | | | | | |
| Garage | 16 | 18 | 0.02 | 52 | b |

[a]Location is shown on Figs. 6-9.

[b]No measurement taken.

Table 6. Radon and radon daughter measurements at 467 Latham Street

| Location | Concentration of $^{222}Rn$ in air (pCi/L) | Radon daughter concentration in air (WL) | Concentration of radionuclides in air (pCi/L) | | | | |
|---|---|---|---|---|---|---|---|
| | | | $^{218}Po$ (Ra A) | $^{214}Pb$ (Ra B) | $^{214}Bi$ (Ra C) | $^{212}Pb$ (Th B) | $^{212}Bi$ (Th C) |
| Basement | 0.68 | 0.00017 | 0.12 | 0.0027 | 0.0090 | 0.014 | 0.0071 |

Table 7. Summary of outdoor measurements and survey results at 467 Latham Street.

| Measurement or sample type | Number of measurements/samples | Range | Mean | Biased readings[a] |
|---|---|---|---|---|
| Grid Point Measurements | | | | |
| External gamma-ray exposure rate at 1 m (μR/h) | 84 | 7-110 | 16 | |
| External gamma-ray exposure rate at surface (μR/h) | 84 | 6-58 | 14 | |
| Systematic surface soil samples | | | | |
| $^{232}$Th concentration (pCi/g) | 14 | 0.77-1.5 | 1.1 | |
| $^{238}$U concentration (pCi/g) | 14 | 0.68-0.89 | 0.76 | |
| $^{226}$Ra concentration (pCi/g) | 14 | 0.66-1.0 | 0.78 | |
| Biased Measurements[a] | | | | |
| Maximum external gamma-ray exposure rate at 1 m (μR/h) | | | | 86 |
| Maximum external gamma-ray exposure rate at surface (μR/h) | | | | 86 |
| Maximum concentration of $^{232}$Th in surface soil (pCi/g) | | | | 26 |

[a]Biased measurements included gamma-ray scanning of the entire yard and surface soil sampling at biased locations.

Table 8. Summary of indoor measurements and survey results at 467 Latham Street

| Measurement or sample type | Number of measurements/samples | Range | Mean | Biased Readings[a] |
|---|---|---|---|---|
| Systematic room surveys | | | | |
| External gamma-ray exposure rate at 1m (μR/h) | 19 | 8-16 | 10 | |
| Beta-gamma dose rate at 1 cm above surface (mrad/h) | 19 | 0.01-0.04 | 0.02 | |
| Direct alpha activity on surface (dpm/100 $cm^2$) | 19 | <26-52 | <26 | |
| Biased Measurements[a] | | | | |
| Maximum external gamma-ray exposure rate at surface (μR/h) | | | | 18 |
| Maximum beta-gamma dose rate at 1cm (mrad/h) | | | | 0.04 |
| $^{222}Rn$ concentration in air (pCi/L) | | | | 0.68 |
| $^{222}Rn$ daughter concentration in air (WL) | | | | 0.00017 |

[a]Biased measurements included gamma-ray scanning of each room, measurement of the beta-gamma dose rates at locations of elevated gamma levels, and measurements of indoor radon and radon daughter concentrations.

Table 9. Summary of measurements results in contaminated areas at 467 Latham Street

| Location[a] | Measurement type | Measurement result |
|---|---|---|
| Area A | Maximum external gamma-ray exposure rate at surface (μR/h) | 86 |
| | $^{232}$Th concentrations measured in surface soil (pCi/g) | 10 |
| | Estimated areal extent of contamination ($m^2$) | 4.5 |
| | Estimated average depth of contamination (m) | 0.15 |
| | Estimated total volume of contaminated material[b] ($m^3$) | 0.7 |
| Area B | Maximum external gamma-ray exposure rate at surface (μR/h) | 47 |
| | $^{232}$Th concentration measured in surface soil (pCi/g) | 26 |
| | Estimated areal extent of contamination ($m^2$) | 1.0 |
| | Estimated average depth of contamination (m) | 0.15 |
| | Estimated total volume of contaminated material[b] ($m^3$) | 0.2 |

[a]For area designation see Fig. 4.

[b]Volume estimates are based on a correlation of surface measurements and subsurface investigations using a reasonable number of drill holes. The exact shape of the contaminated regions cannot be precisely determined by this type of investigation. Actual irregular shapes have therefore been approximated by the most reasonable regular geometric shape (e.g., cylinder, or rectangular prism).

# APPENDIX I

## SURVEY PLAN, INSTRUMENTATION AND ANALYSIS METHODS FOR THE RADIOLOGICAL SURVEY CONDUCTED IN MAYWOOD, NEW JERSEY

# ACTION PLAN FOR PRIVATE PROPERTY SURVEYS IN MAYWOOD, NEW JERSEY

## Purpose

This plan defines the ORNL activities to survey private properties in Maywood, New Jersey, which are believed to be contaminated with residues from thorium processing operations at the former Maywood Chemical Company. There are three objectives of these surveys: (1) define the current radiological status of each property, (2) define the sources of radiation exposures on each property and estimate the volume of material involved, and (3) prepare an exposure evaluation, comparing radiation exposures with guidelines.

## Approach

Initially, ORNL will review all available data relevant to the properties involved. A generic survey plan will then be developed for conduct of private property surveys and will be modified in the field as needed to characterize the properties and radiation sources. Following approval of this approach, ORNL will conduct the radiological surveys at each private property for which consent can be obtained. The findings of each field survey will be prepared and submitted to DOE as a preliminary report; a final report on each property will be submitted after environmental samples are analyzed. The required work is separated into individual tasks which may be summarized as follows:

### Task 1. Review of Available Data

Data provided by ESED have been reviewed and incorporated in the survey planning process. Other data have been volunteered by ORAU, and by the New Jersey Department of Environmental Protection. It is anticipated that additional contacts will be made with NRC Region I personnel. Historical information about each property will be obtained from brief home owner/occupant interviews.

Task 2. Preparation of Survey Plan

The radiological survey plan for private properties will be developed after the available data are reviewed. Ordinarily, a site visit would precede this task. However, due to the immediate need for the surveys, a general plan will be prepared based on prior experience. This plan will be modified in the field as needed to fully characterize any property.

Task 3. Implementation of Radiological Surveys

Radiological surveys of private properties will be conducted according to the approved survey plan. Surveys will only be conducted on properties for which consent can be obtained. Outdoor drilling will be done on an as-needed basis. Drilling or coring through basement floors will only be done as a last resort for obtaining necessary data about subsurface radioactivity profiles.

Task 4. Gamma-Ray Scans of Adjacent Properties

Because of the crescent shapes of the isopleths in the EG&G aerial survey and the possibility of spill-over contamination, it is recommended that gamma-ray scans be conducted on adjacent properties along Latham and Davidson Streets. These scans would be conducted by survey personnel walking on the property. The ground would be scanned with an NaI(Tl) scintillation survey meter at the surface; building foundation walls would also be scanned. If any anomalies were found during this scan, a full radiological survey of the property would be conducted. A scanning survey of a property would be done only with the property owner's consent.

Task 5. Radiological Survey Reporting

The radiological survey findings for each property will be reported in two separate reports. One report will contain all field measurement data obtained at each property. These preliminary letter reports will be submitted to DOE within five days following the completion of the

survey. Conclusions in these letter reports will relate the radiation exposures found on each site to established guidelines for members of the public. Sources of radiation exposures will be identified and the quantity of radioactive material involved will be estimated. An evaluation of radiation exposure will be prepared for each property. The second letter report for each property will contain all analytical results for environmental samples taken during the survey. These analytical results will be related to on-site measurements. Comments received on the preliminary report will be incorporated in preparation of the second report. Any properties for which access was denied will be identified as will any property which had no anomalies on the surface gamma-ray scan. These identifications will be made in the cover letter transmitting the first series of reports.

## Schedule

Task 1 and Task 2.

These tasks will be completed during the week ending May 20, 1981.

Task 3 and Task 4.

These tasks will be performed concurrently. Task 3 is scheduled to begin June 3, 1981.

Task 5.

Preliminary reports will be transmitted during the week of June 19, 1981. Target date for transmittal is June 15, 1981. Draft final letter reports will be transmitted approximately six weeks following the preliminary report transmittal.

# RADIOLOGICAL SURVEY PLAN FOR PRIVATE PROPERTIES IN MAYWOOD, NEW JERSEY

## INTRODUCTION

The Stepan Chemical Company (formerly Maywood Chemical Company) was developed in 1895. From about 1916 until 1957 the Maywood Chemical Company processed thorium for use in the manufacture of gas mantles for various lighting devices.[1] In 1932, Route 17 was built to the west of the main plant through an area that was used for disposal of process wastes. Although access to the site was probably restricted, the waste disposal area had no access restrictions. In 1959, Maywood Chemical Company was purchased by the Stepan Chemical Company. A federally supervised cleanup of a portion of the waste dump was conducted in 1960. Presently, Stepan Chemical Company owns a 30-acre site east of N.J. Route 17, just south of the New York, Susquehanna and Western Railroad right of way. On the west side of N.J. Route 17, SWS Industries owns a vacant 8.7-acre site (formerly a portion of the waste disposal area); plans have been made to locate a warehouse/office complex on this site.

During an aerial survey of the Stepan Chemical Company and the surrounding area in Maywood, New Jersey, by EG&G[1] on January 26, 1981, anamously high gamma-ray exposure rates (principally $^{232}$Th daughter radionuclides were observed in a residential area close to the Stepan Chemical site. Seven private homes in Maywood, New Jersey, were later identified in a follow-up ground survey by the Nuclear Regulatory Commission[2] as having external gamma radiation levels significantly above background. Exposure rates up to 3 mR/h have been observed on these properties. It is surmized that thorium residues were obtained from the Maywood Chemical Waste disposal area and used as fill material on these private properties.

At the request of the Environmental and Safety Engineering Division (ESED) of the Department of Energy, the Off-Site Pollutant Measurements Group, at Oak Ridge National Laboratory (ORNL) will perform a comprehensive radiological survey on seven private properties in Maywood, New Jersey. The survey is scheduled to begin June 3, 1981.

# SURVEY METHODS

The following section describes the survey methods to be employed in performing the ORNL radiological survey. Detailed descriptions of instrumentation, measurement procedures and sample analyses are provided elsewhere in this Appendix I.

## Outdoor Survey

### Grid system

Prior to radiological measurements, a rectangular grid will be established covering the entire area to be surveyed. The spacing of mutually perpendicular grid lines will be determined by the size of the area involved and by the level of detail required for any given area. At least 30 grid points (intersection of grid lines) will be established for each property. At some locations where significant levels of contamination are observed, a smaller grid system will be superimposed to provide more detailed information as required. The size of the smaller grid system will be determined in the field as conditions dictate.

### External gamma radiation measurements

External gamma radiation levels will be measured using a 3.2 cm × 3.8 cm NaI(Tl) probe attached to a ratemeter (calibration for this instrument is performed in the field using a Reuter-Stokes Pressurized Ion Chamber [PIC]). External gamma-ray exposure rates are measured at the ground surface and 1 m above the ground surface at grid points; these measurements will be recorded. Each grid block (square formed by the grid lines) will be scanned at the surface, and the maximum gamma radiation level within each block will be noted.

### Beta-gamma dose rates

Beta-gamma dose rate measurements at 1 cm above the ground surface will be performed at those locations where surface gamma radiation levels are significantly above background. The instrument used for

these measurements is a Geiger-Mueller (G-M) survey meter with a window thickness of 7 mg/cm$^2$ and a halogen-quenched GM tube (open and closed window).

Surface deposits of radioactive materials

Samples of surface soil (a 10 cm × 10 cm area soil sample to a 15-cm depth) will be collected at systematic locations and analyzed in order to identify the locations and estimated quantities of surface deposits of radioactivity. In addition, biased surface soil samples will be obtained at representative locations where elevated external gamma radiation levels are observed. Soil samples will be packaged and transported back to ORNL for processing and analyses for concentrations of $^{238}U$, $^{226}Ra$, $^{232}Th$ and other radionuclides as appropriate.

Subsurface deposits of radioactive materials

Drillings and/or corings will be made at selected locations throughout any area suspected of having subsurface deposits of contaminated materials. The purpose of drilling and/or coring is to locate and estimate the quantities of subsurface deposits of radioactivity. If subsurface radioactivity is suspected within an area and no surface contamination is evident, a random search technique of drilling and gamma-ray logging within that area will be used to locate and identify the boundaries of any subsurface contamination. Drill holes will be augered to an approximate 15-cm diameter and to a depth where a naturally occurring soil strata is encountered. A plastic pipe with a 10-cm (4-inch) inside diameter will be placed in each hole, and an NaI(Tl) gamma-ray scintillation probe will be lowered inside the pipe. The probe is encased in a lead shield with a narrow collimating slot on the side. This arrangement provides measurement of gamma radiation intensities resulting from contamination within small fractions of the hole depth. Measurements are usually made at 15-cm or 30-cm intervals. This "logging" of the core holes is done in order to define the profile of radioactivity underground and as a first step in determining the extent of subsurface contamination at each location. Samples of

subsurface soil from core holes will be collected at random locations and returned to ORNL for analysis for $^{226}Ra$, $^{238}U$, $^{232}Th$ and other radionuclides deemed appropriate. The number of locations of core holes will be determined in the field based on the results of auger-hole loggins and surface gamma radiation levels. The core holes will be drilled and split-spoon samples will be taken at 15- to 30-cm intervals as required. After sampling, the core holes will be augered to a 15-cm diameter and logged at 15- to 30-cm intervals (as required) using the lead-shielded gamma-ray scintillator.

## Indoor Surveys

### External gamma radiation measurements

External gamma radiation levels will be measured at a height of 1 m above the floor in the center of each room using an NaI(Tl) scintillation survey meter. The survey meter will be cross-calibrated with the Reuter-Stokes PIC in the most frequently occupied room of the house. The floor and walls of each room will be scanned for gamma radiation at the surface and the maximum gamma radiation level associated with each surface will be noted.

### Beta-gamma dose rates

Beta-gamma dose rates will be measured at those locations where external gamma-ray exposure rates were found to be significantly above background. These measurements will consist of open- and closed-window Geiger-Mueller (G-M) survey meter readings.

### Surface alpha radiation levels

Surface alpha radiation levels will be measured at the center of the room as well as several other locations as determined in the field. A ZnS(Ag) detector (covered by a 0.03-mil aluminized mylar sheet) will be used and have an attached photomultiplier tube with a portable scaler/ratemeter.

Removable alpha and beta-gamma activity from surfaces

Removable or transferable surface contamination levels will be measured by taking standard smears. The smears are lightly rubbed over a 100-$cm^2$ area and counted for removable long-lived alpha and beta-gamma activity. A smear sample will be obtained near the center of the room where a hard surface is accessible. Smear samples will also be taken at locations where elevated gamma, beta-gamma, and/or alpha radiation levels are observed.

Radon and radon progeny measurements

Concentration of radon ($^{222}Rn$) will be measured indoors at the houses if evidence of indoor contamination is found. Individual radon (radon [$^{222}Rn$], thoron [$^{220}Rn$], actinon [$^{219}Rn$]) progeny concentrations in air will be measured at various locations and times within all houses.

Other samples

During the gamma-ray scanning of the property, building materials such as wood, concrete, or bricks may be found to have elevated gamma radiation levels associated with them. These materials as well as atypical samples from the outdoor survey (e.g., large rocks, vegetation, etc.) may be obtained and returned to ORNL for analyses. The resulting laboratory analysis is sample-specific, dependent on the pattern of contamination (i.e., radionuclide concentration versus measurement of surface contamination).

## RADIATION SURVEY METERS

### Alpha Survey Meters

The type of alpha survey meter used at the residences in Maywood, New Jersey, to measure alpha radioactivity on surfaces uses a ZnS(Ag) scintillator to detect the alpha radiation.

The alpha scintillation survey meter consists of a large area (100 $cm^2$) ZnS(Ag) detector with a photomultiplier tube in the probe which is coupled to a portable scaler/ratemeter (Fig. I-A). The ZnS(Ag) detector is covered with a 5-mil aluminized mylar sheet in order to make the instrument light-tight. A metal grid is used to avoid puncturing the mylar when surveying over rough surfaces. This instrument is capable of measuring alpha surface contamination levels of a few disintegrations per minute per 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. This instrument is calibrated at ORNL using $^{239}Pu$ alpha sources. Calibration factors are typically 5 to 7 dpm/cpm.

### Beta-Gamma Survey Meter

A portable Geiger-Mueller (G-M) survey meter (Fig. I-B) 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- 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.

The G-M survey meters were calibrated by comparison with a pre-calibrated Victoreen Model 440 ionization chamber (Fig. I-C). The open-window calibration factor was found to be 2,000 cpm/(mrad/h) for surfaces contaminated with $^{226}Ra$ in equilibrium with $^{238}U$ and 2,300 cpm/(mrad/h) for surfaces contaminated with initially pure uranium. The closed-window

(gamma) calibration factor, determined by use of a National Bureau of Standards (NBS) standard $^{226}Ra$ source, was 3,200 cpm/(mrad/h).

### 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 (Fig. I-D). This unit is capable of measuring radiation levels from a few microroentgens per hour to several hundred microroentgens per hour. This instrument is calibrated at Oak Ridge National Laboratory (ORNL) with an NBS standard $^{226}Ra$ source. Typical calibration factors are of the order of 500 cpm/(μR/h). The sensitivity of this instrument may be influenced by factors such as temperature, humidity, and small changes in photomultiplier tube voltage. Therefore, each instrument used in the field is standardized daily, and its response is compared with readings made with a Reuter-Stokes Model RSS-111 Pressurized Ionization Chamber (PIC) (Fig. I-E). This latter instrument has response which is proportional to exposure to Roentgens over a wide energy range. Readings made with the portable scintillation survey meter and compared with exposure rates determined at the same time using the PIC may be used as a factor to convert the reading in counts per unit time to exposure rate per unit time (μR/h).

## 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.[3] This detector assembly was used with electronic components housed in a portable NIM bin (Fig. I-E). The electronics package consisted of a preamplifier, an 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 (~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 was used in the field to measure beta activity on smear papers and was calibrated daily using a beta standard of known activity (Fig. I-F).

## TECHNIQUE FOR THE MEASUREMENT OF $^{222}$Rn AND PROGENY CONCENTRATIONS IN AIR

### ORNL Cells

An ORNL cell (Fig. I-G) consists of a 500 ml lucite cylinder coated inside with a uniform layer of zinc sulfide. For measurements of radon concentration in the air, the cell is evacuated to a pressure of approximately 100 microns. The cell is then taken to a location where a sample is desired and the collection valve is opened. After collection of air in the cell, sample counting is delayed four hours to allow the radon daughters to attain equilibrium. Alpha particles from the radon daughters produce scintillations in the zinc sulfide. The sample is normally counted with a photomultiplier tube assembly. After the sample has been counted, the cell is again evacuated to approximately 100 microns to prevent contamination buildup.

### Technique for the Measurement of $^{222}$Rn Progeny Concentrations in Air

An alpha spectrometry technique has been refined by Kerr[4,5] for the measurement of $^{222}$Rn progeny concentrations in air. From one integral count of the $^{218}$Po alpha activity and two integral counts of the $^{214}$Po

alpha activity, the concentration in air of $^{218}Po$, $^{214}Bi$, and $^{214}Pb$ may be calculated.

Particulate $^{222}Rn$ daughters attached to airborne dust are collected on a membrane filter with a pore size of 0.4 microns. A sampling time of 5-10 minutes and a flow rate of 12-16 LPM are used. This filter sample is then placed under a silicon surface barrier detector and counted. The detector and counting system used for radon daughter measurements are shown in Fig. I-H. Usually, counting of this kind is performed with a vacuum between the sample and the detector which requires a complicated sample holder and time-consuming sample changing methods. Experiments at this laboratory have shown that ease in sample handling is obtained with little loss in resolution when helium is used as a chamber fill gas. In this counter, helium is flowed between the diode and the filter sample, which are separated by a distance of 0.5 cm. One integral count of the $^{218}Po$ alpha activity is obtained from 2 to 12 minutes, and two integral counts of the $^{214}Po$ activity are obtained from 2 to 12 minutes and 15 to 30 minutes, respectively. All counting intervals are referenced to t = 0 at the end of sampling.

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

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

where

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

$\lambda_i$ = 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

$$n_i(t) = e^{-\lambda_i t} \; n_i^o + \quad C_i V + \lambda_{i-1} n_{i-1}(t) \quad e \; i \; dt$$

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

As described in reference 6, during investigations utilizing this alpha spectrometry technique at another site, daughters of $^{219}Rn$ (actinon) were discovered during the counting procedure. The presence of these progeny, primarily a result of contamination with uranium ore raffinates, in observable and sometimes rather high concentrations could result in large errors in the calculation of $^{222}Rn$ daughter concentrations using the previously described method. Hence, a revised procedure has been developed to determine the daughter concentration of both radon isotopes. This technique is based on a similar filter counting procedure, utilizing measurements over two additional energy regions.

## DESCRIPTION OF GERMANIUM DETECTOR SYSTEM

Soil samples for $^{226}Ra$ analysis are dried for 24 h at 110°C and then pulverized to a particle size no greater than 500 μm in diam. (35 mesh). Aliquots from this dried sample are transferred to 25-$cm^3$ polyethylene bottles (standard containers for liquid scintillation samples), weighed, and stored for approximately 30 days to allow for buildup of radon and radon daughters. These bottled samples are then analyzed on the germanium detector system of the Off-Site Pollutant Measurements Group at ORNL.

A holder for 12 of the polyethylene bottles and background shields has been designed for use with the germanium detector systems (Fig. I-I).

During counting of the samples, the holder is used to position 10 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-$cm^3$ 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 and $^{227}Ac$ within an error of ±10% or less. The minimum detectable concentration (MDC) for the system, considering the background of the counting system, is generally about 0.3 pCi/g.

Pulses produced by the crystal are sorted by one of three multichannel analyzers, one of which stores the data on magnetic tape (Fig. I-J), while the other two store data on a floppy disk (Fig I-K). All samples are analyzed using a least squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. Those spectra stored on magnetic tape are entered into the computer via a remote terminal. The computer program which analyzes these spectra runs continuously on the IBM-360 system at ORNL and relies on a radioisotope library containing 700 isotopes and 2500 gamma-rays. Those spectra stored on floppy disk are directly analyzed by a Tennecomp 5/11 computer which uses a library of radioisotopes tailored specifically for environmental measurements. In identifiying and quantifying $^{226}Ra$ in either system, 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.

## NEUTRON ABSORPTION TECHNIQUE FOR $^{238}U$ ANALYSIS

Following the initial soil sample drying and pulverizing, a 30-$cm^3$ aliquot is sent to the Anaytical Chemistry Division of ORNL for $^{238}U$ analysis by neutron activation.[7] The concentration of $^{235}U$ in the soil sample is determined by counting delayed neutrons emitted from fission products produced by neutron activation of the $^{235}U$ in the sample. Neutron activation of the samples are made in the pneumatic tube irradiation facility of the Oak Ridge Research Reactor. Following exposure to a thermal neutron flux of approximately $6 \times 10^{13}$ n/$cm^2$-s, a count of the delayed-neutron activity is made using a paraffin moderator with a $BF_3$ tube detector assembly having a neutron counting efficiency of about 5%.

The $^{235}U$ content of a test sample is obtained by comparing its delayed-neutron count to that obtained with a comparator sample containing a known quantity of $^{235}U$. Calculations are then made utilizing the following equation:

$$^{235}U \text{ in test sample} = {}^{235}U \text{ in comparator sample } \left(\frac{\text{Net count of test sample}}{\text{Net count of comparator sample}}\right)$$

The $^{238}U$ concentration is then calculated assuming that 0.72% of natural uranium is $^{235}U$. The precision of this method is approximately ±3% (expressed as the relative standard deviation for $2\sigma$ or 95% confidence intervals), with a lower limit of detection of ~40 ppb ($10^5$ pCi/g) for $^{238}U$.

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6. P. T. Perdue, R. W. Leggett, and F. F. Haywood, "A Technique for Evaluating Airborne Concentrations of Daughters of Radon Isotopes," National Radiation Environment III, Vol. 1 (1978).

ORNL-Photo 2062-81

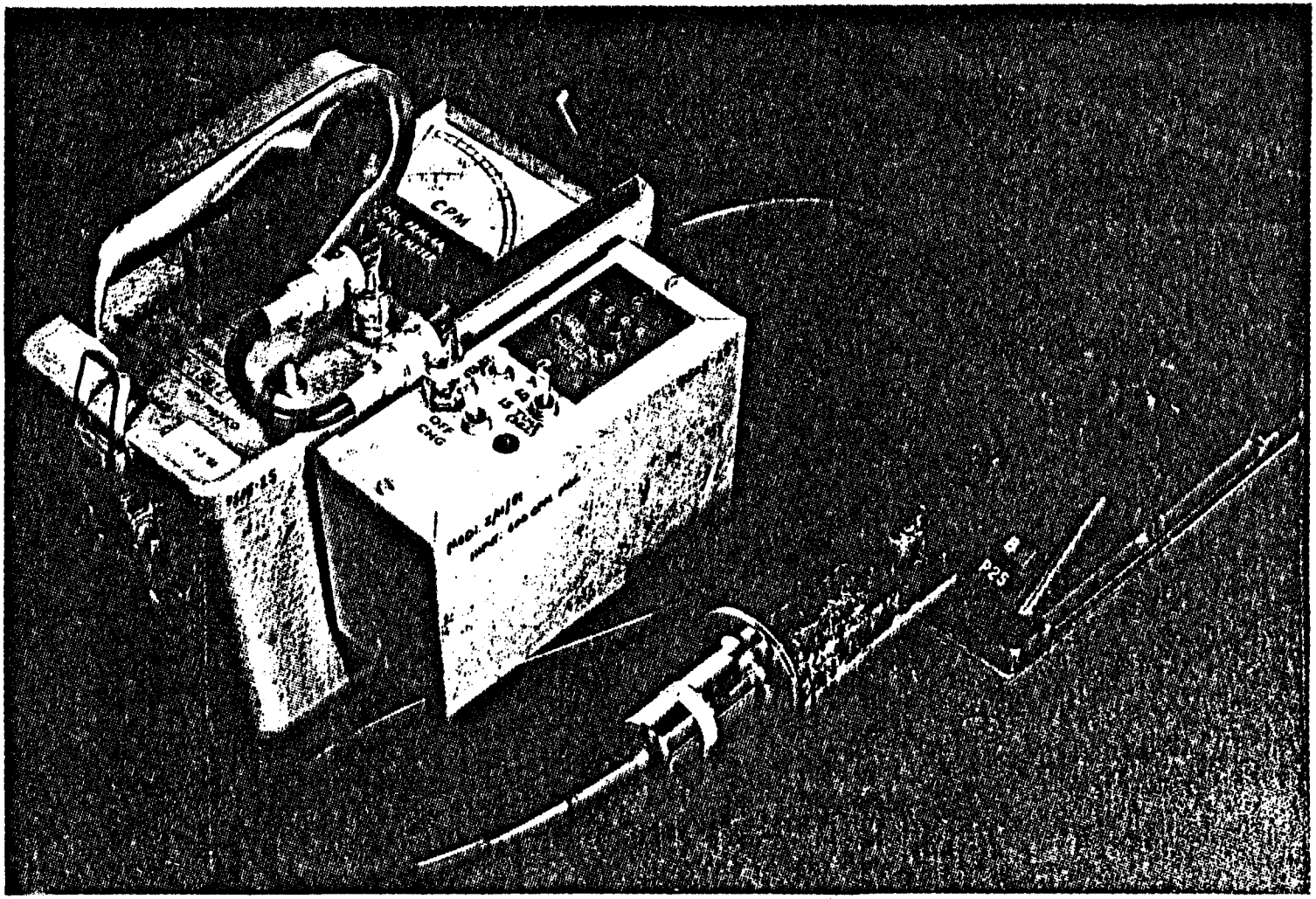


Fig. I-A. Alpha scintillation survey meter.

ORNL-Photo 6704-76

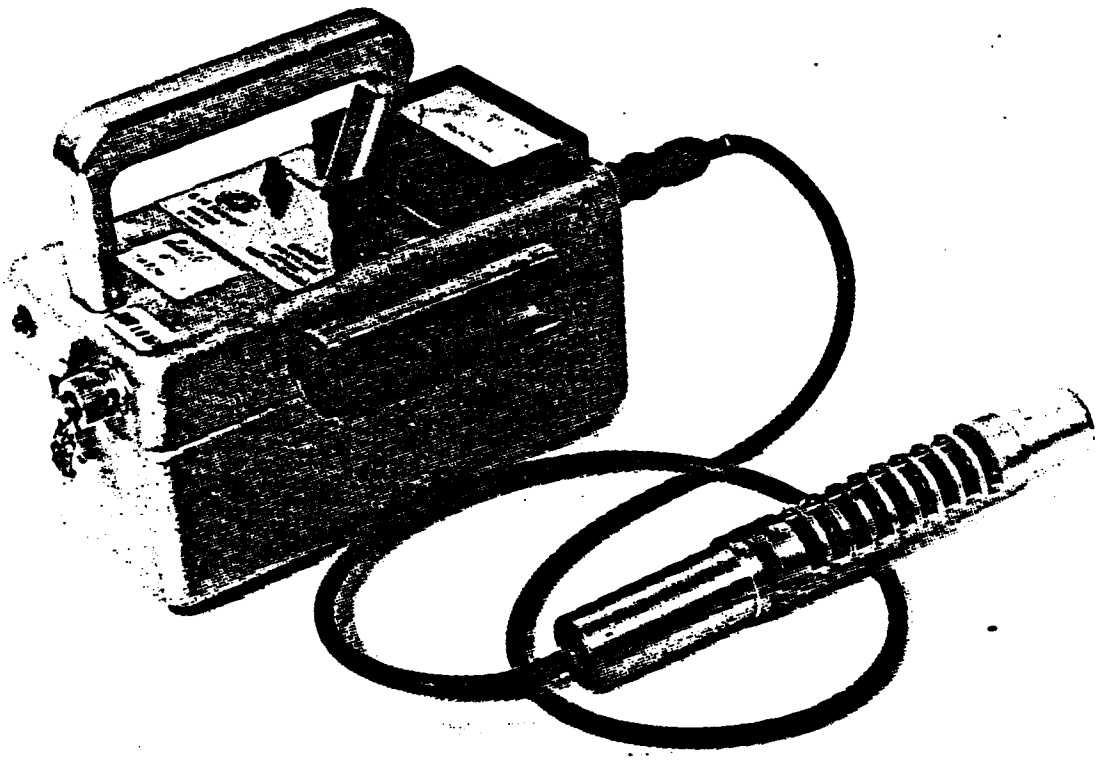

Fig. I-B. Geiger-Mueller survey meter.

ORNL-Photo 6710-76

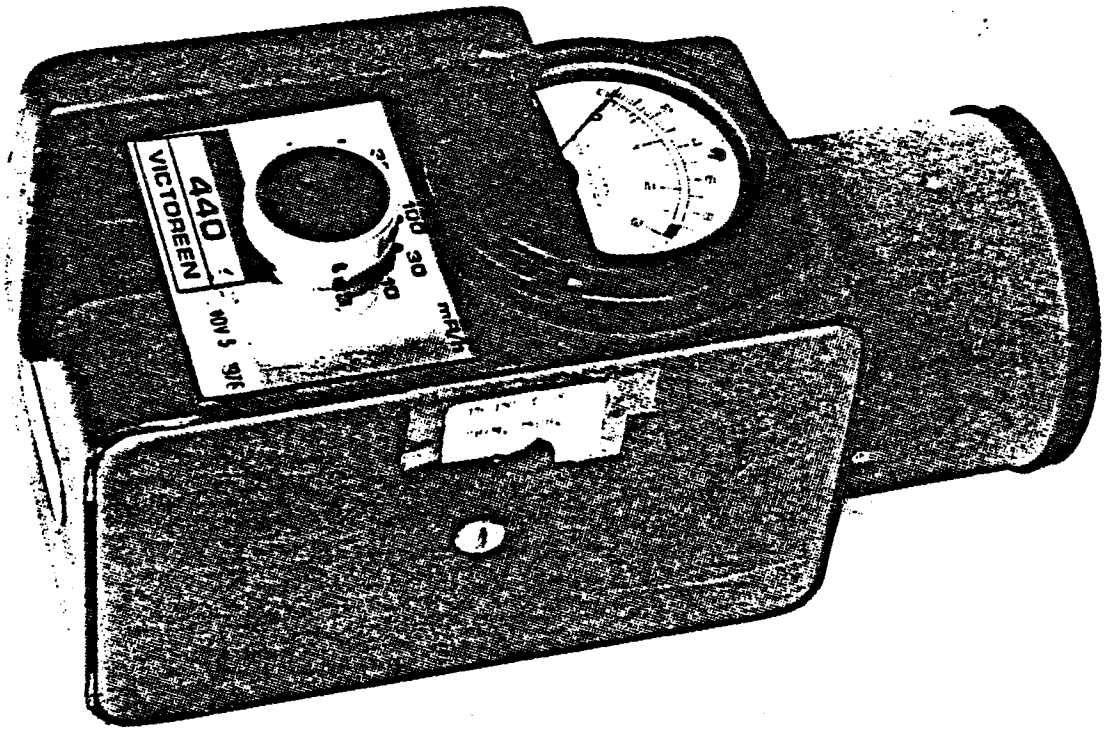


Fig. I-C. Victoreen Model 440 ionization chamber.

ORNL-Photo 6707-76

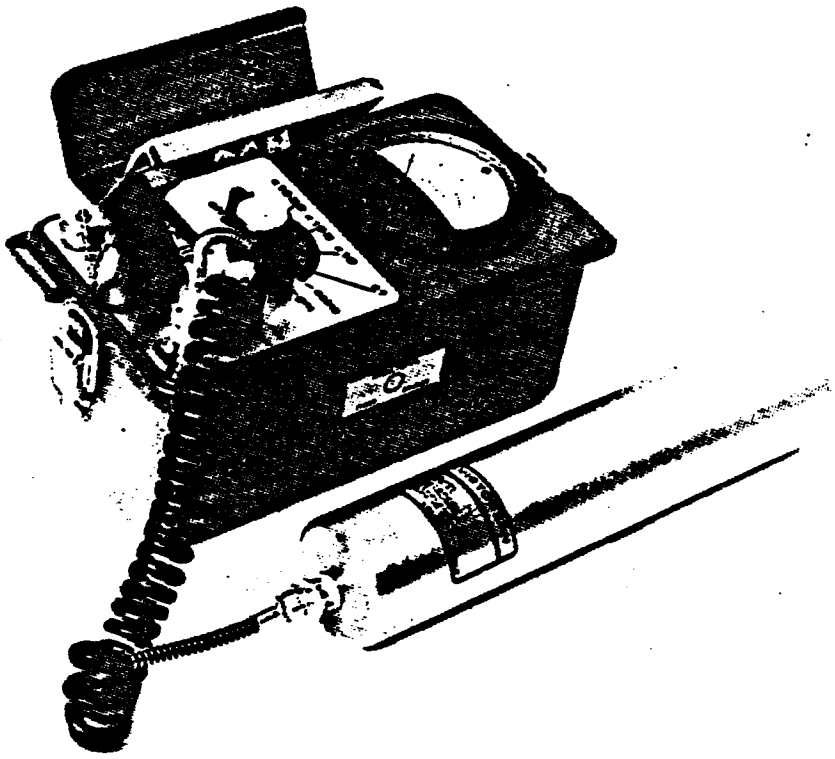

Fig. I-D. Gamma scintillation survey meter.

ORNL-Photo 4424-81

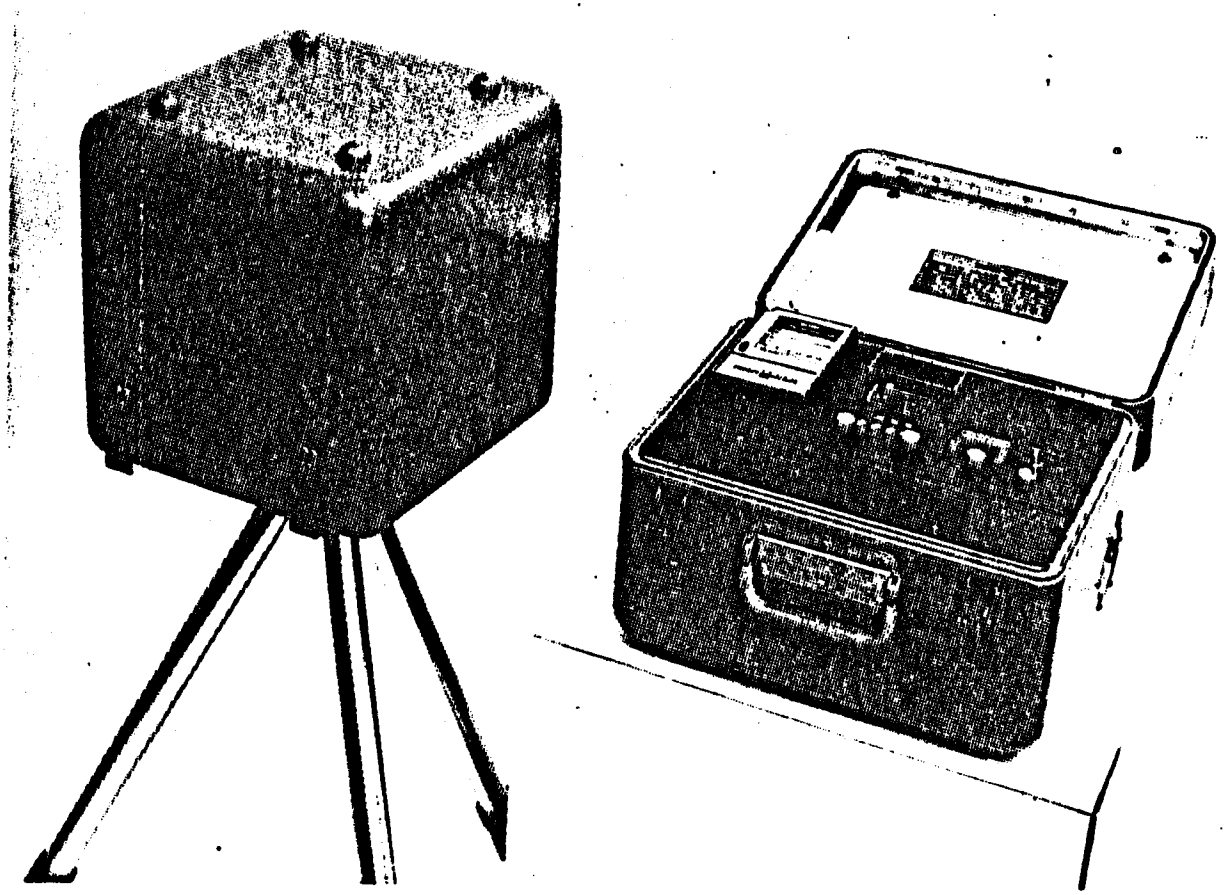

Fig. I-E. Pressurized Ion Chamber.

ORNL-Photo 1070-78

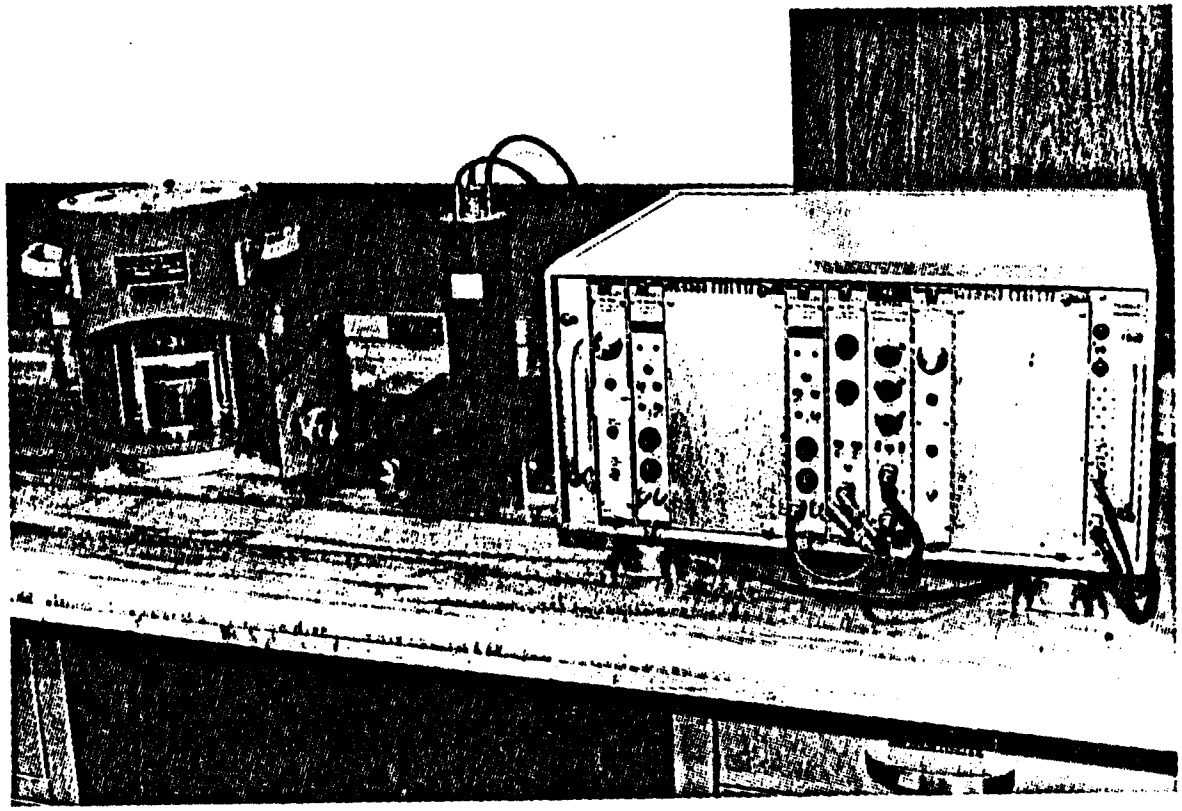

Fig. I-F. Smear counter and associated electronics. The beta counter is on the left and the alpha counter is on the right.

ORNL-Photo 2060-81

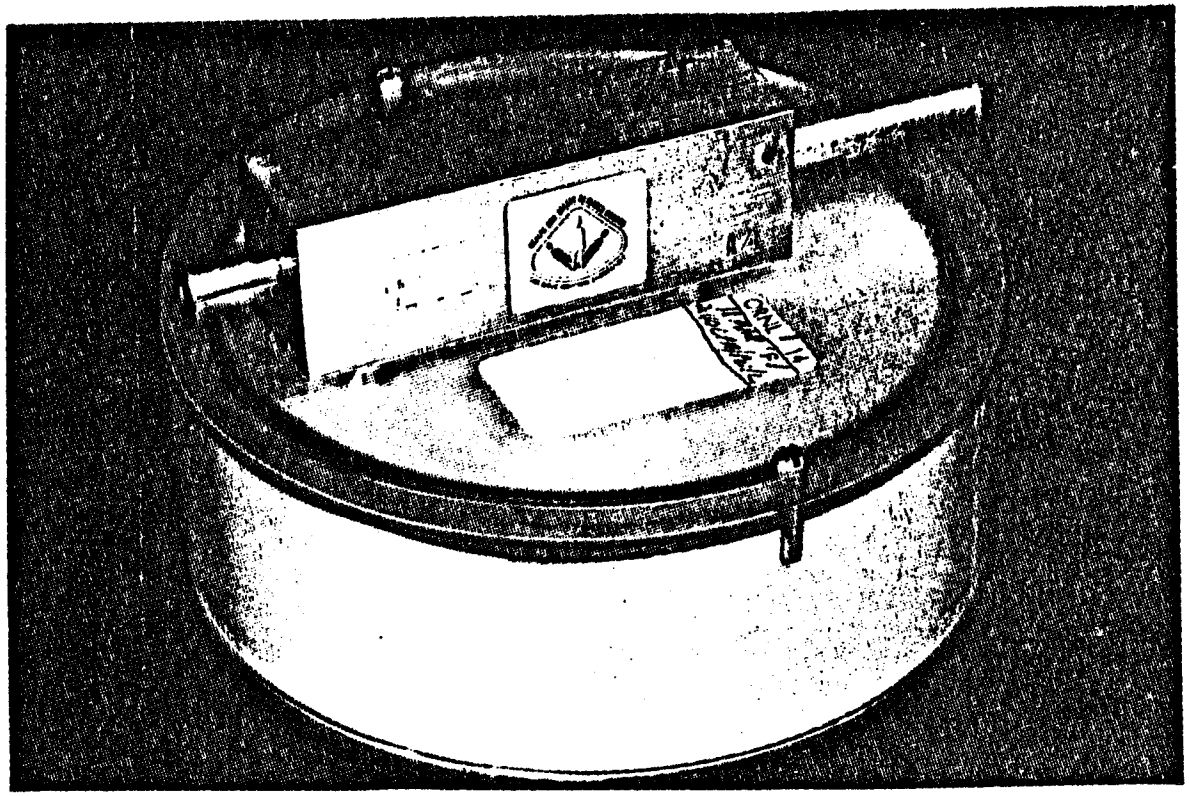

Fig. I-G. ORNL Cell.

ORNL-Photo 1081-78

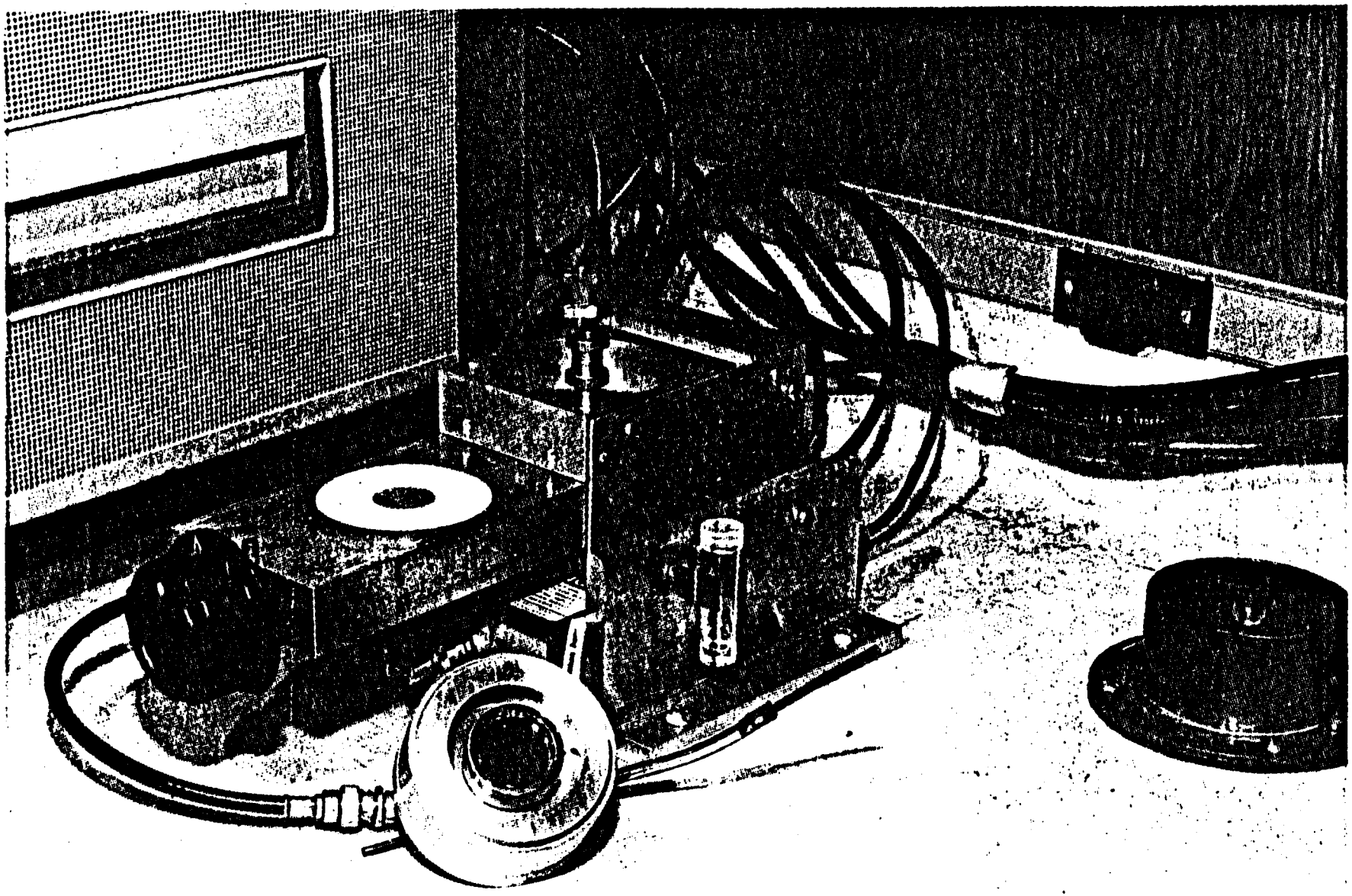

Fig. I-H. Alpha spectrometer used to assess radon daughter concentrations.

ORNL-Photo 4348-81

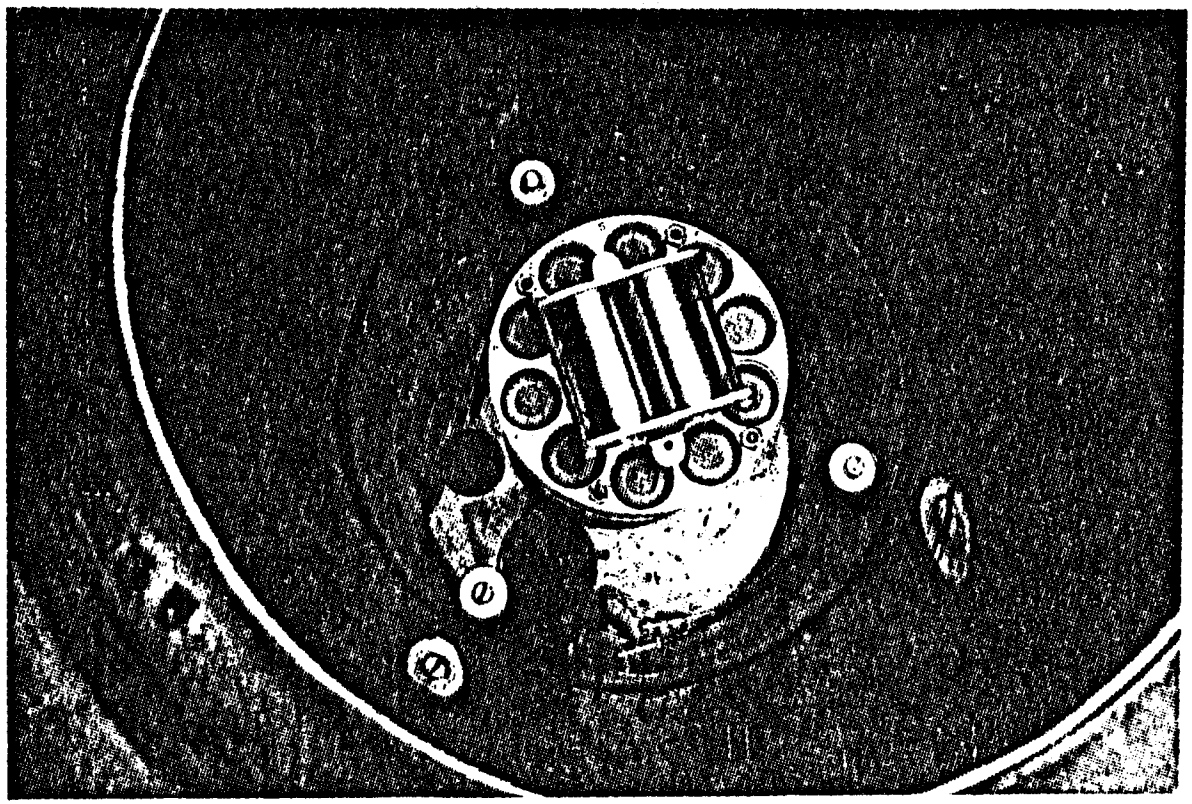

Fig. I-I. Soil sample holder on germainum-detector system.

ORNL-Photo 4351-81

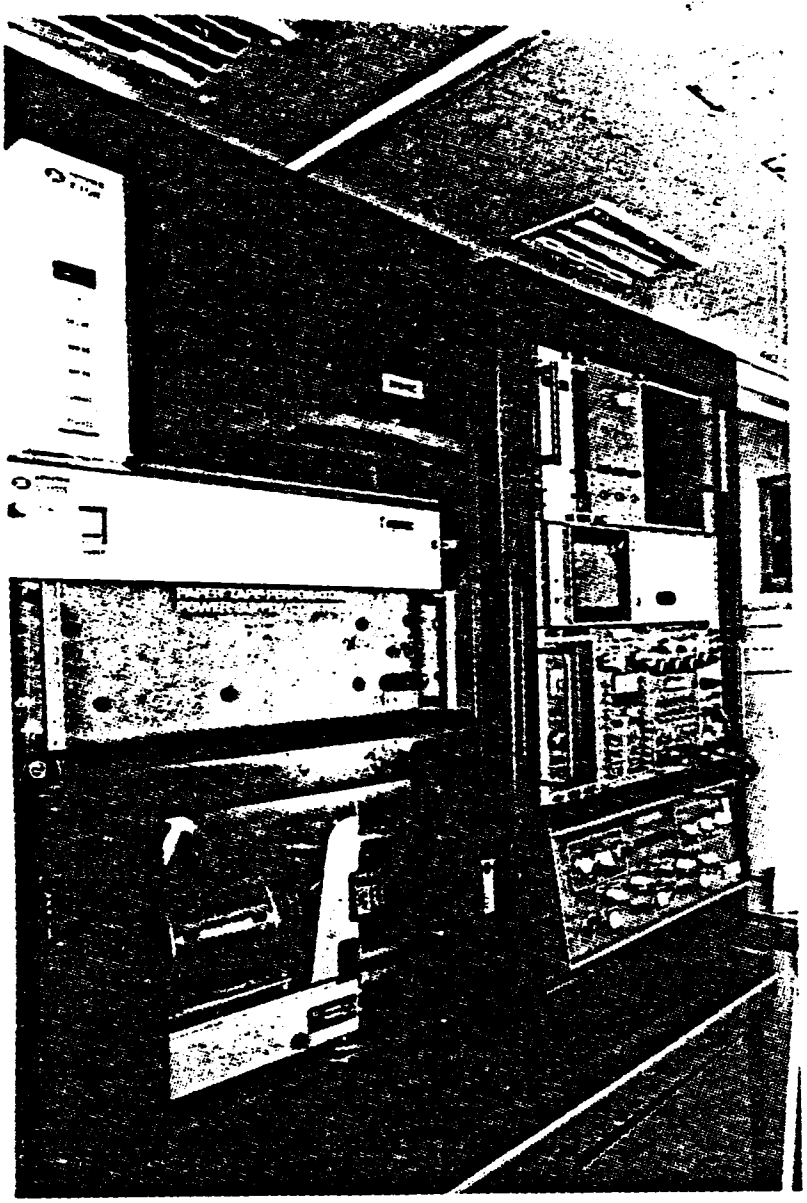

Fig. I-J. Multichannel analyzer with magnetic tape storage and vertical Ge(Li) detector system.

ORNL-Photo 4350-81

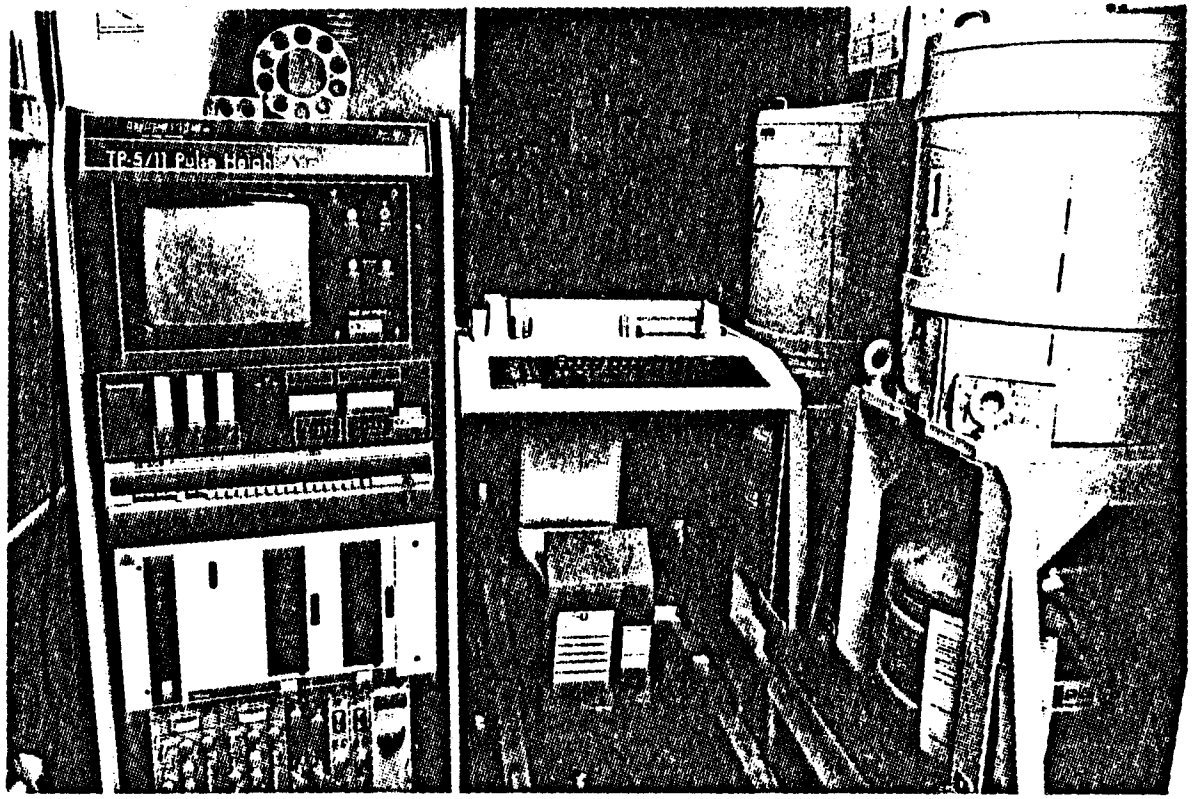


Fig. I-K. Multichannel analyzer with floppy disk storage and two vertical germanium systems.

# APPENDIX II

## EVALUATION OF RADIATION EXPOSURES AT 467 LATHAM STREET IN MAYWOOD, NEW JERSEY

# EVALUATION OF RADIATION EXPOSURES AT 467 LATHAM STREET IN MAYWOOD, NEW JERSEY

## INTRODUCTION

Contaminated material was first discovered at this property and several nearby properties during an EG&G aerial radiological survey and subsequent ground-level Nuclear Regulatory Commission radiological survey. Because the contaminated material was similar to waste material that was generated by the Maywood Chemical Company (now Stepan Chemical Company), the material is believed to have originated from that source.

In June 1981, on request of the Department of Energy (DOE), Oak Ridge National Laboratory (ORNL) performed a radiological survey of this property. It was determined that radioactive material of the naturally occurring thorium and uranium decay chains was present in two isolated locations outdoors on the property. The contamination is limited to approximately the upper 6 inches (15 cm) of soil. No residual radioactive materials were found inside the house.

## BACKGROUND RADIATION EXPOSURES

The naturally occurring radionuclides present at this property are present normally 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 limits established for workers in the nuclear industry.

As described previously, the contaminated materials present on this property consisted of radionuclides of the thorium and the uranium decay chains. Uranium-238 and thorium-232 were created when the earth was formed, and are still present today because they take a very long time to undergo radioactive decay. The half-life is a measure of the time required for radioactive decay; for uranium-238 it is 4.5 billion years. Thus, if 4.5 billion years ago you had a curie* of uranium-238, today you would have one-half curie; 4.5 billion years hence, this would only be one-fourth curie. As the uranium-238 decays, it changes into another substance, thorium-234. Thorium-234 is called the "daughter" of uranium-238. In turn, thorium-234 is the "parent" of protactinium-234. Radioactive decay started by uranium-238 continues as shown in Table II-1 until stable lead is formed. The "decay product" listed in Table II-1 is the radiation produced as the parent decays. Radioactive decay started by thorium-232 continues as shown in Table II-2 until stable lead is also formed.

## RADIATION EXPOSURES AT 467 LATHAM STREET

There are four primary pathways to humans from the type of contaminated material found on this property. These potential pathways are: (1) direct gamma-ray exposures, (2) inhalation of radon and radon daughters from radon decay, (3) inhalation of airborne radioactive particles, and (4) ingestion of radioactively contaminated foods or water. In the following sections, the magnitude of each of these pathways at 467 Latham Street is described, based on the radiological conditions determined from the recent radiation survey. A summary of this radiation exposure data is given in Table II-3 along with a listing of the normal background levels for this area and the applicable guideline values for comparison.

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

## Direct Gamma-Ray Exposures

As shown in Tables II-1 and II-2, several of the daughters of uranium-238 and of thorium-232 emit gamma radiation (gamma-rays are penetrating radiation like X-rays). Hence, the contamination present on this property is a source of external gamma radiation exposure to persons who reside near or come in contact with this material. Measurements of the gamma radiation levels outdoors on the property determined that the exposure rate at 1 m above the ground ranged from 7 to 110 microroentgens* per hour, with an average of 16 microroentgens per hour. Inside the house, the exposure rates ranged from 8 to 16 microroentgens per hour, with an average value of 10 mircoroentgens per hour. For comparison, the normal background gamma-ray exposure rate for the Maywood area is 8 microroentgens per hour.

The NRC guidelines (found in the Code of Federal Regulations, Title 10, Part 20†) require that the continuous gamma radiation exposure to any individual in the general population not exceed 500 milliroentgens per year. For persons residing at this property, continuous exposure (24 hours a day, 365 days per year) to the average levels found outdoors would result in an annual gamma-ray exposure of 140 milliroentgens, a value well below the guideline limit. Indoors, the continuous annual exposure from the average radiation levels would be 88 milliroentgens. Again, this exposure is below the applicable guideline. For comparison with everyday exposures, these values can be compared to a normal background exposure of 70 milliroentgens per year in New Jersey or a typical chest X-ray exposure of 27 milliroentgens.

## Inhalation of Radon and Radon Daughters

Radon-222 (the daughter of radium-226) and radon-220 (the daughter of radium-224) are inert gases produced by decay of their respective

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*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. A milliroentgen is one-thousandth of a roentgen, or one thousand microroentgens.

†Title 10, Code of Federal Regulations, Part 20, is a regulatory document published by the Nuclear Regulatory Commission and may be found in the Federal Register.

parent radionuclides. When produced, this gas can migrate through the soil or other materials and eventually be released to the atmosphere. If the gas enters a structure with poor ventilation, accumulation of the gas and its short-lived daughters in room air can occur. Breathing of this short-lived radon daughter results in exposure of the respiratory tract to radiation.

Since contaminated soil containing the radioactive parents of radon-222 and radon-220 was found on this property, the potential for radon migration into the house was believed to exist. Measurements of the indoor concentrations of radon and its daughters in air were made for comparison with normal background levels, as well as current guidelines. The radon (radon-222 and radon-220) concentration in the basement of the house was determined to be 0.68 picocuries* per liter, a value in the range of normal background for the Maywood area (0.8 to 1.7 picocuries per liter). The NRC guideline value for radon-222 in air is 3 picocuries per liter and for radon-220 is 10 picocuries per liter (10 CFR 20).

The measured average radon daughter concentrations in the basement of the house were determined to be 0.00017 working level.† This concentration is within the normal background range for the New Jersey area (0.004 to 0.008 working level), and is well below the guideline values of 0.03 working level suggested in 10 CFR 20 or 0.01 working level given in the Surgeon General's Guidelines.§

## Inhalation of Airborne Radioactive Particles

Radioactive particles associated with soil or similar materials can become airborne due to natural (e.g., wind) or human (scraping) forces. Once airborne, these particles can become inhaled, with subsequent

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*One picocurie is one million-millionth of a curie, previously defined.

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

§Federal Register, Vol. 41, No. 253, pages 56777-56778, December 30, 1976 (10 CFR 712).

exposure of the respiratory tract. Guidelines for acceptable concentrations of radionuclides in air have been developed and are presented in 10 CFR 20. At 467 Latham, this exposure pathway is of no concern due to the location of the contaminated material under grass and other vegetation. However, if present land use changes and extensive handling or scraping of the contaminated material occurs, the potential for radiation exposure from this pathway would be increased.

### Ingestion of Radioactivity

The final pathway of potential radiation exposure for residents at this property is the ingestion of radionuclides through contaminated foods or water. Since the water supply at this residence is the public water system, unaffected by the contamination on the property, ingestion of contaminated water is considered insignificant.

The magnitude of the radiation exposure to an individual ingesting foods grown in contaminated soil is dependent upon a number of factors, including: (1) the concentration of radionuclides in the soil, (2) the amount of uptake of the specific radionuclide by the plant of concern, and (3) the amount of the plant consumed by the individual. At the present time, no guidelines are available listing the acceptable concentrations of radionuclides in the soil or foods for the radionuclides of concern at this property. Due to the small amount of contaminated material on this property and its spotty distribution, this radiation exposure pathway would be negligible in comparison to the direct gamma-ray exposure pathway.

## PRELIMINARY ESTIMATE OF RADIATION RISK

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 exist in any estimates of the number of increased cancer deaths in the relatively small population exposed at this property.

Using the results of the radiological survey at this property, preliminary estimates of the increased risk of cancer for residents living there have been calculated. These estimates considered only the two most significant exposure pathways (direct radiation exposure and inhalation of radon and radon daughters) and were based on the following assumptions:

1. The measurements that are reported in Table II-3 are respresentative of the conditions throughout the year and for every year. It is recognized that radon and radon-daughter levels in the homes could be higher in winter because of less ventilation.
2. The inhabitants spend 5% of their time in the basement (or the radon escaping to the upstairs when the door is opened adds an equivalent exposure).
3. The inhabitants live in this house all of their lives, from birth to age 70.
4. Each day the inhabitants spend an average of two hours away from the house and property, four hours outside the house but on the property, and 18 hours inside the house.

The total estimated increased risk due to radiation induced cancer for residents at 467 Latham Street was calculated to be 0.01%.* Thus, for persons living for a lifetime at 467 Latham, instead of an average chance of 24.4% of eventually dying from cancer (the average for Bergen County, New Jersey in 1975)†, they might have a hypothetical average

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*J. W. Healy and W. J. Bair, "Preliminary Report – Radiological Appraisal of Houses in Maywood, N. J." Attachment to letter from W. J. Bair, Battelle Pacific Northwest Laboratories to W. E. Mott, Department of Energy, Washington, D. C., July 17, 1981.

†Mortality statistics were obtained from data in Vital Statistics of the United States – 1975, Volume II – Mortality, Part B, U. S. Department of Health, Education and Welfare, Public Health Service, National Center for Health Statistics, (PHS) 78-1102, 1977.

chance of 24.41% of dying from cancer. These values compare with a lifetime average chance of dying from cancer of 21.8% for the state of New Jersey, and a 19.3% for the United States.

## SUMMARY

A summary of radiation exposure data at 467 Latham Street is presented in Table II-3. Of the four primary radiation exposure pathways, none are of immediate concern at this site under present conditions of property use. Inhalation of radionuclides is considered a negligible source of radiation exposure at the present since there is no apparent ordinary mechanism to cause contaminated material in the soil to become airborne. It is believed that possible future use of portions of the property for growing food could contribute appreciable radiation exposure to an individual consuming this food for a considerable period of time as a large fraction of his diet; however, under current conditions of use, this pathway is of no concern. Average exposures to gamma radiation on this property were below the guidelines for exposure to individuals in the general public although elevated levels do exist at two isolated locations. Finally, radon and radon daughter concentrations measured inside the house were in the normal range of background, indicating that exposure from this pathway would be insignificant.

Table II-1. Uranium-238 decay series

| Parent | Half-life | Decay products | Daughter |
|---|---|---|---|
| Uranium-238 | 4.5 billion years | alpha | thorium-234 |
| Thorium-234 | 24 days | beta, gamma | protactinium-234 |
| Protactinium-234 | 1.2 minutes | beta, gamma | uranium-234 |
| Uranium-234 | 250 thousand years | alpha | thorium-230 |
| Thorium-230 | 80 thousand years | alpha | radium-226 |
| Radium-226 | 1,600 years | alpha | radon-222 |
| Radon-222 | 3.8 days | alpha | polonium-218 |
| Polonium-218[a] | 3 minutes | alpha | lead-214 |
| Lead-214[a] | 27 minutes | beta, gamma | bismuth-214 |
| Bismuth-214[a] | 20 minutes | beta, gamma | polonium-214 |
| Polonium-214[a] | $\frac{2}{10,000}$ second | alpha | lead-210 |
| Lead-210 | 22 years | beta | bismuth-210 |
| Bismuth-210 | 5 days | beta | polonium-210 |
| Polonium-210 | 140 days | alpha | lead-206 |
| Lead-206 | stable | none | none |

[a]Short-lived radon daughters.

Table II-2. Thorium-232 decay series

| Parent | Half-life | Decay products | Daughter |
|---|---|---|---|
| Thorium-232 | 14 billion years | alpha | radium-228 |
| Radium-228 | 6.7 years | beta | actinium-228 |
| Actinium-228 | 6.1 hours | beta, gamma | thorium-228 |
| Thorium-228 | 1.9 years | alpha, gamma | radium-224 |
| Radium-224 | 3.6 days | alpha, gamma | radon-220 |
| Radon-220 | 55 seconds | alpha, gamma | polonium-216 |
| Polonium-216 | 0.15 seconds | alpha | lead-212 |
| Lead-212 | 11 hours | beta, gamma | bismuth-212 |
| Bismuth-212 | 61 minutes | alpha, beta, gamma | polonium-212 (64%) or thallium-208 (36%) |
| Polonium-212 or | 0.3 millionth of a second ($\frac{3}{1,000,000}$) | alpha | lead-208 |
| Thallium-208 | 3.1 minutes | beta, gamma | lead-208 |
| Lead-208 | stable | none | none |

Table II-3. Summary of exposure data at 467 Latham Avenue in Maywood, New Jersey

| Exposure pathway[a,b] | New Jersey background levels | Guideline value for individual in the general public | Average levels found on property |
|---|---|---|---|
| Gamma radiation | Outdoors: 8 microRoentgens per hour at one meter | Outdoors: 60 microRoentgens per hour | Outdoors: 16 microRoentgens per hour at one meter |
| | Indoors: 8 microRoentgens per hour at one meter | Indoors: 60 microRoentgens per hour | Indoors: 10 microRoentgens per hour at one meter |
| Radon in indoor air | Basement: 1.7 picocuries per liter | 3 picocuries per liter | Basement: 0.68 picocuries per liter |
| | Upstairs: 0.8 picocuries per liter | | |
| Radon daughters in indoor air | Basement: 0.008 working level | Basement: 0.01 working level | Basement: 0.00017 working level |
| | Upstairs: 0.004 working level | Upstairs: 0.01 working level | |

[a]Inhalation of radionuclides pathway is not an appreciable source of radiation exposure to individuals living at this property.

[b]Ingestion of vegetables grown in contaminated soil could only be a significant pathway of radiation exposure to individuals living at this property if vegetables grown in contaminated soil constitute a large fraction of their diet.