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Health and Safety Research Division

RESULTS OF THE RADIOLOGICAL SURVEY AT 468 DAVISON AVENUE, MAYWOOD, NEW JERSEY

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for the
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RESULTS OF THE RADIOLOGICAL SURVEY AT 468 DAVISON AVENUE, MAYWOOD, NEW JERSEY*

INTRODUCTION

A comprehensive radiological survey of 468 Davison Avenue, 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 468 Davison Avenue in that it included wastes from the thorium processing operations.

The current owner of 468 Davison is Evelyn Dunphy. She has lived at this residence since 1967 with her two teenage children. The house was constructed about 1950. Front and rear views of the property are provided in Figs. 1 and 2, respectively. This lot is approximately 15 m wide by 37.5 m deep. The layout of the property is shown in Fig. 3.

*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 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. Results of grid point/grid block measurements are presented in Table 3. The location of grid points/blocks are shown in Fig. 3. The elevated gamma radiation levels confirm the presence of contaminated material over much of the outdoor area of the property. A pattern of the most heavily contaminated areas can be obtained from observing the surface gamma-ray exposure rates given in Fig. 4. Highest measurements were along the entire west border of the property (adjacent to 464 Davison). Elevated gamma radiation levels were also observed in the back yard along the east border of the property line, and in the front yard in the shubbery adjacent to the house. The maximum gamma-ray exposure rate at 1 m above the ground on this property (200 μR/h) exceeded the background value by a factor of 25 and the guideline value (10 CFR 20) by a factor of 3. Beta-gamma dose rate measurements at the location of maximum gamma radiation levels ranged from 0.08 to 2 mrad/h.

Surface soil samples. Samples of surface soil (top 15 cm) were taken from various locations on the property for radionuclide analyses. Locations of the systematic (MJ samples) and biased (MJB samples) sampling locations are shown in Fig. 5, with results of laboratory analyses provided in Table 4. (A biased soil sample is one which is collected at a location exhibiting elevated gamma radiation levels.) Concentrations of ^{232}Th exceeded the concentrations of ^{226}Ra and ^{238}U in most of the samples collected at 468 Davison Avenue. The concentration ratio of $^{232}Th/^{226}Ra$ averaged approximately four in these samples. Based on the results of soil sample analyses, the contaminated material is located: (1) within a 3-m wide strip along the entire west side of the property (adjacent to the 464 Davison property); (2) along a 3-m wide strip on the east side of the property in the back yard; and (3) in the shrubbery beds in the front yard adjacent to the house (0+06, 2 L to 6 L and 8 L to 12 L).

Concentrations of ^{232}Th in systematic surface soil samples ranged from 1.2 pCi/g (MJ35) to 33 pCi/g (MJ39). Biased surface soil samples taken from the contaminated area on the western portion of the property had ^{232}Th concentrations of 99 pCi/g (MJB6) and 480 pCi/g (MBJ7). On the eastern side of the back yard a biased surface soil sample (MJB8) contained a ^{232}Th concentration of 44 pCi/g.

Subsurface soil samples and augering. Results of analyses of soil samples taken during augering of holes are presented in Table 5, and locations of auger holes are shown in Fig. 6.

A summary of the results of gamma-ray logging of auger holes is presented in Table 6. The gamma-ray activity as a function of depth is graphically depicted in Appendix II. Those auger holes placed towards the center of the back yard (MJC4, MJC5, MJC12, MJC13, and MJC15-MJC18) indicated that little, if any, contamination is present outside the 3-m strips along the east and west borders of the back yard. Generally, concentrations of contamination within these strips are greatest at the 30-cm depth.

The contaminated material located on the east border of the property is confined to the back yard and extends from the surface to 0.3-0.6 m in depth. On the west border of the property, contamination extends the entire length of the property from the property line up to the house. In the back yard, the greatest depth of contamination is from the surface to 1.2 m in depth. The contamination shallows toward the south edge (rear) of the property, where it extends only from the surface to 0.8 m. Next to the house, the contaminated material extends from the surface to the floor level of the basement (about 1.8 m at the northwest corner of the basement).

Indoor survey results

Alpha, beta-gamma, and gamma-ray measurements. Schematic diagrams of the interior of the house at 468 Davison Avenue are shown in Figs. 7 through 9. The results of the indoor measurements are presented in Table 7 and these figures.

Transferable long-lived alpha and beta-gamma activity on room surfaces was at background levels at all locations in the house. Direct alpha activity on the surface of walls and floors was in the normal background range on the first and second levels of the house. In the basement, only the garage had alpha levels slightly above background.

Beta-gamma dose rate measurements were within background levels at all loations in the house with the exception of the garage; where slightly elevated levels were observed (0.04 mrad/h).

External gamma-ray exposure rates inside the house were all elevated above background. Gamma-ray exposure rates at 1 m ranged from 11 to 22 μR/h, and averaged 15 μR/h. In the garage in the basement, the source of the increased gamma radiation was associated with the west wall (see shading in Fig. 9). It is believed that no contaminated material is located beneath the floor of the garage, however, contamination is present down to the floor level on the outside of the west wall and possibly the very corner of the north wall in the garage. All other elevated radiation levels were related to the radiation arising from outdoor contamination. Indoor external gamma-ray measurements were highest at the west and south sides of the house.

Radon and radon daughter sampling. Preliminary radon and radon daughter measurements were made in the basement and upstairs area of the house to determine the approximate magnitude of this exposure pathway. These measurements are indicative of radon levels only over the sampling period and do not represent annual averages. Further sampling would be required to determine the levels in the house for comparison with applicable guidelines.

Results of the short-term radon and radon daughter measurements inside the house are presented in Table 8. Radon-222 concentration in air was measured in the basement and on the first level at 8.9 pCi/L and 3.8 pCi/L, respectively. Both these values exceed the NRC guideline of 3 pCi/L (Table 1). Radon daughter concentrations in air in the basement (0.06 WL and 0.052 WL) were about a factor of three higher than the first level radon daughter concentration (0.019 WL). All radon daughter concentrations measured at 468 Davison exceeded the levels at which remedial action is indicated (Table 1).

Additional, long-term radon and radon daughter monitoring were conducted at 468 Davison Avenue by the Mound Facility. Based on the results of seven weekly samples, the ^{222}Rn levels in the basement were found to range from 3.4 to 13 pCi/L, with an average of 7.3 pCi/L. Radon daughter concentrations in the basement ranged from 0.039 to 0.17 WL, with an average of 0.10 WL. Upstairs, measured ^{232}Rn concentrations ranged from 0.20 pCi/L to 0.48 pCi/L, with an average of 0.34 pCi/L.

SIGNIFICANCE OF FINDINGS

Summaries of the outdoor and indoor measurement results of the radiological survey conducted at 468 Davison Avenue are provided in Tables 9 and 10, respectively. These measurement results indicate that the property contains radioactive contamination primarily from the ^{232}Th decay chain, and to a lesser extent from the ^{238}U decay chain. This material is found in the following locations, as shown on Fig. 10 and summarized in Table 11: (1) a 3-m wide by 16-m length along the east property border in the back yard (area A on Fig. 10); (2) along the entire length of the west property border (37.5 m) to a width of 3 m (area B on Fig. 10); (3) the two shrubbery beds adjacent to the house on the north side of the house (area C on Fig. 10). The contaminated material extends from the ground surface, down to an average depth of 0.8 m. No contaminated material is believed to be present inside the house or beneath the floor or foundation of the house.

The total estimated volume of contaminated materials on the property is approximately 175 m^3. This estimate is based on an average depth of contamination of 0.5 m along the east side of the property (50 m^2 area), 1.3 m along the west side of the property (110 m^2 area), and 0.5 m in the shrubbery beds (8 m^2 area). Due to the limited number of core holes on which these estimates are based, the total volume may exceed this estimate by as much as 30%.

Outdoors on the property, the average external gamma-ray exposure rate at 1 m above the ground surface was below the NRC guideline for continuous exposure (10 CFR 20). All measured values of external gamma radiation outdoors were above the background level for the Maywood area. Concentrations of ^{232}Th in the surface soil of the yard exceeded background levels, ranging from a factor of 1.3 to 530.

Inside the house, the average external gamma-ray exposure rate at 1 m above the floor was well within NRC guidelines for continuous exposure (10 CFR 20). This elevated exposure rate is due to the presence of contaminated materials outdoors. On the west side of the house, the contaminated material is in the soil from the ground surface to the floor level of the basement. No radioactive material was found inside the house or beneath the basement floor. Elevated alpha activity, and radon/radon daughter concentrations were observed inside the house and were related to the contaminated soil adjacent to the house.

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 for radiation exposure from the type of contamination found on this property are: (1) direct radiation exposures; (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 III. The latter two pathways are not considered to be significant at this property, under present conditions of property use. These pathways could become significant if major changes in land use occur in the future. Based on conservative assumptions, preliminary estimates of the total risk of cancer from radiological conditions at this site are given in Appendix III. The estimated total increased risk due to radiation induced cancer for residents at 468 Davison Avenue was calculated to be 0.56%.[4] Thus, for a person living a lifetime at 468 Davison, the hypothetical average chance of dying from cancer would increase from 24.4% (the average for Bergan County, New Jersey in 1975[5]) to 24.96%.

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.

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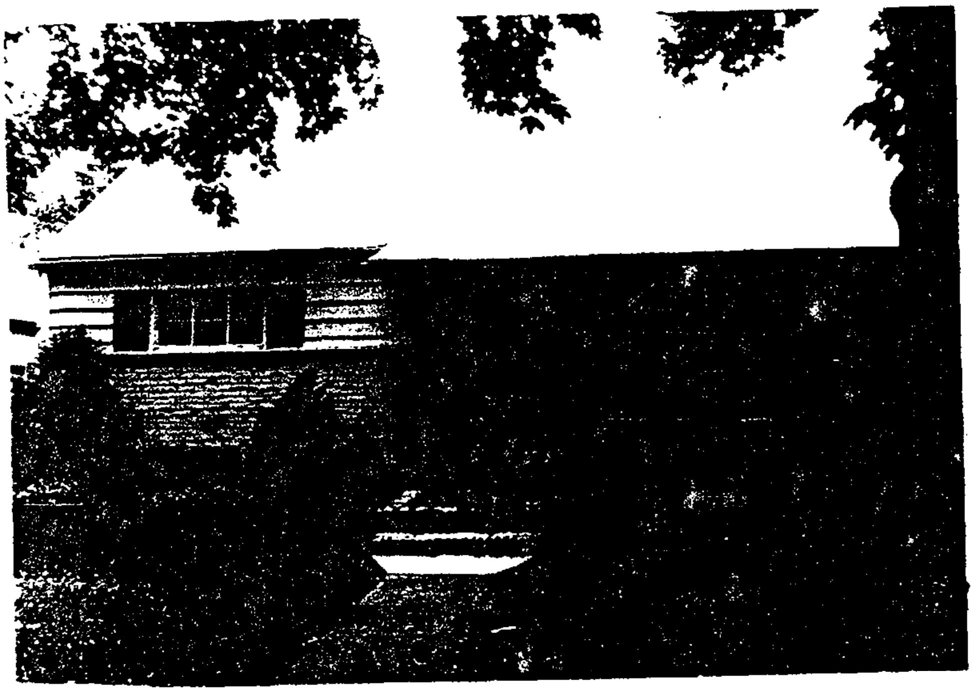

Fig. 1. Front view of property at 468 Davison Avenue

Fig. 2. Rear view of property at 468 Davison Avenue

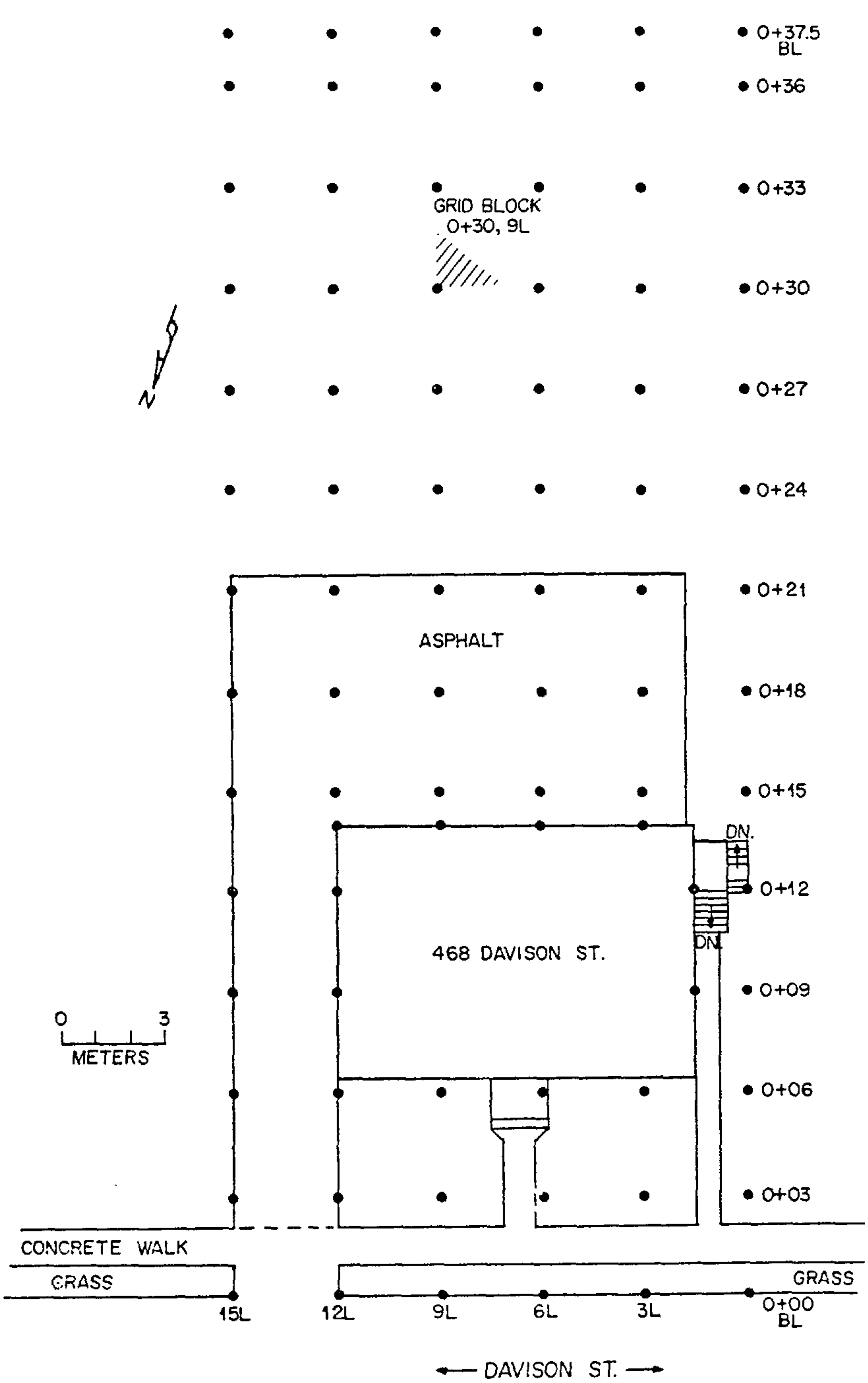

Fig. 3. Grid point and grid block locations at 468 Davison Avenue

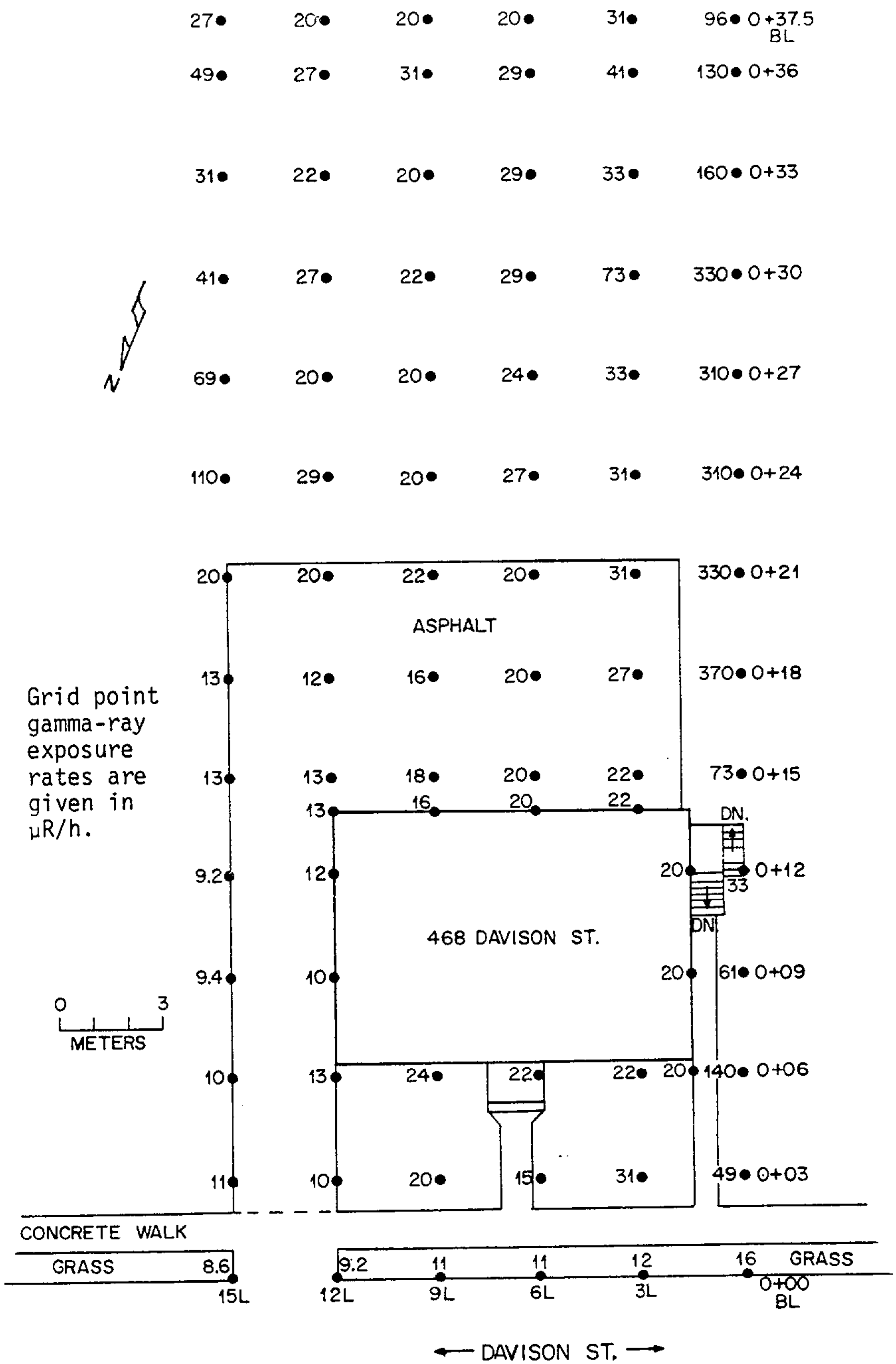

Fig. 4. Surface external gamma-ray measurement results at 468 Davison Avenue

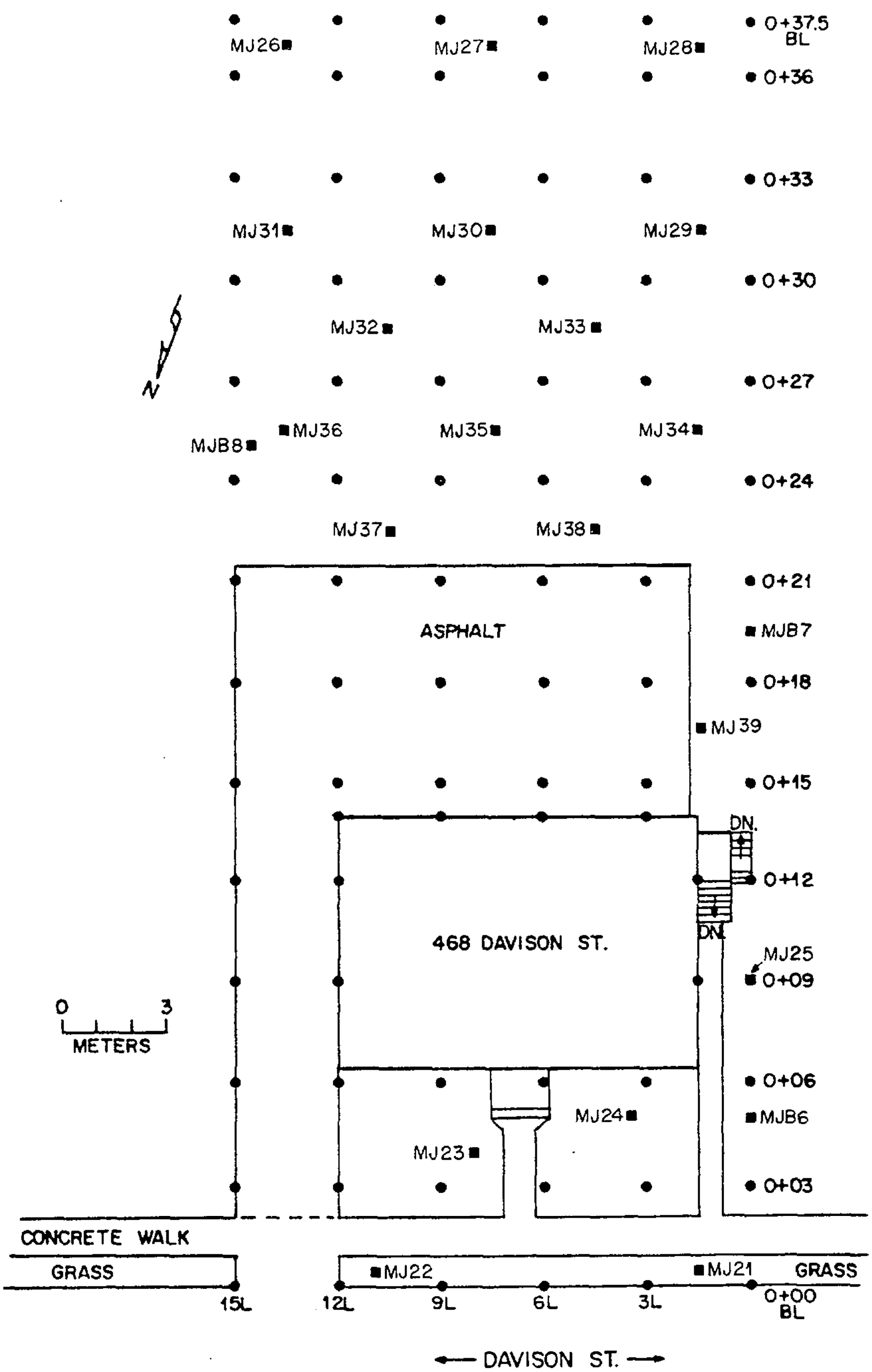

Fig. 5. Location of systematic (MJ) and biased (MJB) soil samples at 468 Davison Avenue

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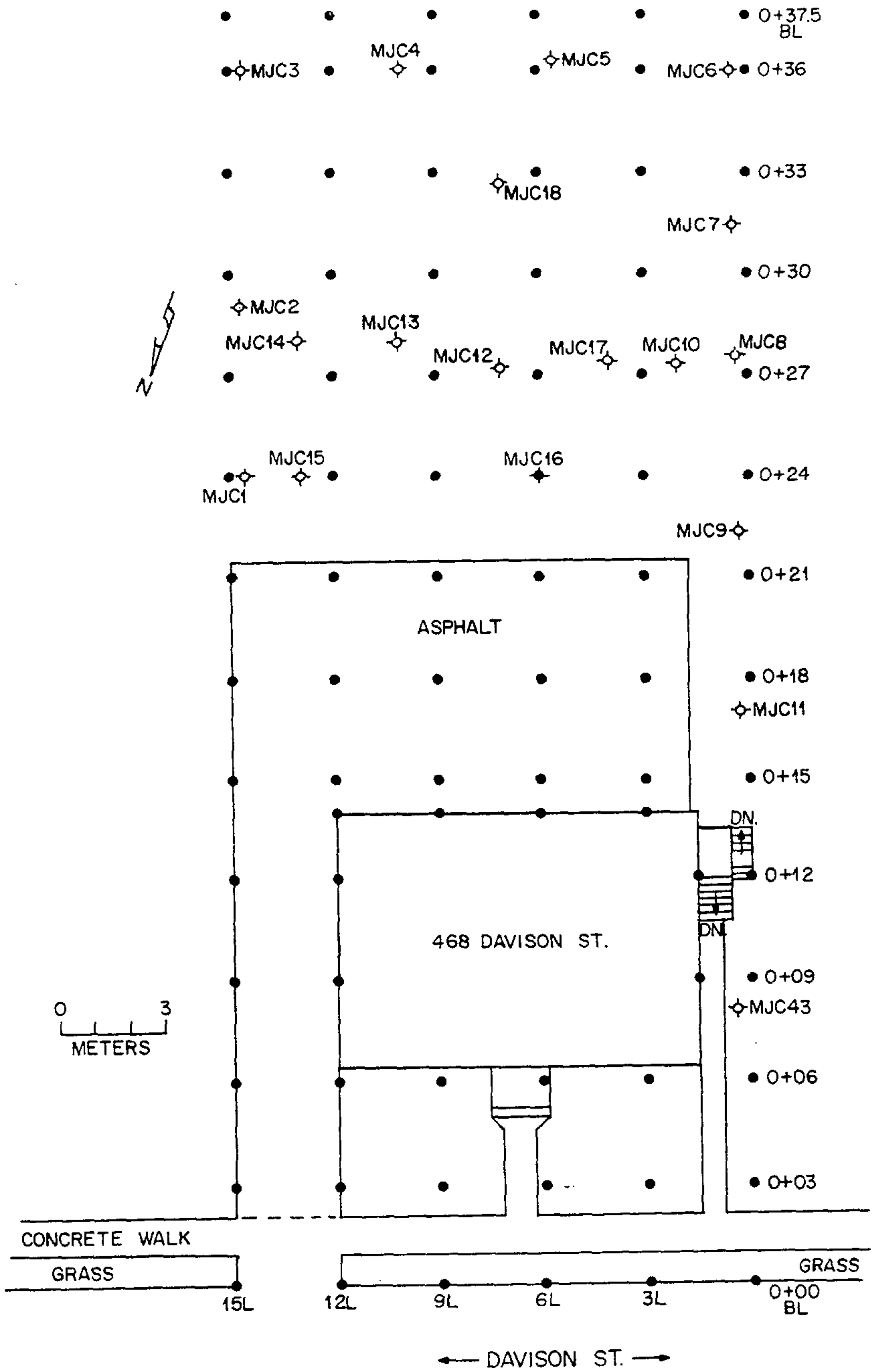

Fig. 6. Location of drill holes at 468 Davison Avenue

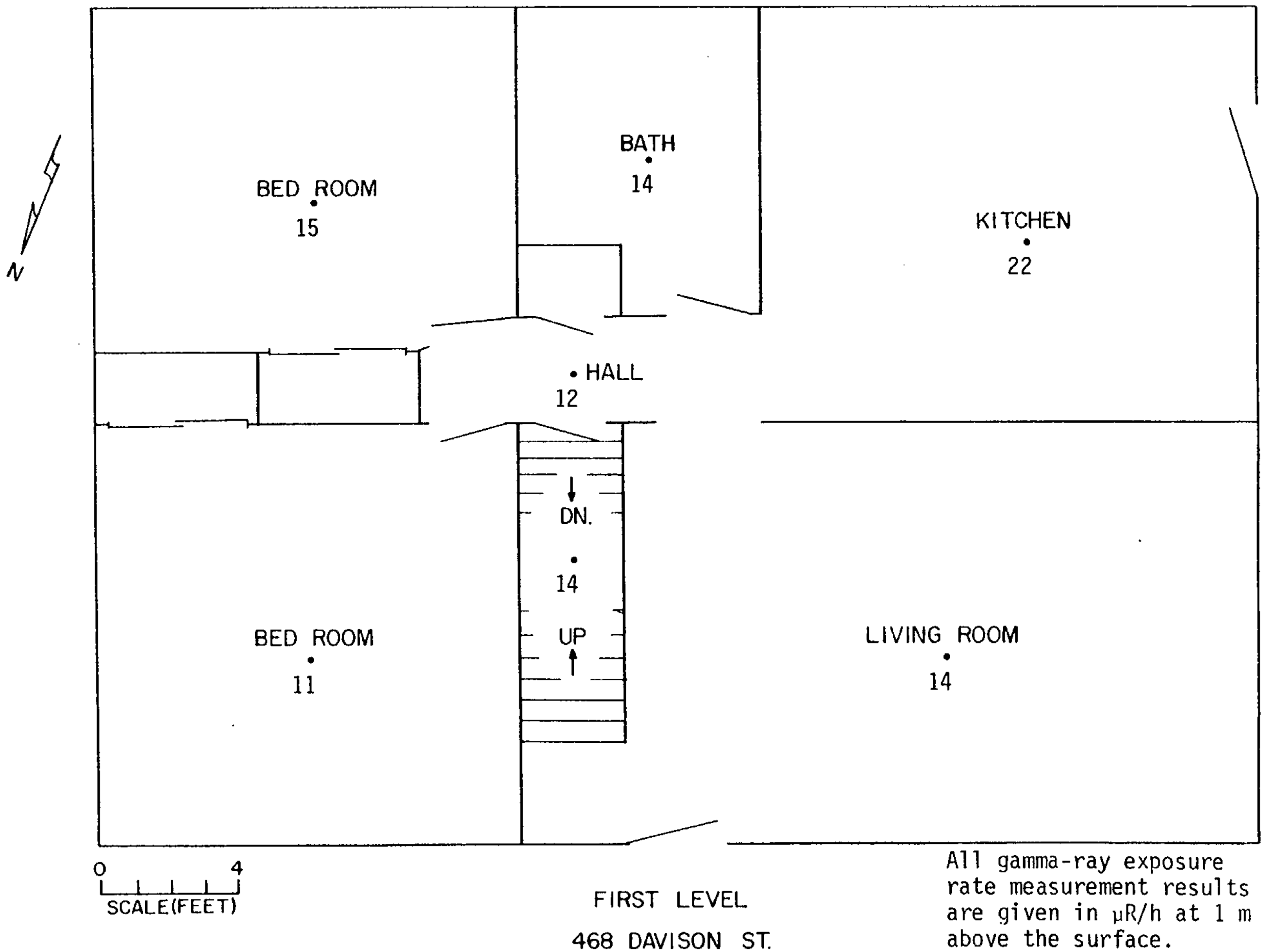

Fig. 7. Schematic of the first level floor plan at 468 Davison Avenue

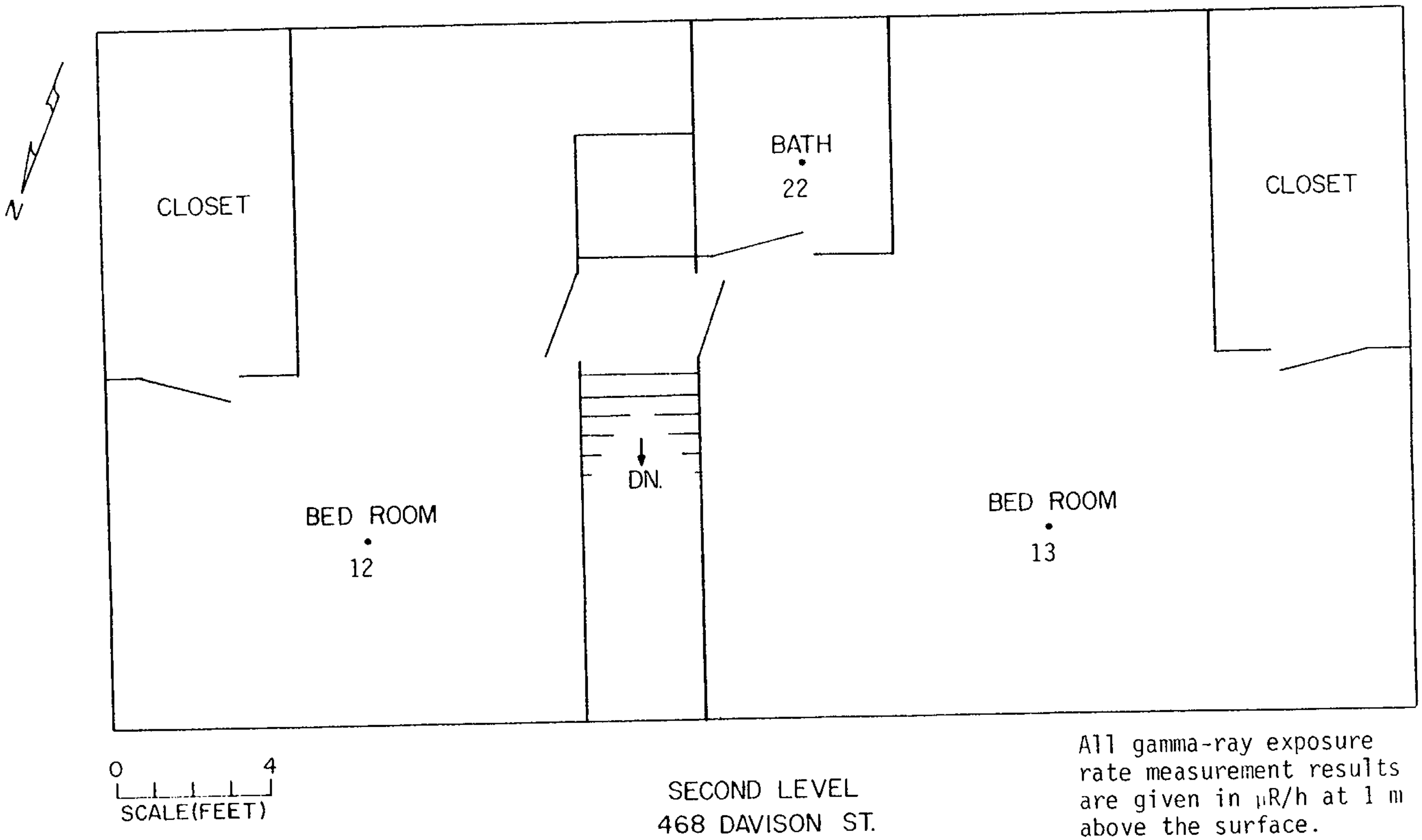

Fig. 8. Schematic of the second level floor plan at 468 Davison Avenue showing external gamma-ray measurement results

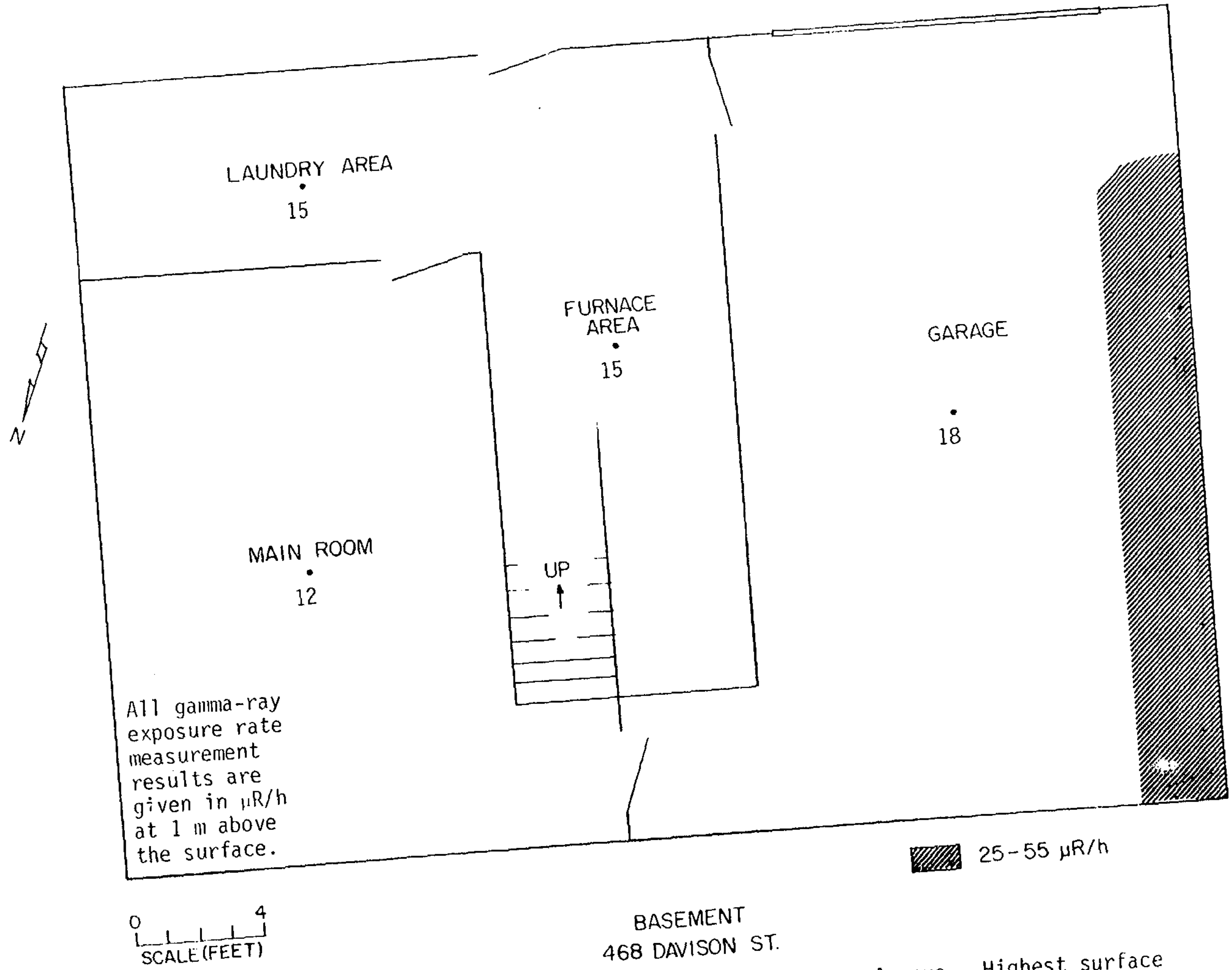

Fig. 9. Schematic of the basement floor plan at 468 Davison Avenue. Highest surface external gamma-ray levels are shaded

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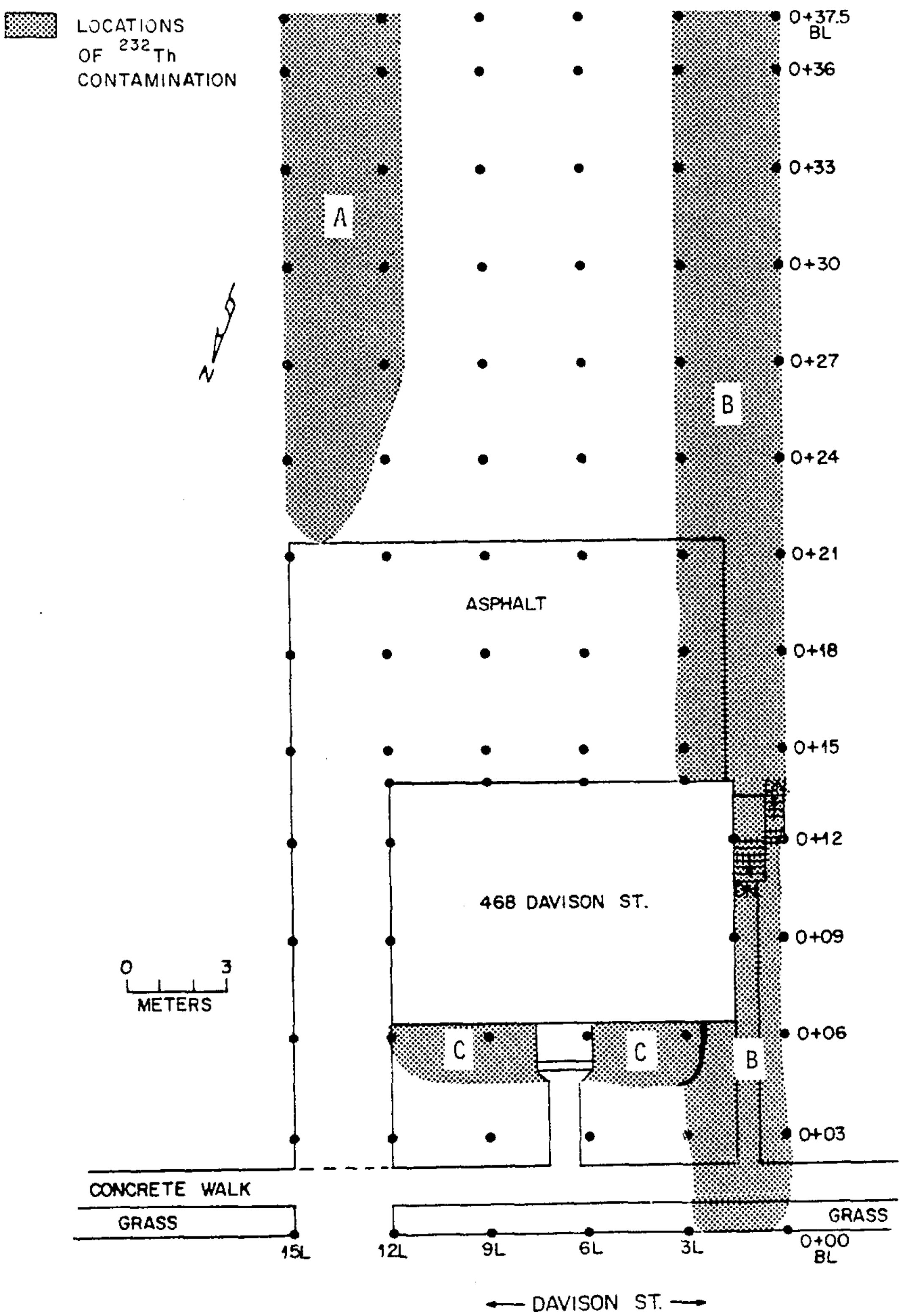

Fig. 10. Estimated extent of contaminated areas at 468 Davison.

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 468 Davison Avenue

Grid[a] location	Grid point measurements[b]			Grid block measurements[c]		
	Gamma exposure at 1 m (μR/h)	Gamma exposure at the surface[d] (μR/h)	Beta-gamma dose rate at 1 cm above the surface[e] (mrad/h)	Maximum gamma exposure at 1 m[e] (μR/h)	Maximum gamma exposure at the surface (μR/h)	Beta-gamma dose rate at maximum 1 cm above the surface[e] (mrad/h)
0+00, BL	20	16	0.03			
0+03, BL	41	49	0.07			
0+06, BL	57	140	0.3			
0+09, BL	37	61	0.1			
0+12, BL	37	33	0.04			
0+15, BL	86	73	0.06			
0+18, BL	160	370	0.9			
0+21, BL	200	330	0.6			
0+24, BL	160	310	0.5			
0+27, BL	160	310	0.5			
0+30, BL	200	330	0.5			
0+33, BL	180	160	0.5			
0+36, BL	140	130	0.4			
0+37.5, BL	120	96	0.2			
0+06, 1.5L	33	20	0.03	55	160	
0+09, 1.5L	20	20	0.03	41	92	
0+12, 1.5L	31	20	0.02	61	180	
0+00, 3L	11	12	0.03	37	53	
0+03, 3L	24	31	0.06	59	180	
0+06, 3L	20	22	0.03			
0+14, 3L	22	22	0.03			
0+15, 3L	37	22	0.04	180	470	
0+18, 3L	31	27	0.03	180	470	2
0+21, 3L	35	31	0.03	160	310	0.8
0+24, 3L	33	31	0.03	180	390	1
0+27, 3L	41	33	0.03	200	390	1
0+30, 3L	53	73	0.08	180	390	0.8
0+33, 3L	53	33	0.03	170	220	0.6
0+36, 3L	57	41	0.05		180	
0+37.5, 3L	45	31	0.03			
0+00, 6L	9	11	0.02	24	35	
0+03, 6L	14	15	0.03	18	33	
0+06, 6L	12	22	0.02			
0+14, 6L	22	20	0.02		20	
0+15, 6L	22	20	0.03		24	
0+18, 6L	27	20	0.03		27	
0+21, 6L	22	20	0.03	31	41	

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Table 3. (continued)

Grid[a] location	Grid point measurements[b]: Gamma exposure at 1 m (μR/h)	Grid point measurements[b]: Gamma exposure at the surface[d] (μR/h)	Grid point measurements[b]: Beta-gamma dose rate at 1 cm above the surface[e] (mrad/h)	Grid block measurements[c]: Maximum gamma exposure at 1 m[e] (μR/h)	Grid block measurements[c]: Maximum gamma exposure at the surface (μR/h)	Grid block measurements[c]: Beta-gamma dose rate at maximum 1 cm above the surface[e] (mrad/h)
0+24, 6L	27	27	0.03		33	
0+27, 6L	29	24	0.03	57	61	
0+30, 6L	31	29	0.04	51	57	0.1
0+33, 6L	24	29	0.03	45	55	
0+36, 6L	27	29	0.03	37	55	
0+37.5, 6L	31	20	0.02			
0+00, 9L	10	11	0.02		14	
0+03, 9L	13	20	0.03		24	
0+06, 9L	13	24	0.03			
0+14, 9L	18	16	0.02		16	
0+15, 9L	16	18	0.02	20	20	
0+18, 9L	20	16	0.03		16	
0+21, 9L	20	22	0.03	20	41	
0+24, 9L	22	20	0.03		24	
0+27, 9L	20	20	0.03		24	
0+30, 9L	20	22	0.03		27	
0+33, 9L	20	20	0.03		29	
0+36, 9L	20	31	0.04	20	37	
0+37.5, 9L	22	20	0.02			
0+00, 12L	10	9.2	0.02		20	
0+03, 12L	10	10	0.02		24	
0+06, 12L	12	13	0.02			
0+09, 12L	8	10	0.02			
0+12, 12L	10	12	0.03			
0+15, 12L	15	13	0.02		15	
0+18, 12L	15	12	0.03	20	29	
0+21, 12L	24	11	0.04	22	31	
0+24, 12L	31	29	0.03		20	
0+27, 12L	27	20	0.03		20	
0+30, 12L	27	27	0.04		20	
0+33, 12L	22	22	0.03	22	31	
0+36, 12L	24	27	0.05		20	
0+3.7, 12L	22	20	0.05			
0+00, 15L	9	9.6	0.03		9.2	
0+03, 15L	10	11	0.02		10	
0+06, 15L	9	10	0.03		10	

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[d] (μR/h)	Beta-gamma dose rate at 1 cm above the surface[e] (mrad/h)	Maximum gamma exposure at 1 m[e] (μR/h)	Maximum gamma exposure at the surface (μR/h)	Beta-gamma dose rate at maximum 1 cm above the surface[e] (mrad/h)
0+09, 15L	10	9.4	0.02		11	
0+12, 15L	11	9.2	0.03		13	
0+15, 15L	14	13	0.03		14	
0+18, 15L	15	13	0.02		16	
0+21, 15L	20	20	0.02	49	120	0.1
0+24, 15L	45	110	0.2	45	180	
0+27, 15R	35	69	0.1	43	100	
0+30, 15R	31	41	0.04	29	57	
0+33, 15R	27	31	0.04	22	45	
0+36, 15R	27	49	0.08			0.08
0+37.5, 15R	27	27	0.03			

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

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

[c]Grid block measurements are obtained by gamma scanning of entire block.

[d]These values are shown in Fig. 4.

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

Table 4. Results of radionuclide analyses of surface soil samples from 468 Davison Avenue

Sample[a]	Location[b]	Radionuclide concentration (pCi/g)		
		^{232}Th[c]	^{238}U[d]	^{226}Ra[c]
MJ21	0+0.3, 1.5L	4.0 ± 0.05	1.2	1.3 - 0.04
MJ22	0+0.3, 11L	1.8 ± 0.008	0.77	0.9 ± 0.06
MJ23	0+04, 8L	2.5 ± 0.09	0.84	1.0 ± 0.05
MJ24	0+05, 3.5L	5.1 ± 0.08	1.0	1.8 ± 0.05
MJ25	0+09, BL	20 ± 4	1.7	4.0 ± 0.2
MJ26	0+36.5, 13.5L	30 ± 0.4	3.1	9.0 ± 0.2
MJ27	0+36.5, 7.5L	1.8 ± 0.04	0.61	0.6 ± 0.04
MJ28	0+36.5, 1.5L	8.3 ± 1	1.1	1.8 ± 0.07
MJ29	0+31.5, 1.5L	15 ± 2	1.7	3.5 ± 0.2
MJ30	0+31.5, 7.5L	4.4 ± 0.6	0.86	1.2 ± 0.06
MJ31	0+31.5, 13.5L	5.7 ± 0.1	1.4	1.4 ± 0.08
MJ32	0+28.5, 10.5L	1.6 ± 0.2	0.78	0.7 ± 0.2
MJ33	0+28.5, 4.5L	1.8 ± 0.08	0.63	0.7 ± 0.08
MJ34	0+25.5, 1.5L	4.6 ± 0.02	0.79	1.6 ± 0.1
MJ35	0+25.5, 7.5L	1.2 ± 0.03	0.54	0.6 ± 0.03
MJ36	0+25.5, 13.5L	10 ± 0.08	1.7	3.0 ± 0.2
MJ37	0+22.5, 10.5L	2.5 ± 0.08	0.73	0.9 ± 0.04
MJ38	0+22.5, 4.5L	1.8 ± 0.03	0.53	0.7 ± 0.02
MJ39	0+16.5, 1.5L	33 ± 4	2.9	8.5 ± 0.8
MJB6	0+05, BL	99 ± 10	4.9	12 ± 1
MJB7	0+19.5, BL	480 ± 100	26	120 ± 4
MJB8	0+25, 14.5L	44 ± 6	6.6	7.9 ± 0.2

[a]MJ is a systematic surface soil sample; MJB is a biased surface soil sample.

[b]Location is shown on Fig. 5.

[c]Indicated counting error is at the 95% confidence level.

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

Table 5. Results of radionuclide analyses of subsurface soil samples from 468 Davison Avenue

Sample	Location[a]	Depth (cm)	Radionuclide concentration (pCi/g)		
			^{232}Th[b]	^{238}U[c]	^{226}Ra[b]
MJC1A	0+24, 14.5L	0-15	160 ± 10	21	24 ± 2
MJC1B	0+24, 14.5L	15-30	28 ± 1	4.3	5.2 ± 0.2
MJC1C	0+24, 14.5L	30-61	8.0 ± 0.2	1.6	1.8 ± 0.07
MJC1D	0+24, 14.5L	61-76	3.5 ± 0.1	1.1	1.0 ± 0.04
MJC1E	0+24, 14.5L	76-91	6.3 ± 4	1.4	1.7 ± 0.1
MJC2A	0+29, 14.5L	0-30	22 ± 6	4.1	4.0 ± 0.6
MJC2B	0+29, 14.5L	30-51	6.3 ± 1	1.7	1.8 ± 0.06
MJC2C	0+29, 14.5L	51-71	1.8 ± 0.04	0.86	0.9 ± 0.02
MJC3A	0+36, 14.5L	0-30	9.8 ± 0.2	1.9	2.8 ± 0.1
MJC3B	0+36, 14.5L	30-61	1.4 ± 0.2	0.80	0.9 ± 3
MJC3C	0+36, 14.5L	61-91	2.7 ± 0.06	0.93	1.1 ± 0.04
MJC4A	0+36, 10L	0-30	2.0 ± 0.08	0.89	1.1 ± 0.06
MJC4C	0+36, 10L	61-91	0.9 ± 0.03	0.66	0.6 ± 0.03
MJC5A	0+36.2, 5.5L	0-30	1.8 ± 0.2	0.83	0.9 ± 0.04
MJC5B	0+36.2, 5.5L	30-61	1.0 ± 0.04	0.74	0.6 ± 0.05
MJC5C	0+36.2, 5.5L	61-91	1.0 ± 0.04	0.66	0.7 ± 0.04
MJC6A	0+36, 0.5L	0-30	54 ± 8	3.5	27 ± 2
MJC6B	0+36, 0.5L	30-61	6.6 ± 2	1.3	3.4 ± 0.1
MJC6C	0+36, 0.5L	61-91	4.7 ± 0.05	1.1	2.2 ± 0.04
MJC7A	0+31.5, 0.5L	0-30	420 ± 60	19	57 ± 2
MJC7B	0+31.5, 0.5L	30-61	18 ± 4	2.7	5.0 ± 0.6
MJC7C	0+31.5, 0.5L	61-91	9.7 ± 0.1	1.4	2.6 ± 0.2
MJC8A	0+27.5, 0.5L	0-30	460 ± 80	24	270 ± 8
MJC8B	0+27.5, 0.5L	30-61	6.2 ± 0.1	0.97	4.9 ± 0.1
MJC8C	0+27.5, 0.5L	61-91	7.4 ± 0.1	1.4	4.4 ± 1
MJC9A	0+22.5, 0.5L	0-30	150 ± 20	8.3	37 ± 0.6
MJC9B	0+22.5, 0.5L	30-61	2.3 ± 0.1	0.90	1.0 ± 0.2
MJC9C	0+22.5, 0.5L	61-91	59 ± 6	5.7	15 ± 0.6
MJC10A	0+27.5, 2L	0-30	3.4 ± 0.6	1.1	2.3 ± 0.1
MJC10B	0+27.5, 2L	30-61	5.1 ± 0.4	1.5	2.9 ± 0.2
MJC10C	0+27.5, 2L	61-91	1.4 ± 0.05	0.78	0.9 ± 0.08
MJC11A	0+17, 0.5L	0-30	210 ± 20	15	46 ± 4
MJC11B	0+17, 0.5L	30-61	18 ± 0.3	2.4	4.8 ± 0.2
MJC11C	0+17, 0.5L	61-91	14 ± 0.3	1.9	3.6 ± 0.2
MJC12A	0+27.2, 7L	0-30	1.4 ± 0.06	0.57	0.6 ± 0.06
MJC13A	0+28, 10L	0-30	1.7 ± 0.04	0.70	0.7 ± 0.04
MJC14A	0+28, 13L	0-30	6.0 ± 2	1.3	1.4 ± 2
MJC14B	0+28, 13L	30-61	1.5 ± 0.1	0.74	0.8 ± 0.08
MJC14C	0+28, 13L	61-91	1.1 ± 0.03	0.66	0.7 ± 0.03
MJC14D	0+28, 13L	91-97	3.1 ± 1	0.99	1.1 ± 0.06
MJC15B	0+24, 13L	30-61	1.3 ± 0.1	0.75	0.8 ± 0.1
MJC15C	0+24, 13L	61-91	0.8 ± 0.04	0.58	0.6 ± 0.06

[a]Location is shown on Fig. 6.

[b]Indicated counting error is at the 95% confidence level.

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

Table 6. Summary of gamma logging of auger holes at 468 Davison Avenue

Hole	Location[a]	Depth of hole (m)	Estimated extent of contaminated soil (m)	Depth of maximum contamination (m)	Measurement at depth of maximum contamination[b] (cpm)
MJC1	0+24, 14.5L	0.91	0-0.45	0.15	23,000
MJC2	0+29, 14.5L	0.61	0-0.30	0.15	7,500
MJC3	0+36, 14.5L	0.76	0-0.30	0.15	2,000
MJC4	0+36, 10L	1.22	c	c	c
MJC5	0+36.2, 5.5L	1.07	c	c	c
MJC6	0+36, 0.5L	1.07	0-0.80	0.30	26,000
MJC7	0+31.5, 0.5L	1.22	0-1.1	0.30	88,000
MJC8	0+27.5, 0.5L	1.07	0-1.2	0.30	120,000
MJC9	0+22.5, 0.5L	1.07	0-1.2	0.30	70,000
MJC10	0+27.5, 2L	0.91	0-0.61	0.46	1,900
MJC11	0+17, 0.5L	0.76	0-1.0	0.15	41,000
MJC12	0+27.2, 7L	1.07	c	c	c
MJC13	0+28, 10L	1.07	c	c	c
MJC14	0+23, 13L	1.07	0-0.61	0.46	2,700
MJC15	0+24, 13L	0.91	c	c	c
MJC16	0+24, 6L	0.91	c	c	c
MJC17	0+27.5, 4L	0.76	c	c	c
MJC18	0+32.5, 7L	0.76	c	c	c
MJC43	0+08, 0.5L	2.90	0-1.8	1.2	82,000

[a] Location of these auger holes is shown on Fig. 6.

[b] Background for this measurement is typically 1200 ± 700 counts per minute (cpm).

[c] No significant amount of contaminated soil measured.

Table 7. Indoor measurements at 468 Davison Avenue

Location[a]	External gamma exposure rate (μR/r)			Beta-gamma dose rate at 1 cm (mrad/h)		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	Location of maximum	Center of room	Location of gamma maximum	Average	Maximum	
Street level								
Living Room	14	27	West wall of room	0.03	b	<26	<26	b
Kitchen	22	33	Near sink	0.02	b	<26	<26	b
Southeast bedroom	15	16	General	0.02	b	<26	<26	<10/<20
Northeast bedroom	11	c	c	0.03	c	<26	<26	b
Bathroom	14	c	c	0.03	c	<26	<26	b
Hall	12	c	c	0.02	c	<26	<26	b
Stairs to 2nd floor	14	c	c	0.02	c	<26	39	b
Second floor								
Northeast bedroom	12	16	General	0.01	b	<26	<26	b
Southwest bedroom	13	c	c	0.03	c	<26	<26	b
Bathroom	22	16	General	0.02	b	<26	<26	b
Basement								
Main room	12	c	c	0.02	c	<26	<26	<10/<20
Laundry area	15	c	c	0.02	c	<26	39	<10/<20
Furnace area	15	c	c	0.03	c	<26	<26	b
Garage	18	60	West wall at floor[d]	0.04		39	52	b

[a]Location shown on Figs. 7 [illegible].

[b]Not measured.

[c]No distinct maximum found.

[d]See shading shown in Fig. 8.

Table 8. Radon and radon daughter measurements at 468 Davison Avenue

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	a	0.060	7.9	6.0	5.9	0.065	0.71
Basement	8.9	0.052	6.7	5.4	4.6	0.067	0.092
First level, living room	3.8	0.019	2.3	1.8	2.0	b	b

[a]Sample not taken.

[b]Below minimum detectable concentration (MDC).

Table 9. Summary of outdoor measurements and sample results at 468 Davison Avenue

Measurement or sample type	Number of measurements/ samples	Range	Mean	Biased readings[a]
Grid point measurements				
External gamma exposure rate at 1 m (μR/h)	84	8-200	38	
External gamma exposure rate at the surface (μR/h)	84	9-370	49	
Beta-gamma dose rate at 1 cm above the surface (mrad/h)	84	0.02-0.6	0.08	
Systematic surface soil samples				
Systematic soil samples (pCi/g)				
^{232}Th	19	1.2-33	8.2	
^{238}U	19	0.53-3.1	1.2	
^{226}Ra	19	0.6-9.0	2.3	
Biased measurements[a]				
Maximum external gamma-ray exposure at 1 m (μR/h)				200
Maximum external gamma-ray exposure at surface (μR/h)				470
Maximum concentration of ^{232}Th in surface soil (pCi/g)				480
Maximum concentration of ^{232}Th in subsurface soil (pCi/g)				460
Average depth of contaminated soil (m)				0.8

[a]Biased measurements included gamma-ray scanning of the entire yard, surface soil sampling at biased locations, and subsurface investigation through the use of augered holes.

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Table 10. Summary of indoor measurements and sample results at 468 Davison Avenue

Measurement or sample type	Number of measurements/ samples	Range	Mean	Biased readings[a]
Systematic room surveys				
External gamma-ray exposure rate at 1 m (μR/h)	14	11-22	15	
Beta-gamma dose rate at 1 cm (mrad/h)	14	0.2-0.04	0.02	
Direct alpha activity on surface (dpm/100 cm^2)	14	<26-52	<26	
Biased measurements[a]				
Maximum external gamma-ray exposure rate at surface (μR/h)				60
Maximum beta-gamma dose rate at 1 cm (mrad/h)				0.04
Maximum direct alpha activity on surface (dpm/100 cm^2)				52
Maximum ^{222}Rn concentration in air (pCi/ L)				8.9
Maximum ^{222}Rn daughter concentration in air (WL)				0.06

[a]Biased measurements included gamma-ray scanning of each room, measurement of the beta-gamma dose rates at locations of elevated gamma levels, random measurements of direct alpha and transferable alpha and beta-gamma activity on interior surface, and measurement of indoor radon and radon daughter concentrations.

Table 11. Summary of measurements results in contaminated areas at 468 Davison Avenue

Location[a]	Measurement type	Measurement result
Area A	Maximum external gamma-ray exposure rate at surface (μR/h)	180
	Range of ^{232}Th concentrations measured in surface soil (pCi/g)	5.7-44
	Maximum ^{232}Th concentration measured in subsurface soil (pCi/g)	160
	Estimated areal extent of contamination (m^2)	50
	Estimated average depth of contamination (m)	0.5
	Estimated total volume of contaminated material[b] (m^3)	25
Area B	Maximum external gamma-ray exposure rate at surface (μR/h)	470
	Range of ^{232}Th concentrations measured in surface soil (pCi/g)	4.0-480
	Maximum ^{232}Th concentration measured in subsurface soil (pCi/g)	420
	Estimated areal extent of contamination (m^2)	110
	Estimated average depth of contamination (m)	1.3
	Estimated total volume of contaminated material[b] (m^3)	145
Area C	Maximum external gamma-ray exposure rate at surface (μR/h)	33
	^{232}Th concentration measured in surface soil (pCi/g)	5.1
	Estimated areal extent of contamination (m^2)	8
	Estimated average depth of contamination (m)	0.5
	Estimated total volume of contaminated material[b] (m^3)	4

[a]For area designation see Fig. 10.

[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 precalibrated 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

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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,

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

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

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 6×10^{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 2σ or 95% confidence intervals), with a lower limit of detection of $\sim$40 ppb (10^5 pCi/g) for ^{238}U.

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

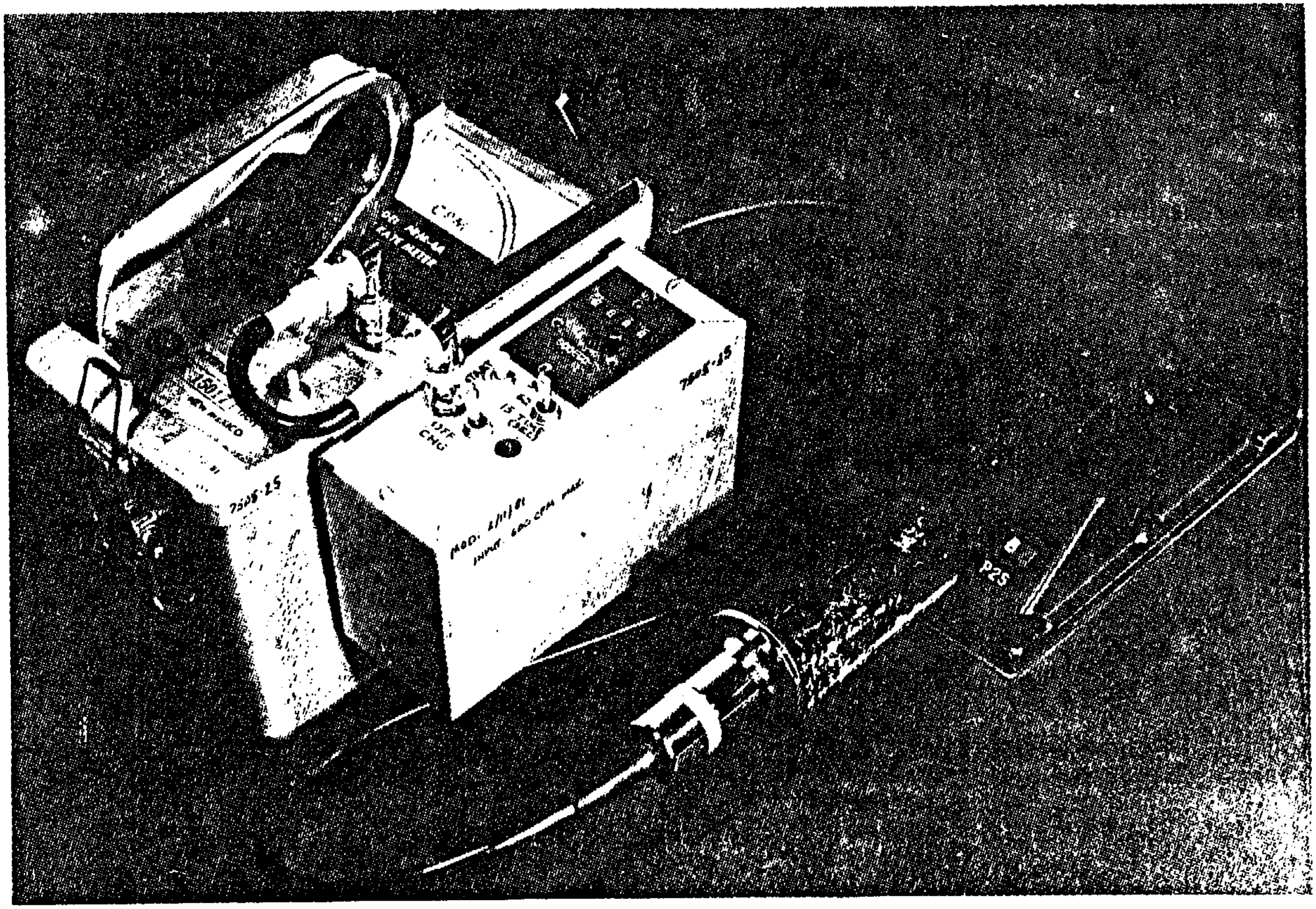

Fig. I-A. Alpha scintillation survey meter.

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ORNL-Photo 6704-76

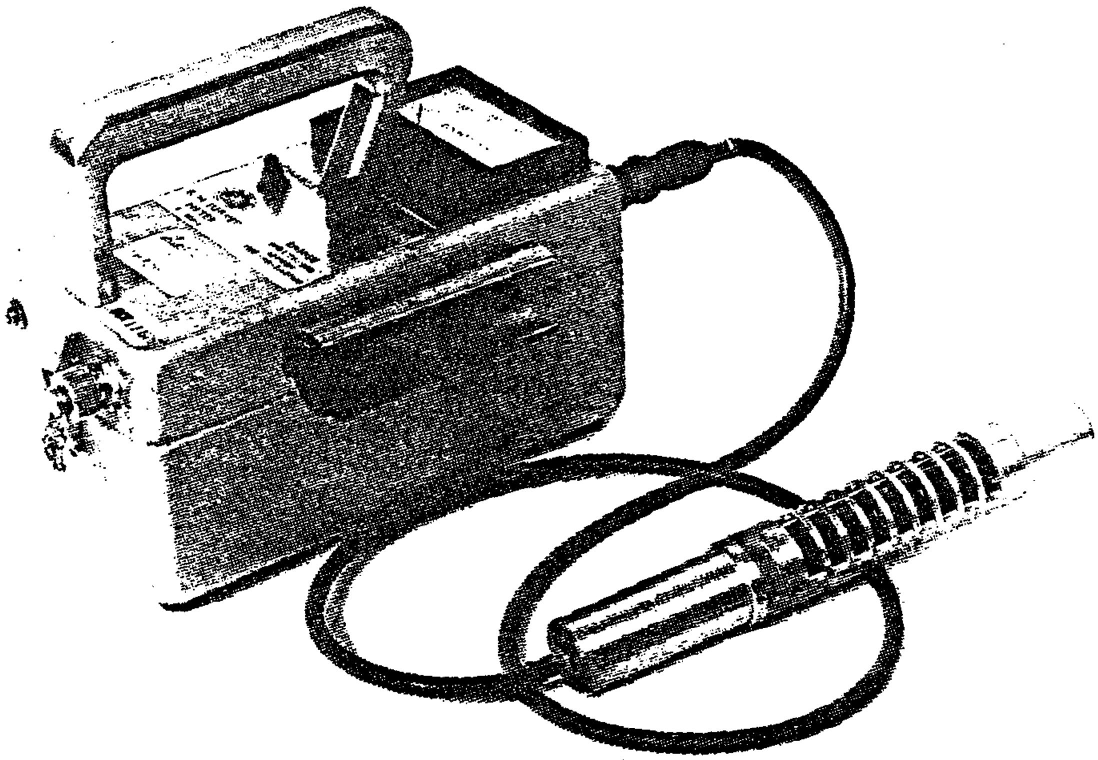

Fig. I-B. Geiger-Mueller survey meter.

ORNL-Photo 6710-76

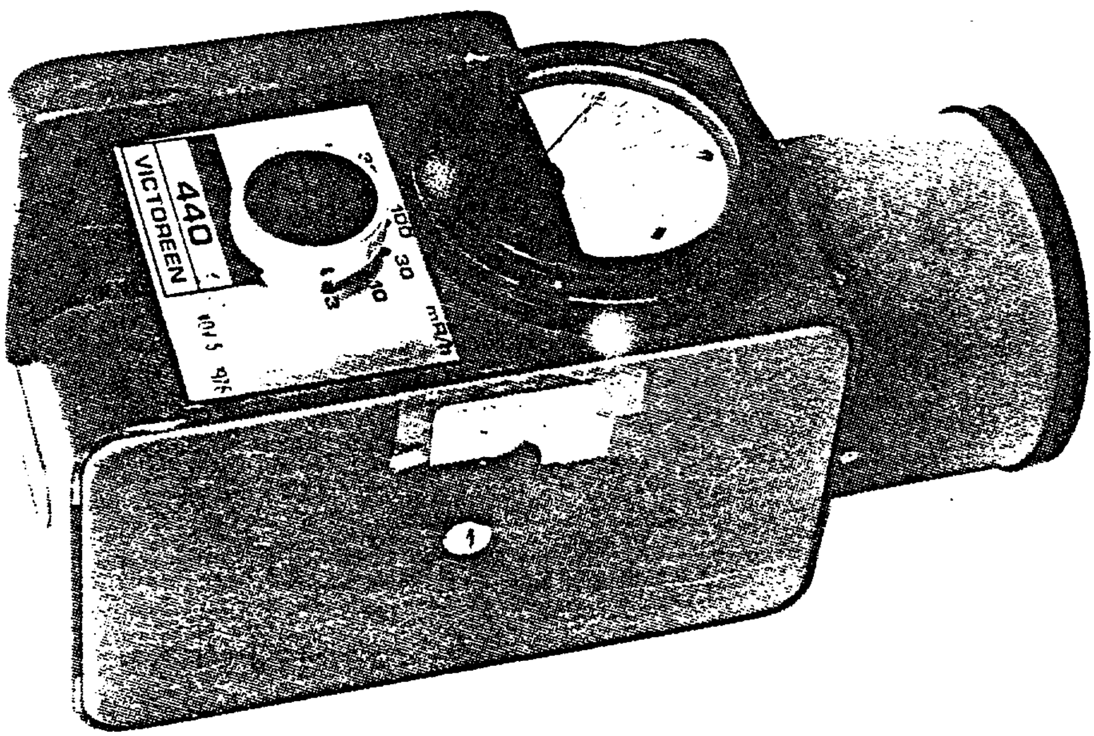

Fig. I-C. Victoreen Model 440 ionization chamber.

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ORNL-Photo 6707-76

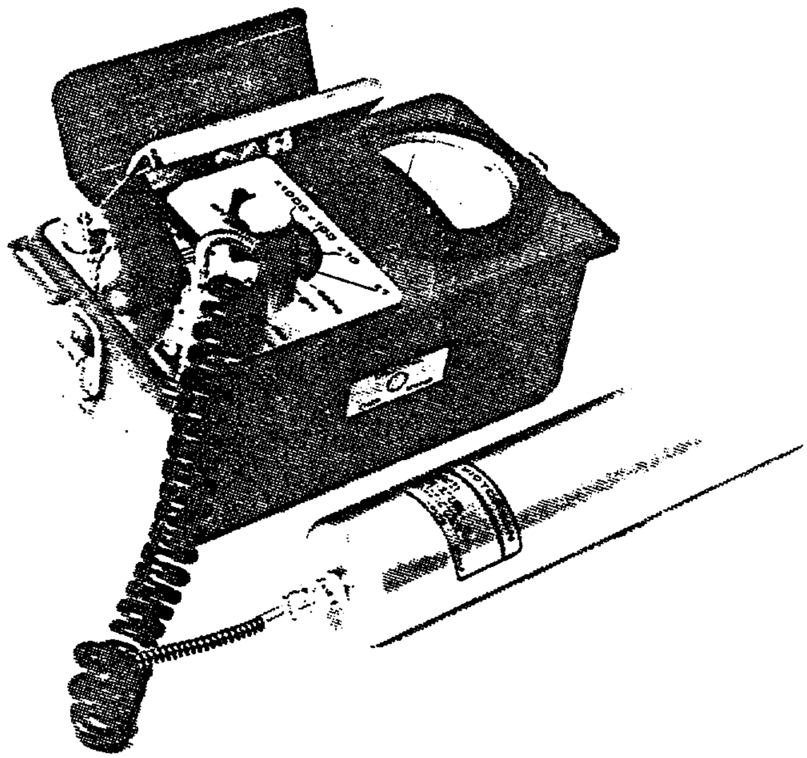

Fig. I-D. Gamma scintillation survey meter.

ORNL-Photo 4424-81

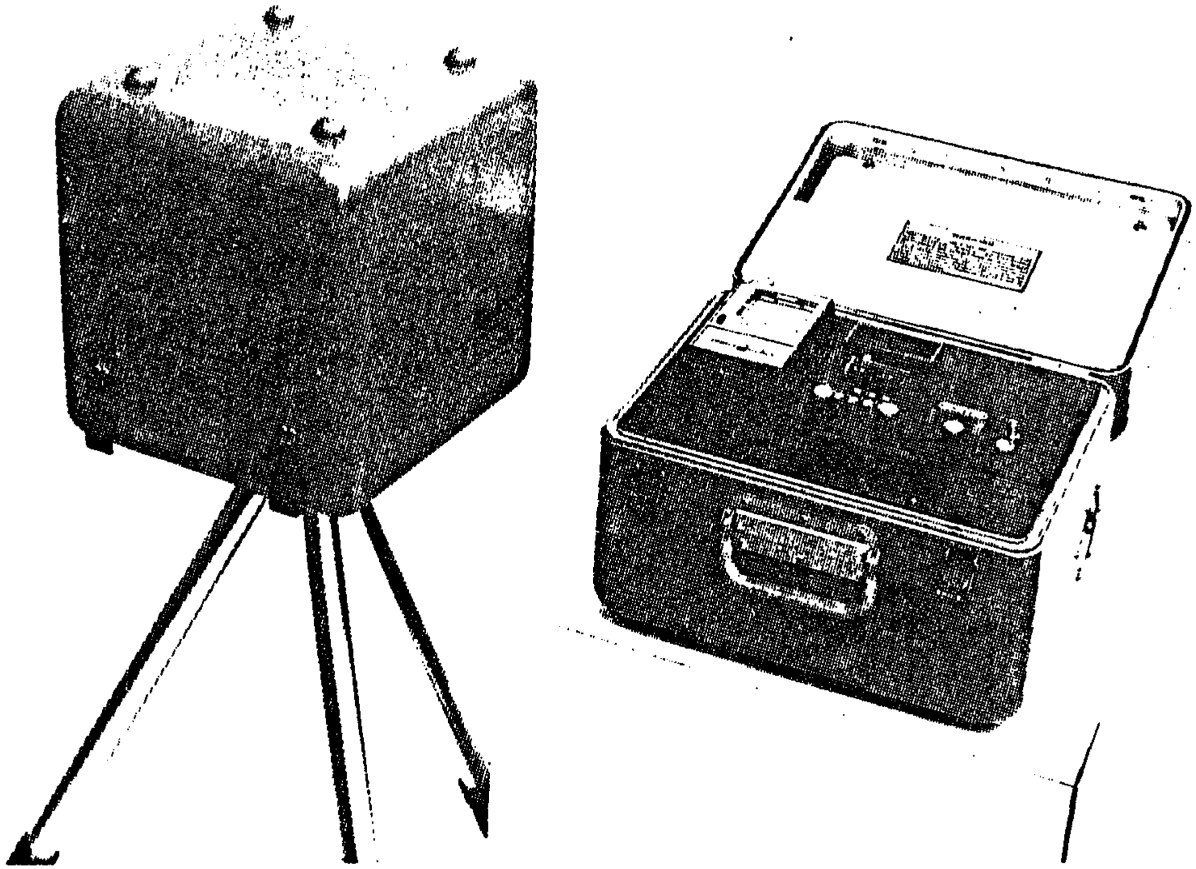

Fig. I-E. Pressurized Ion Chamber.

ORNL-Photo 1070-78

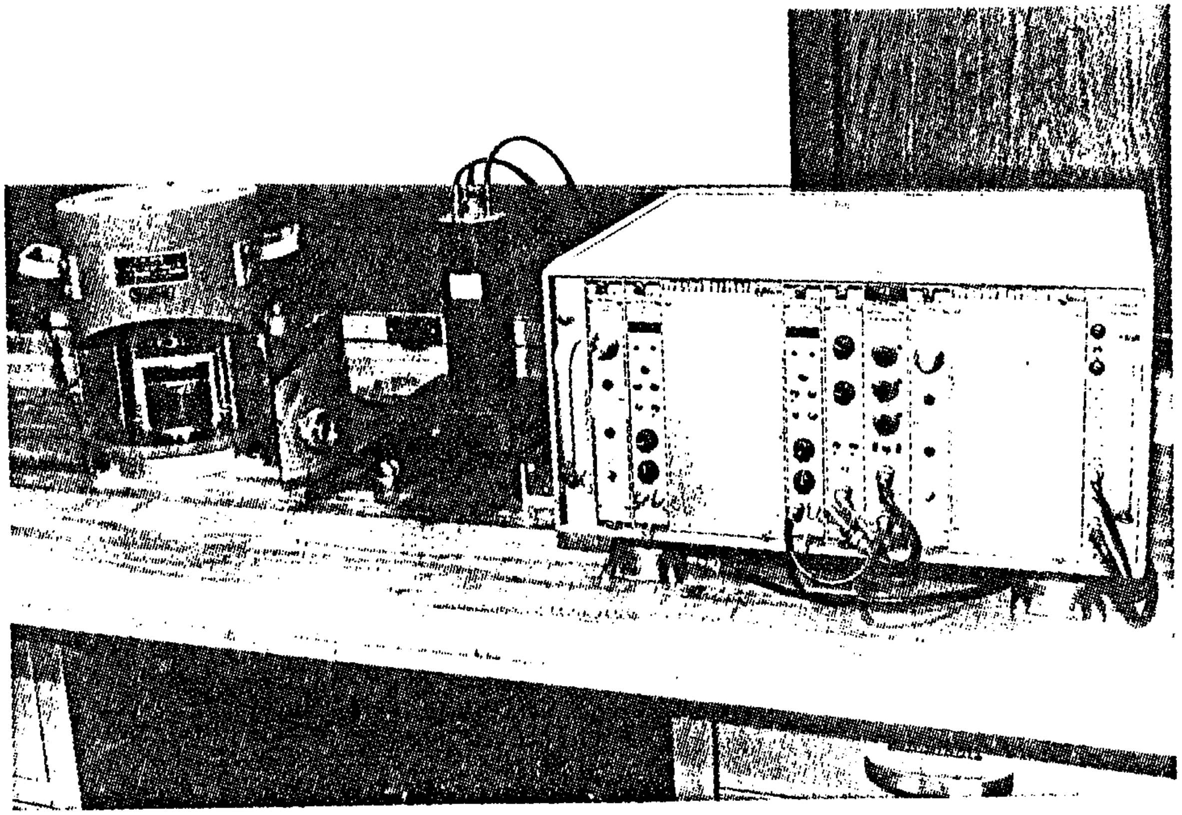

Fig. I-F. Smear counter and associated electronics. The beta counter is on the left and the alpha counter is on the right.

ORNL-Photo 2060-81

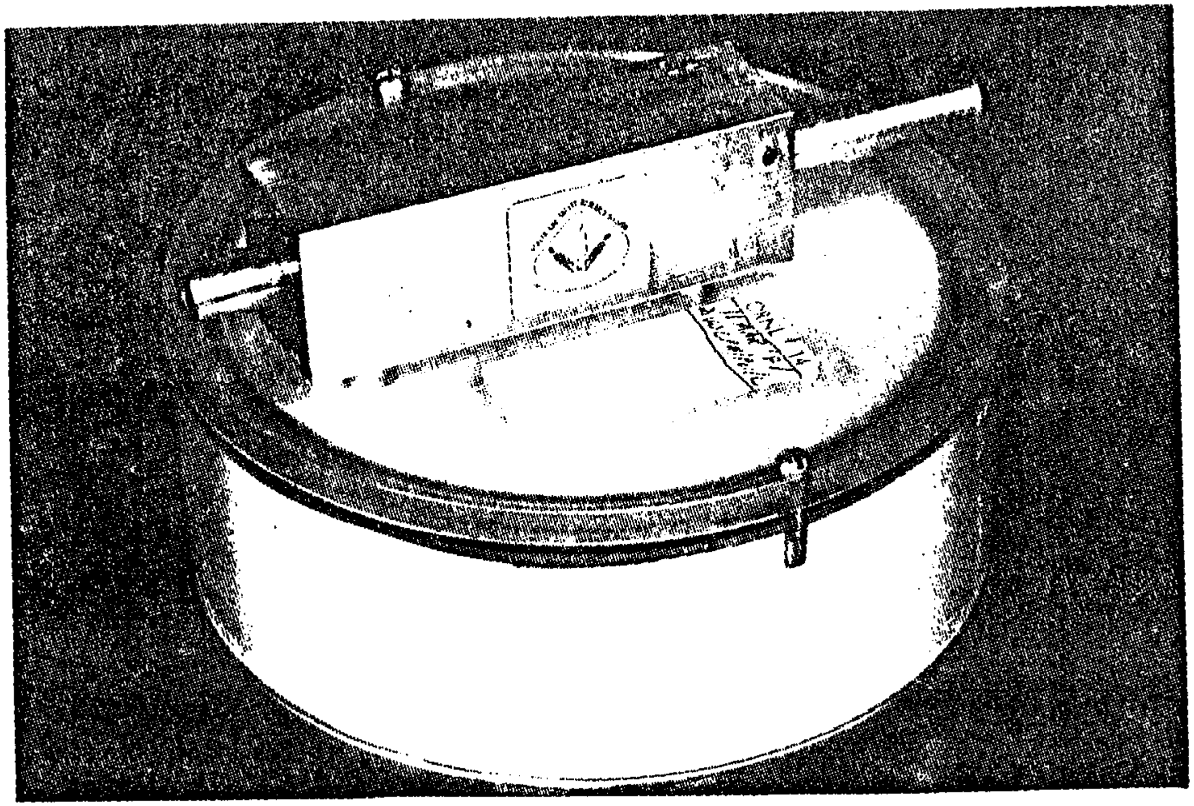

Fig. I-G. ORNL Cell.

ORNL-Photo 1081-78

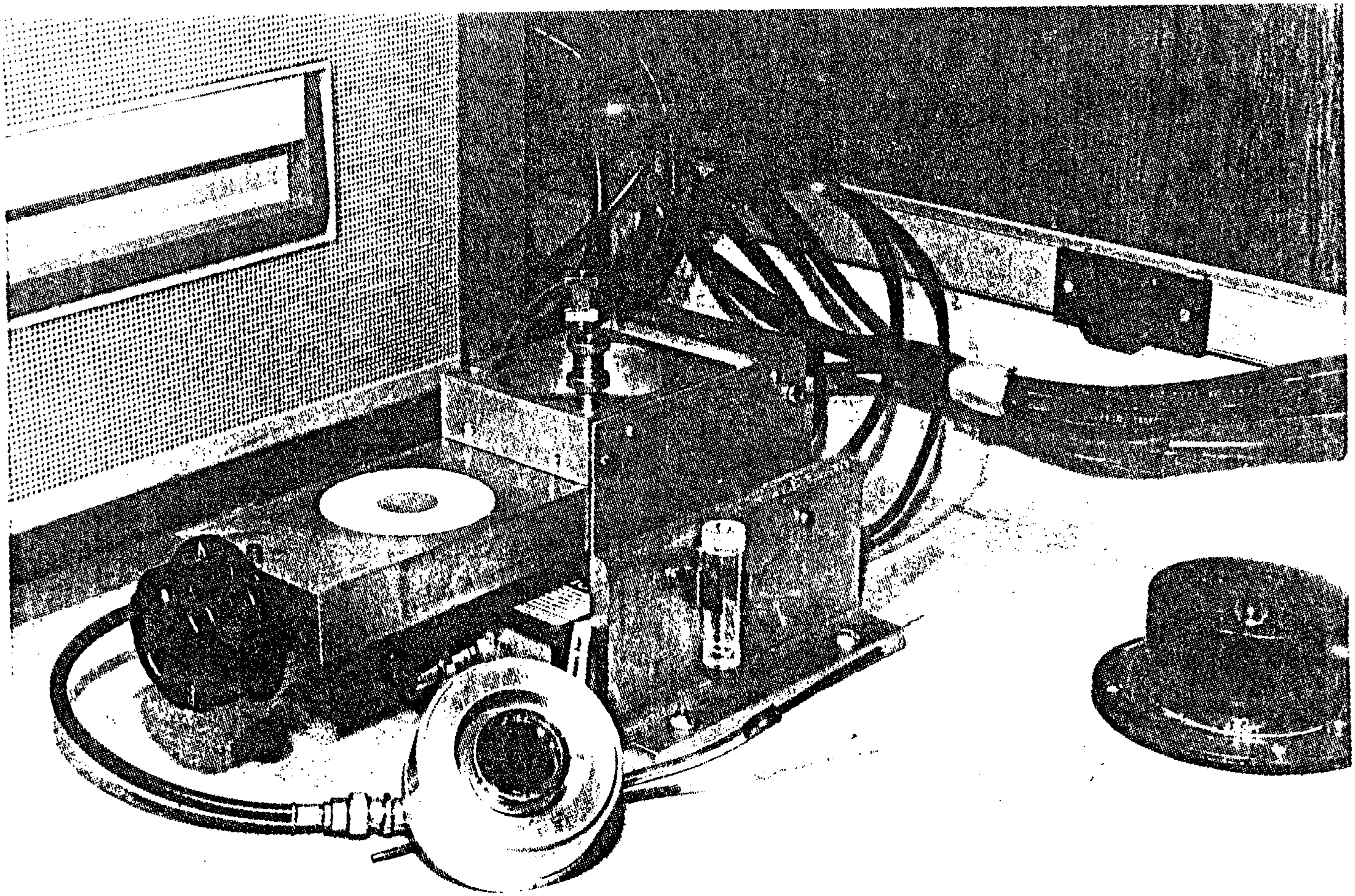

Fig. I-11. Alpha spectrometer used to assess radon daughter concentrations.

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ORNL-Photo 4348-81

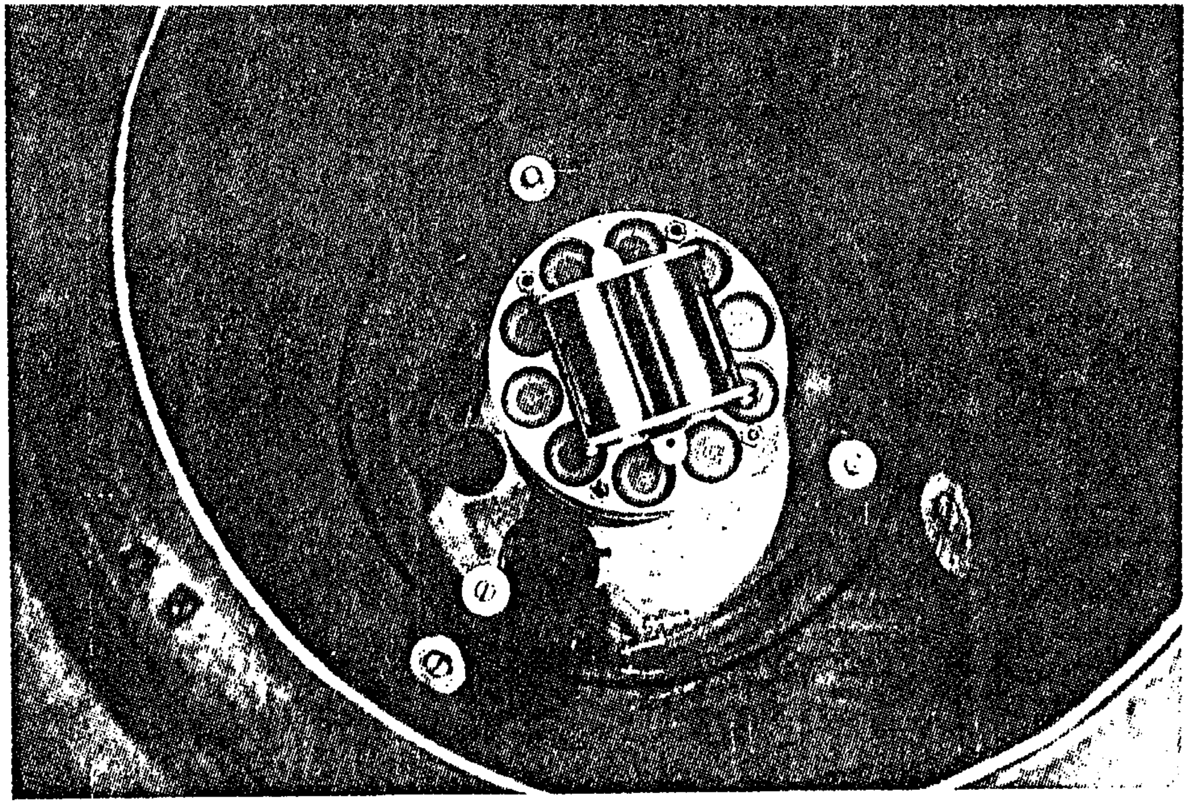

Fig. I-I. Soil sample holder on germainum-detector system.

ORNL-Photo 4351-81

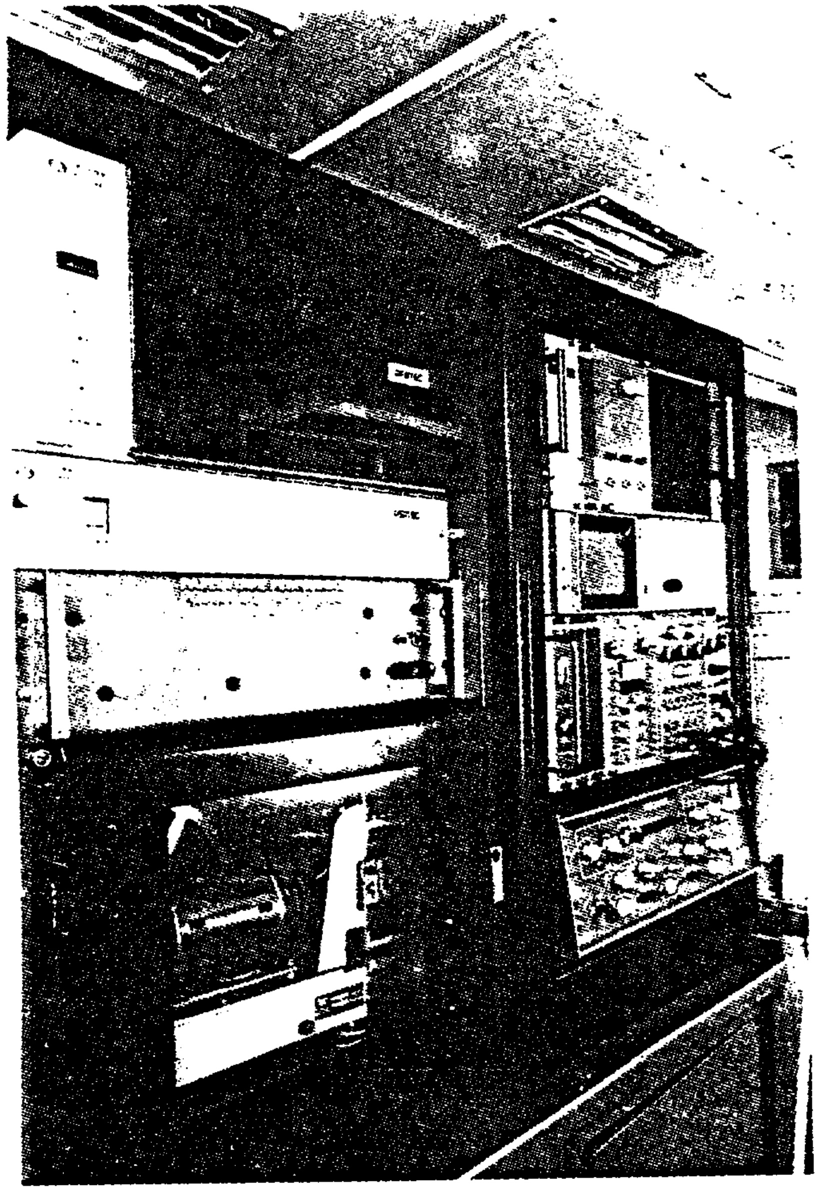

Fig. I-J. Multichannel analyzer with magnetic tape storage and vertical Ge(Li) detector system.

ORNL-Photo 4350-81

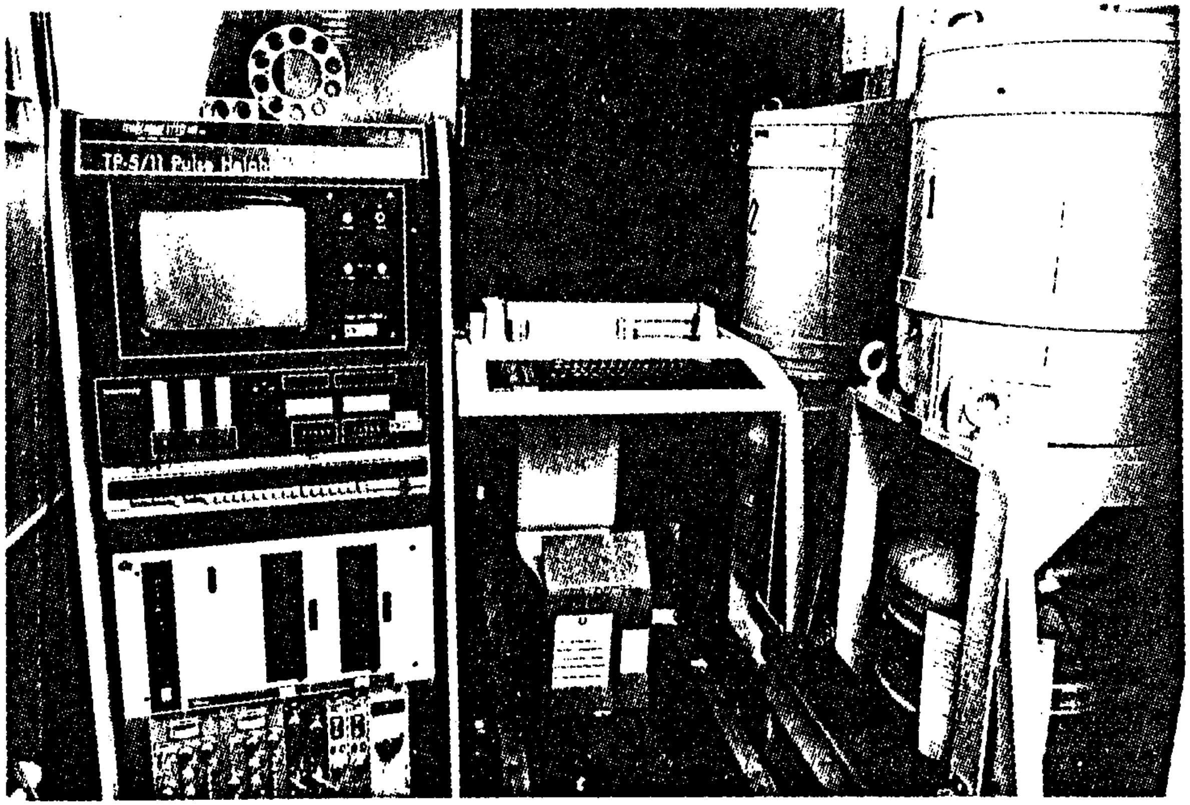

Fig. I-K. Multichannel analyzer with floppy disk storage and two vertical germanium systems.

APPENDIX II

GAMMA PROFILE GRAPHS OF CORE HOLES AT 468 DAVISON AVENUE IN MAYWOOD, NEW JERSEY

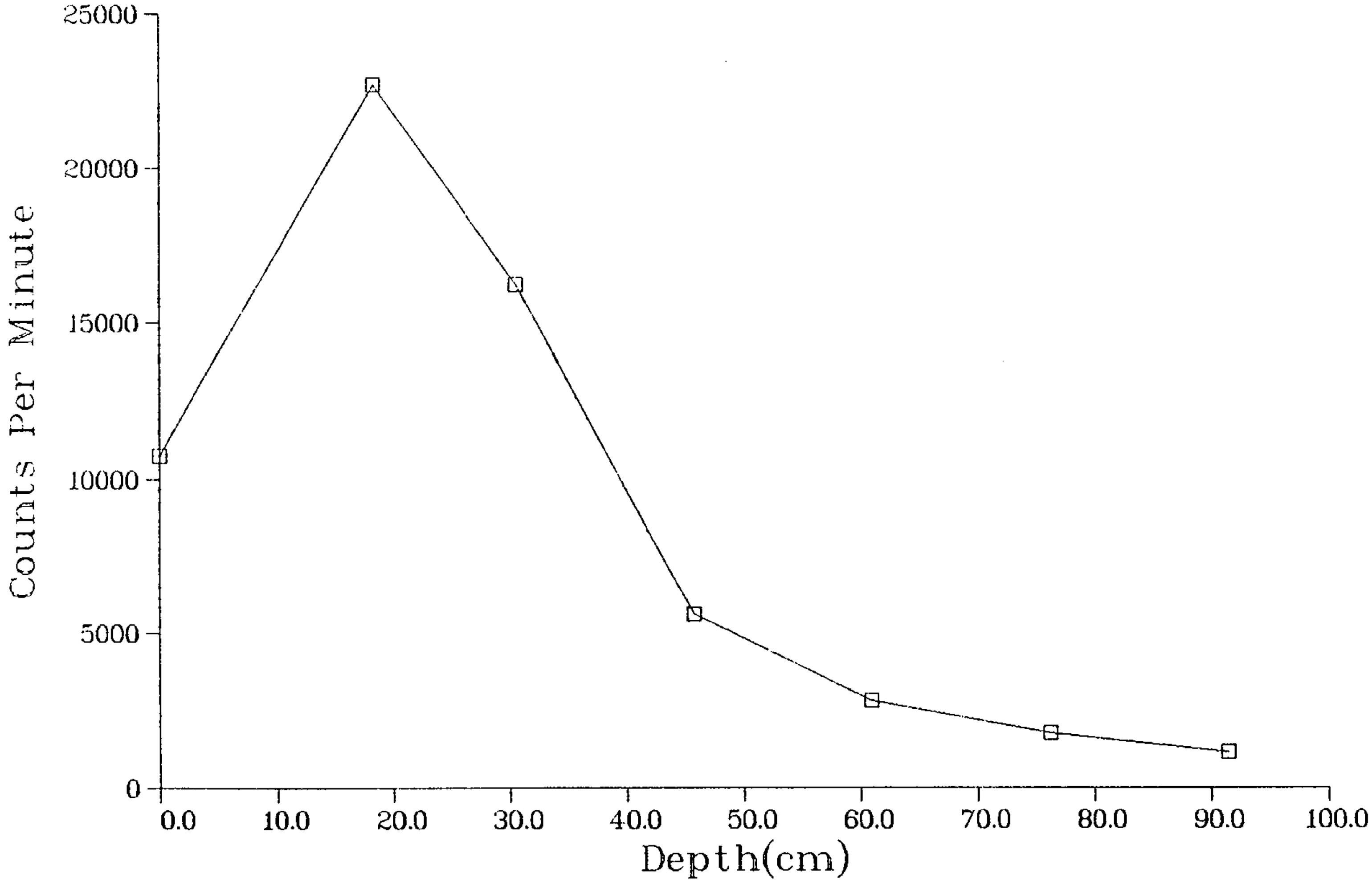

Fig. II–1. Gamma profile of core hole MJC1 (see Fig. 6)

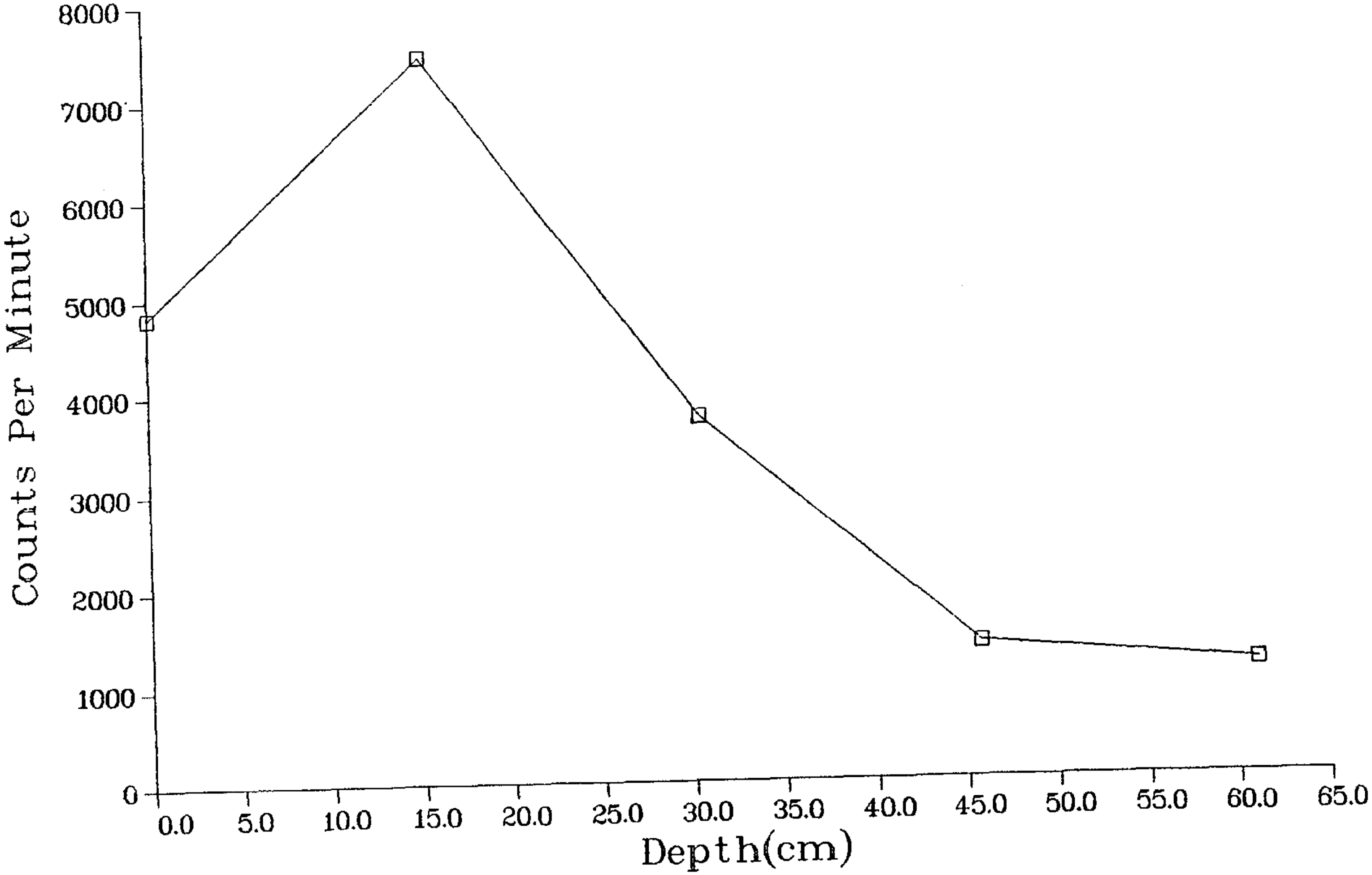

Fig. II–2. Gamma profile of core hole MJC2 (see Fig. 6)

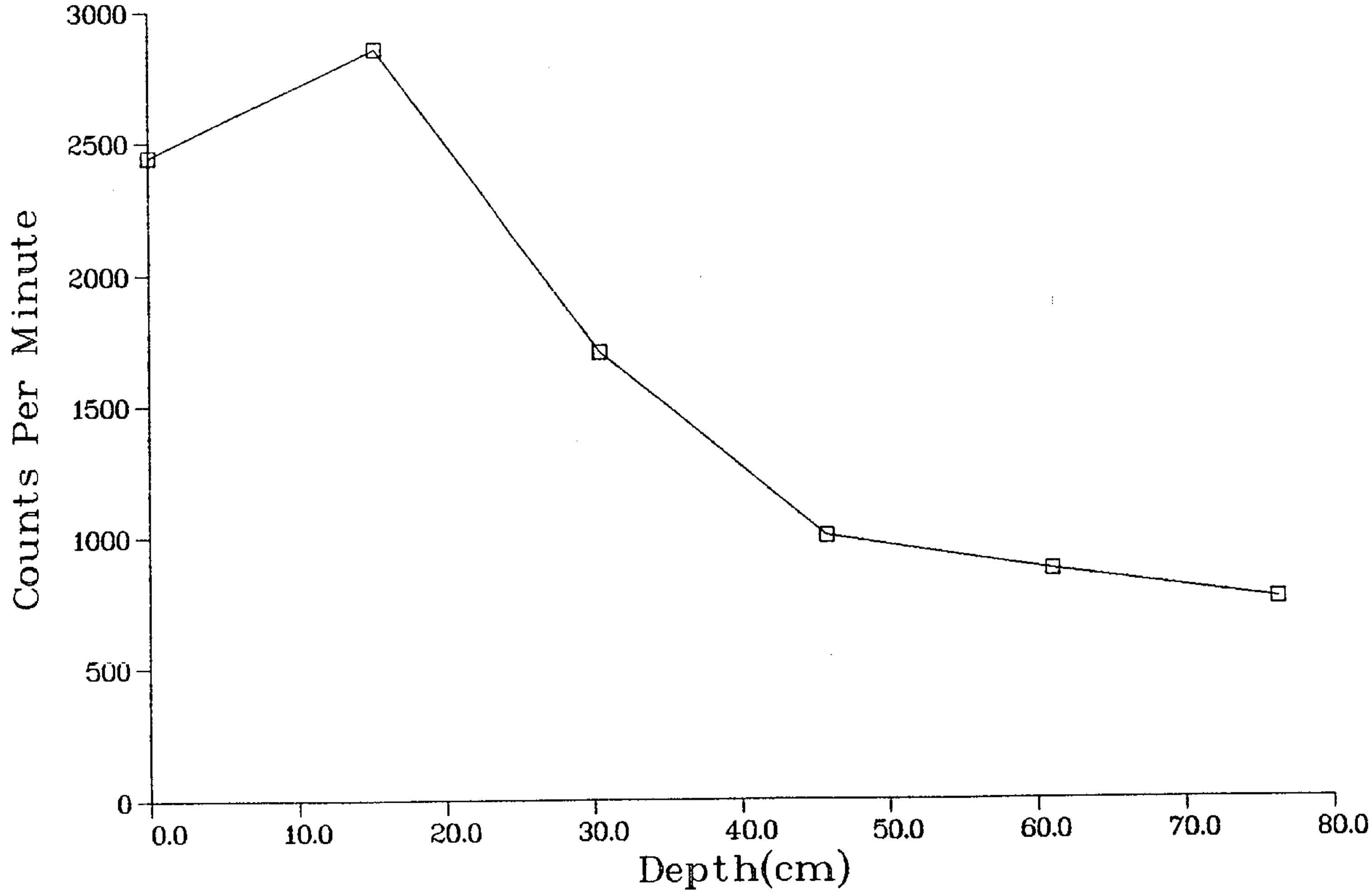

Fig. II–3. Gamma profile of core hole MJC3 (see Fig. 6)

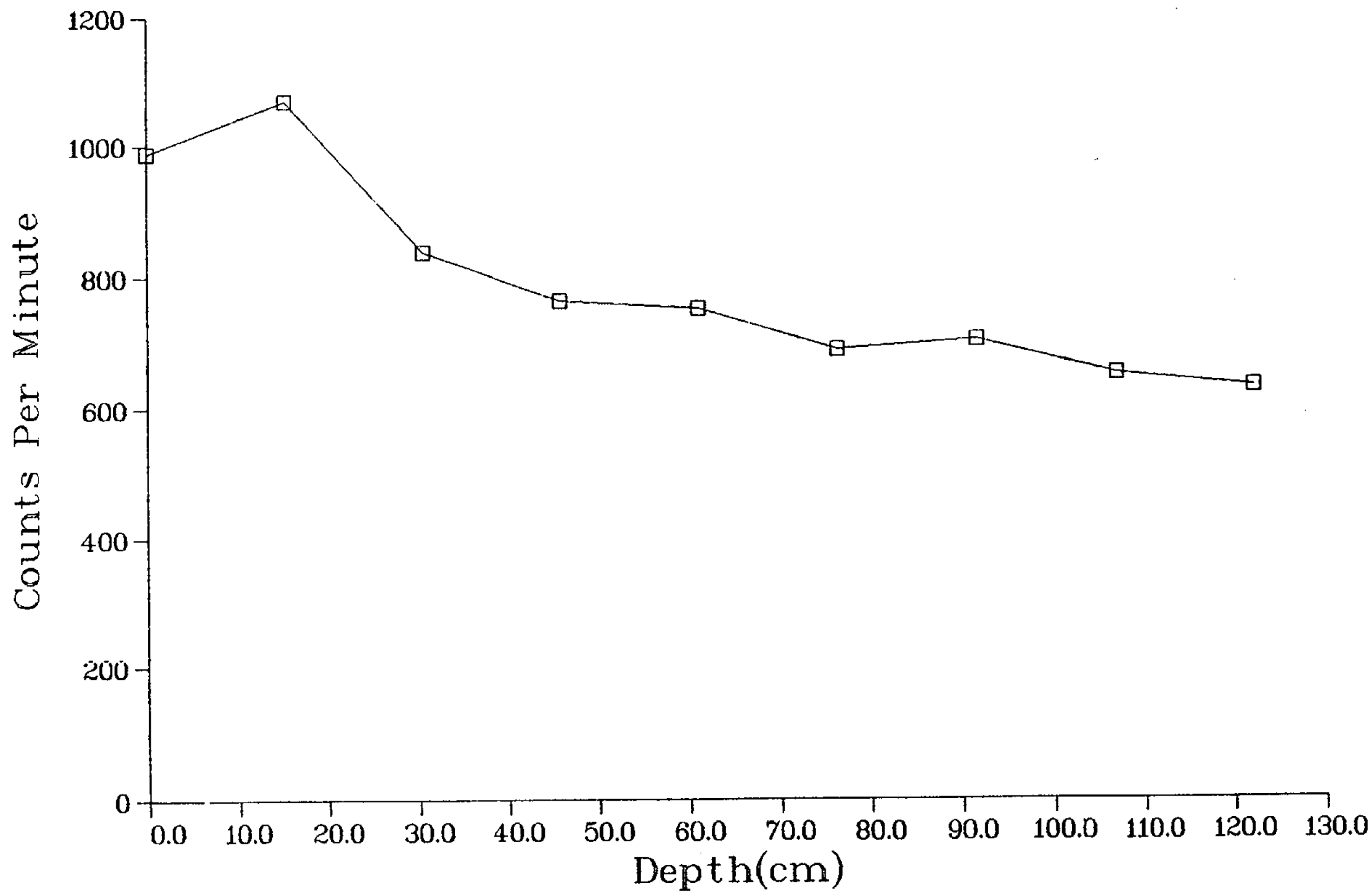

Fig. II–4. Gamma profile of core hole MJC4 (see Fig. 6)

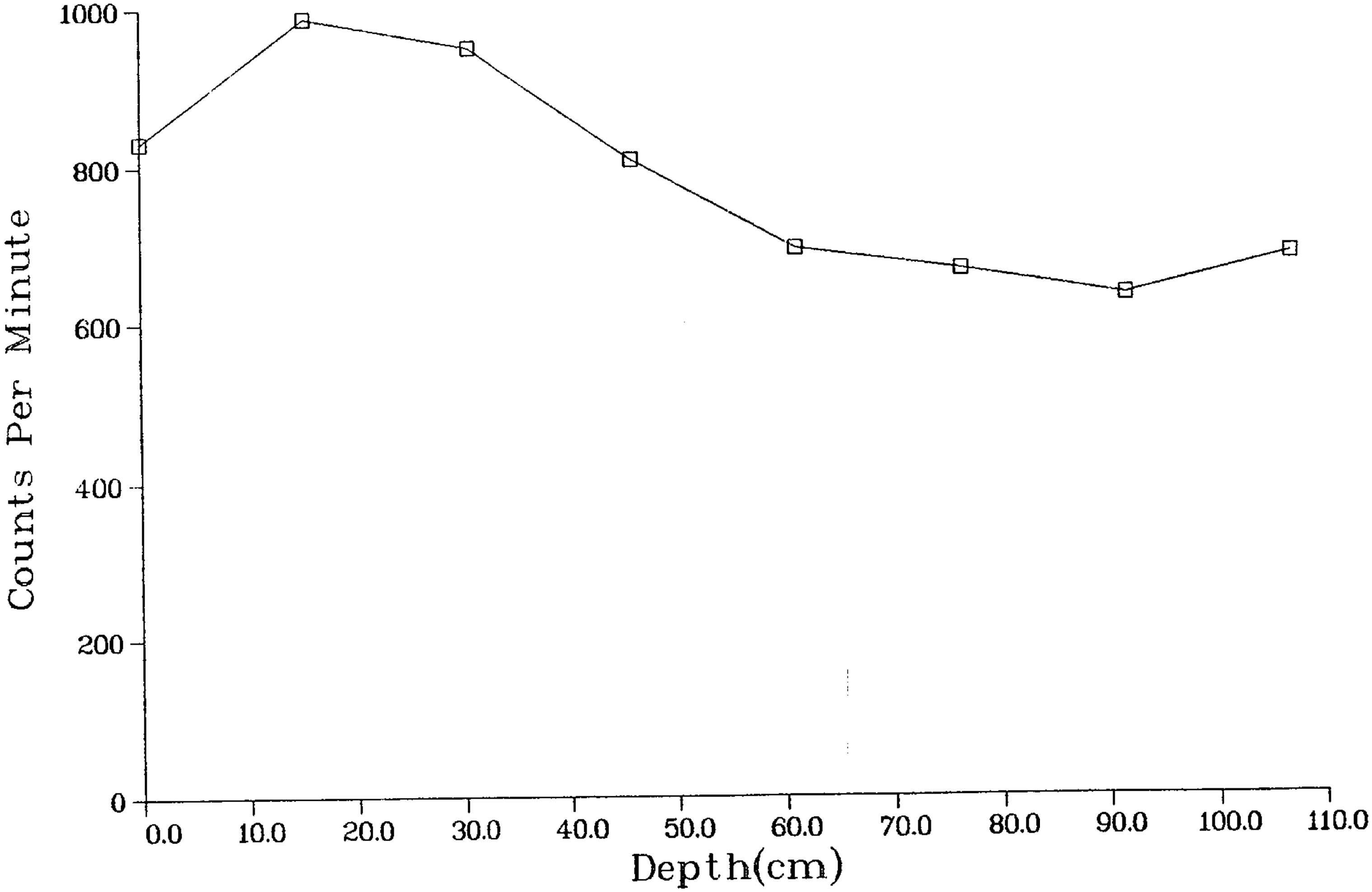

Fig. II-5. Gamma profile of core hole MJC5 (see Fig. 6)

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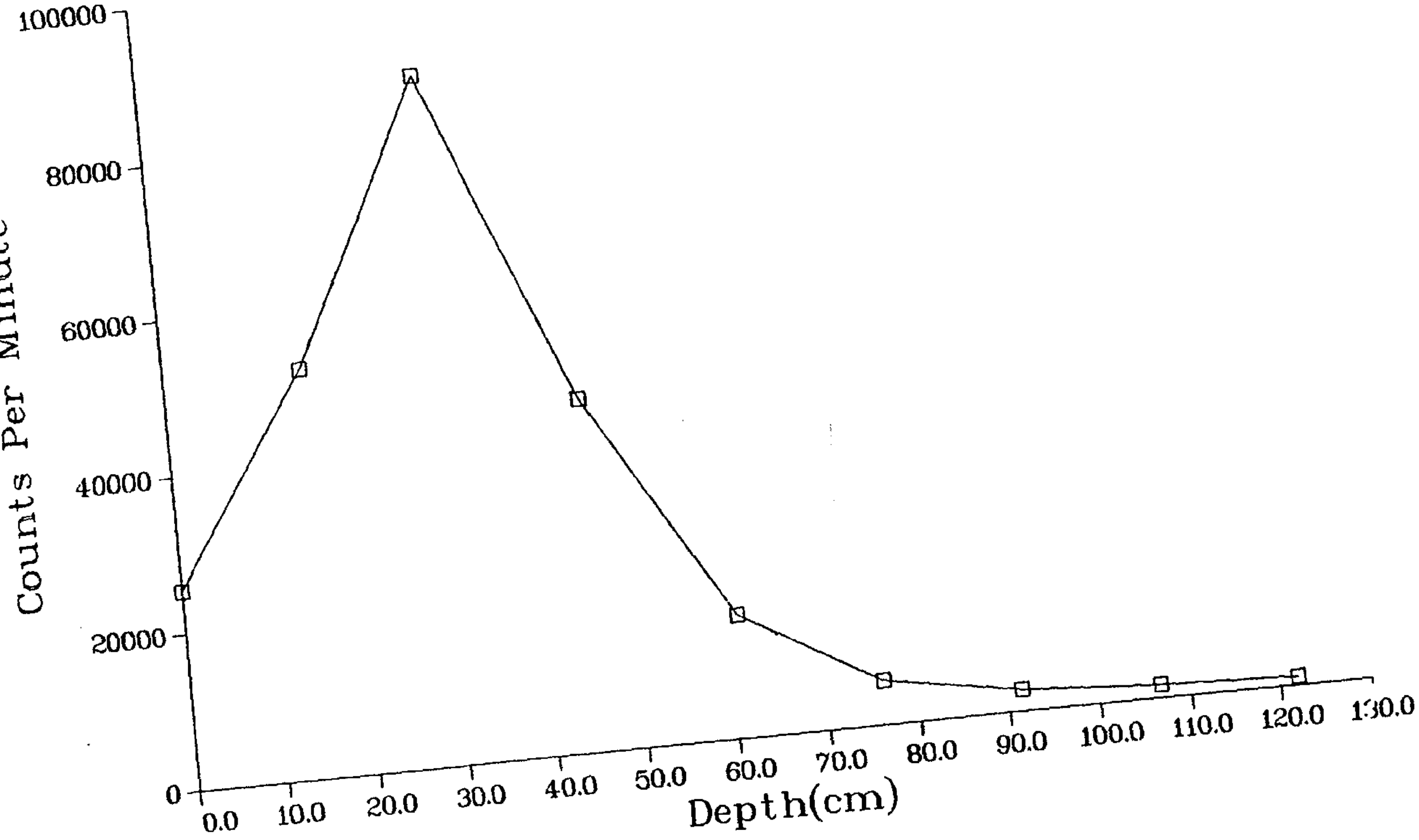


Fig. II-7. Gamma profile of core hole MJC7 (see Fig. 6)

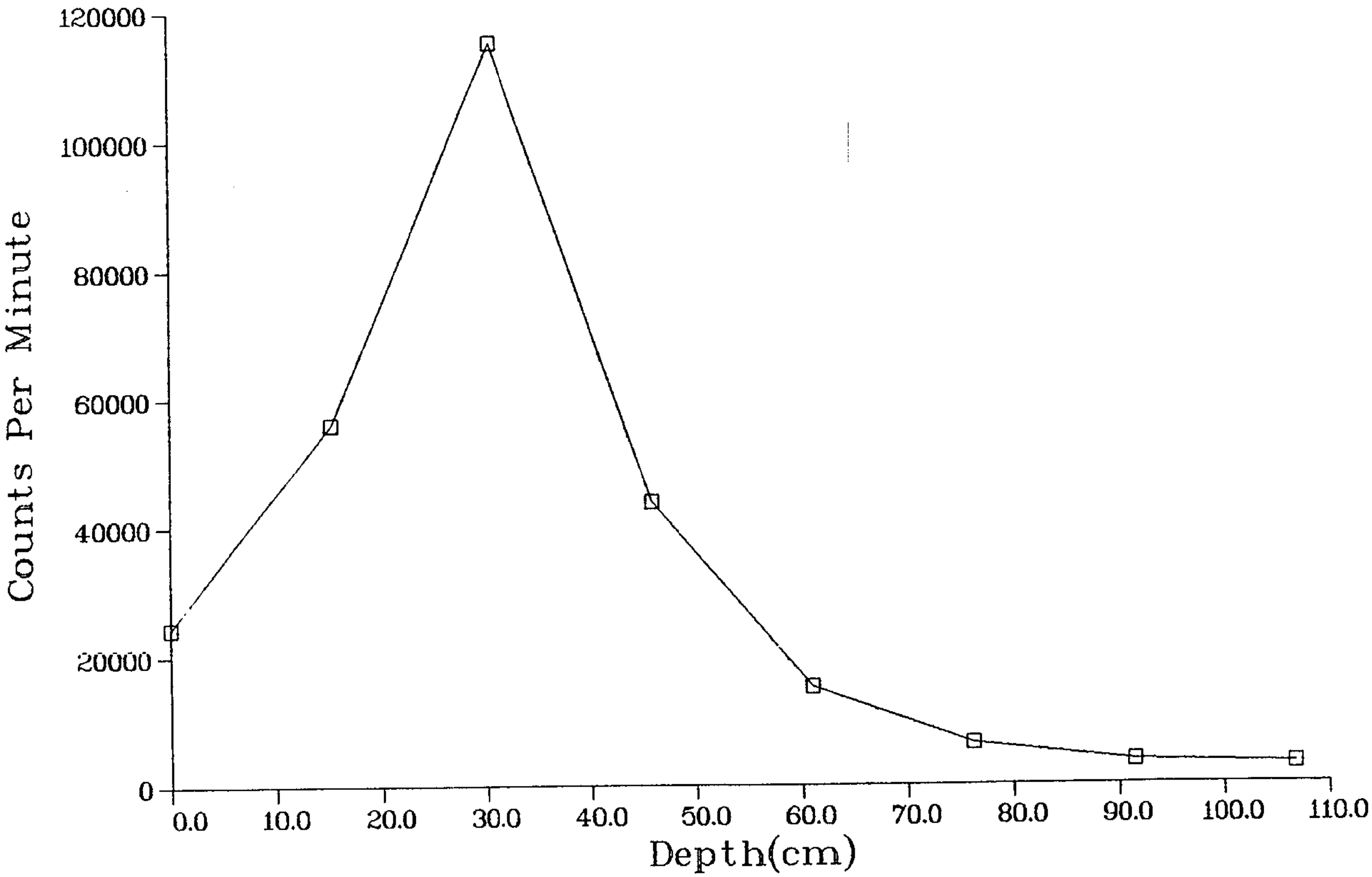
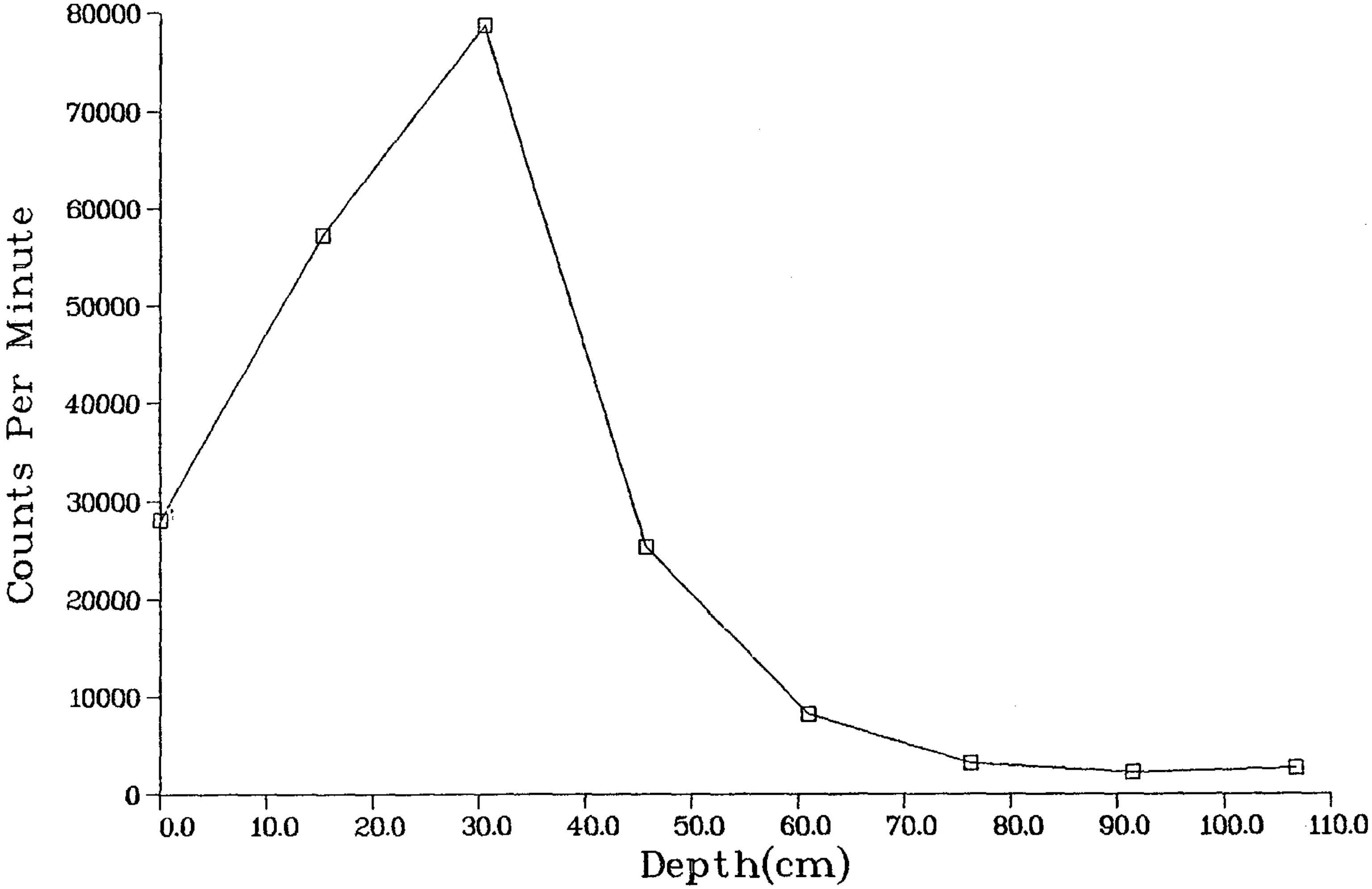


Fig. II–8. Gamma profile of core hole MJC8 (see Fig. 6)


Counts Per Minute
80000
70000
60000
50000
40000
30000
20000
10000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
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80.0
90.0
100.0
110.0
Depth(cm)

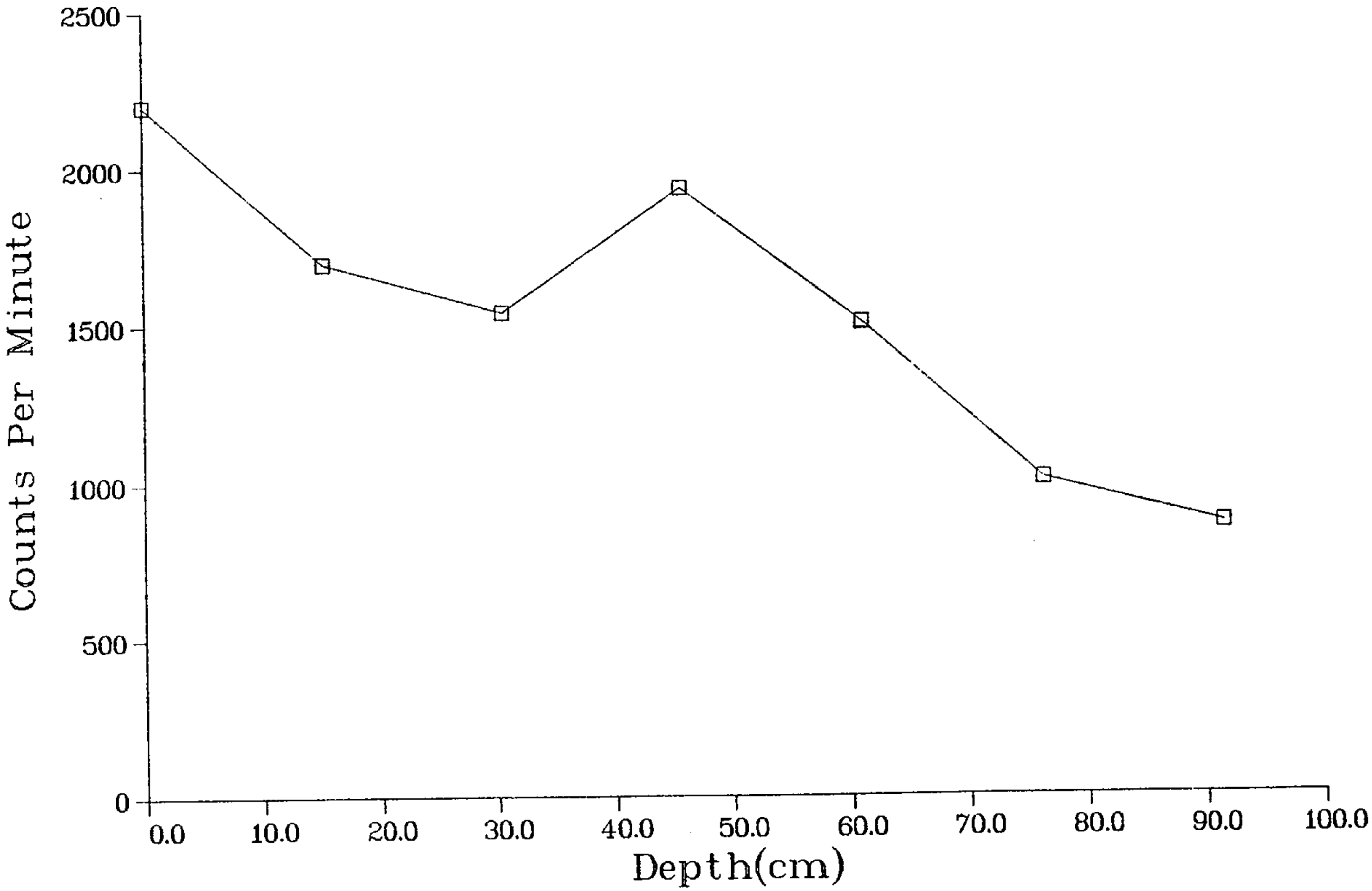

Fig. II–10. Gamma profile of core hole MJC10 (see Fig. 6)

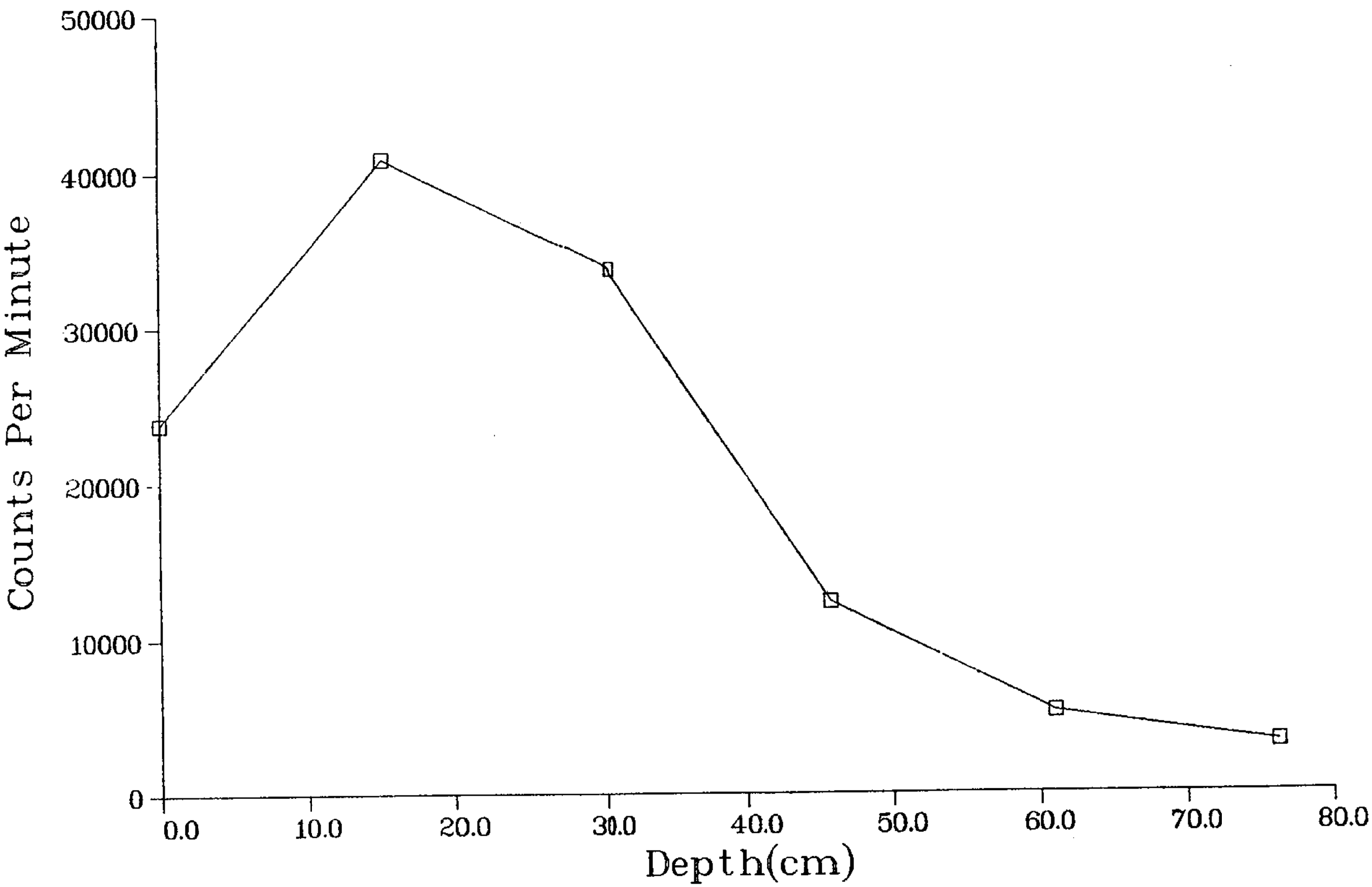

Fig. II-11. Gamma profile of core hole MJC11 (see Fig. 6)

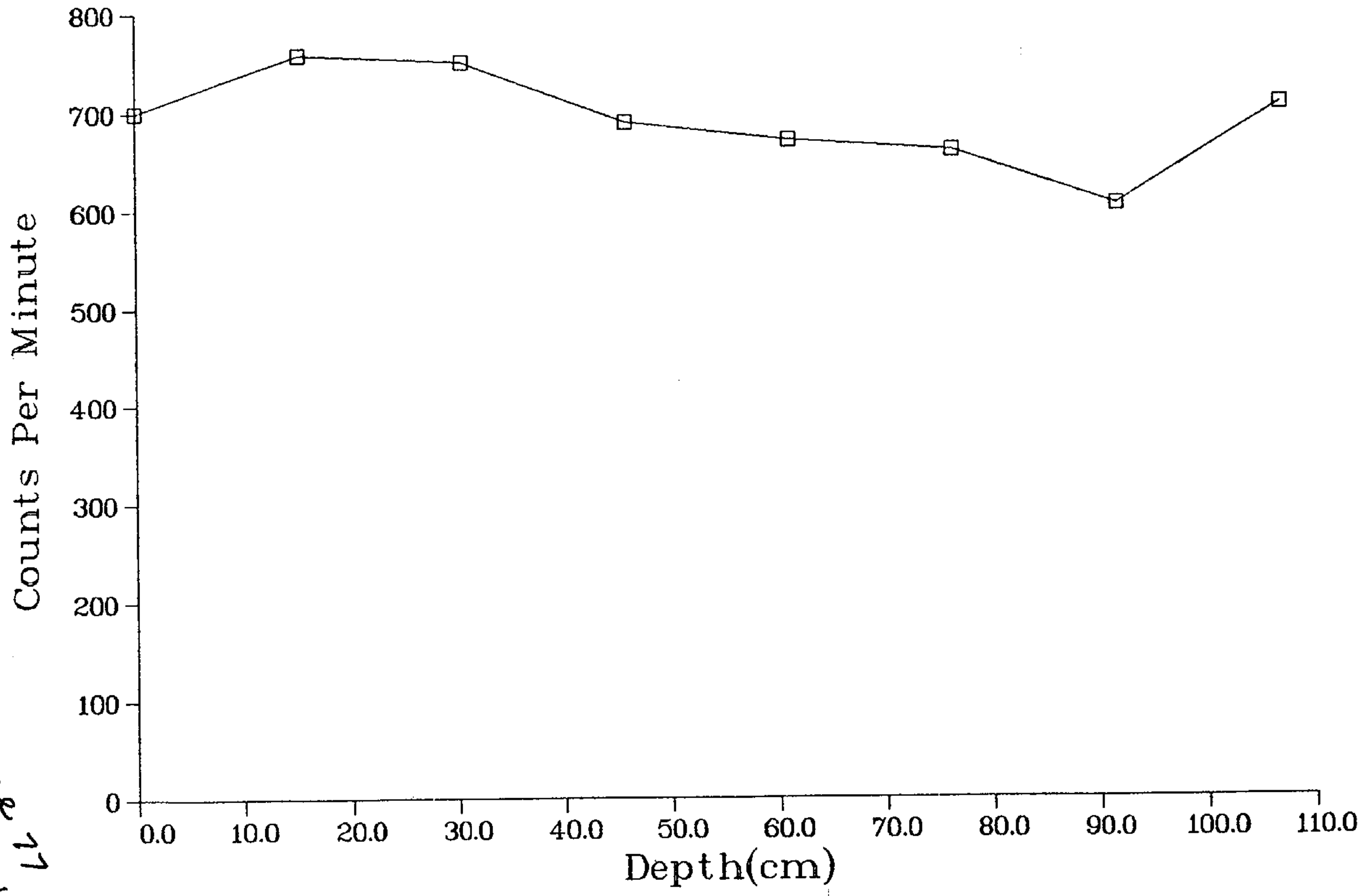

Fig. II-12. Gamma profile of core hole MJC12 (see Fig. 6)

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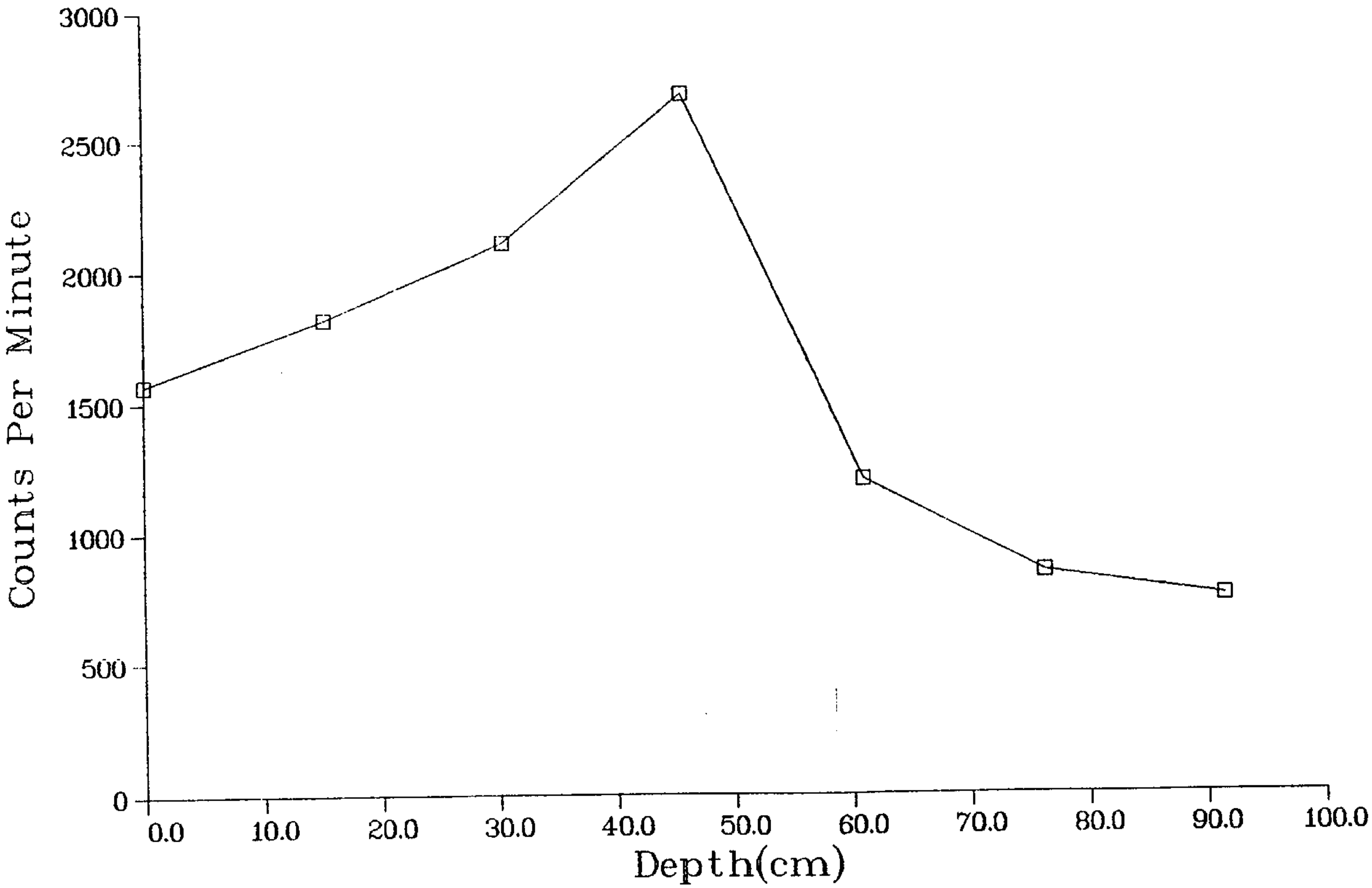

Fig. II-14. Gamma profile of core hole MJC14 (see Fig. 6)

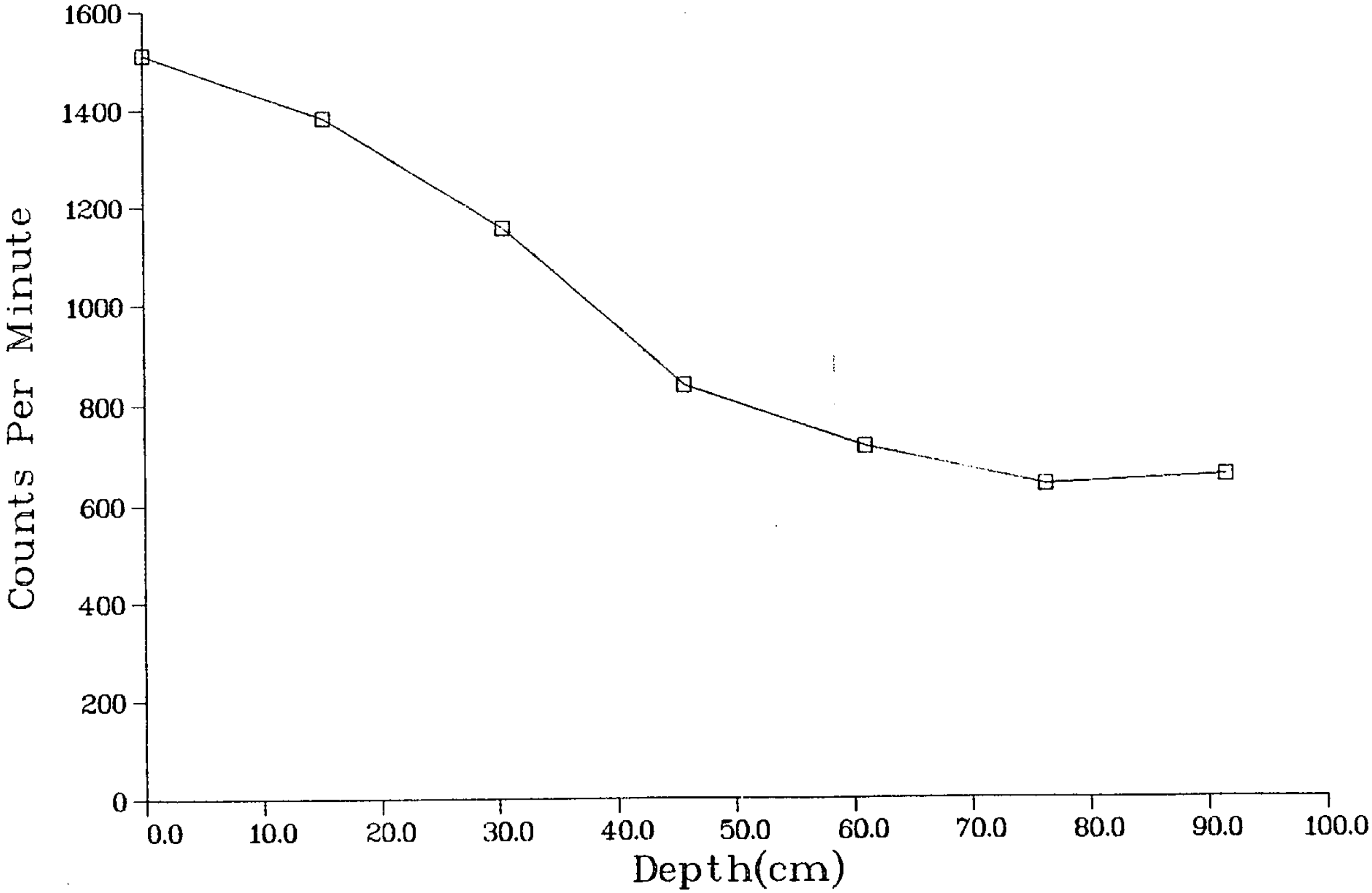

Fig. II–15. Gamma profile of core hole MJC15 (see Fig. 6)

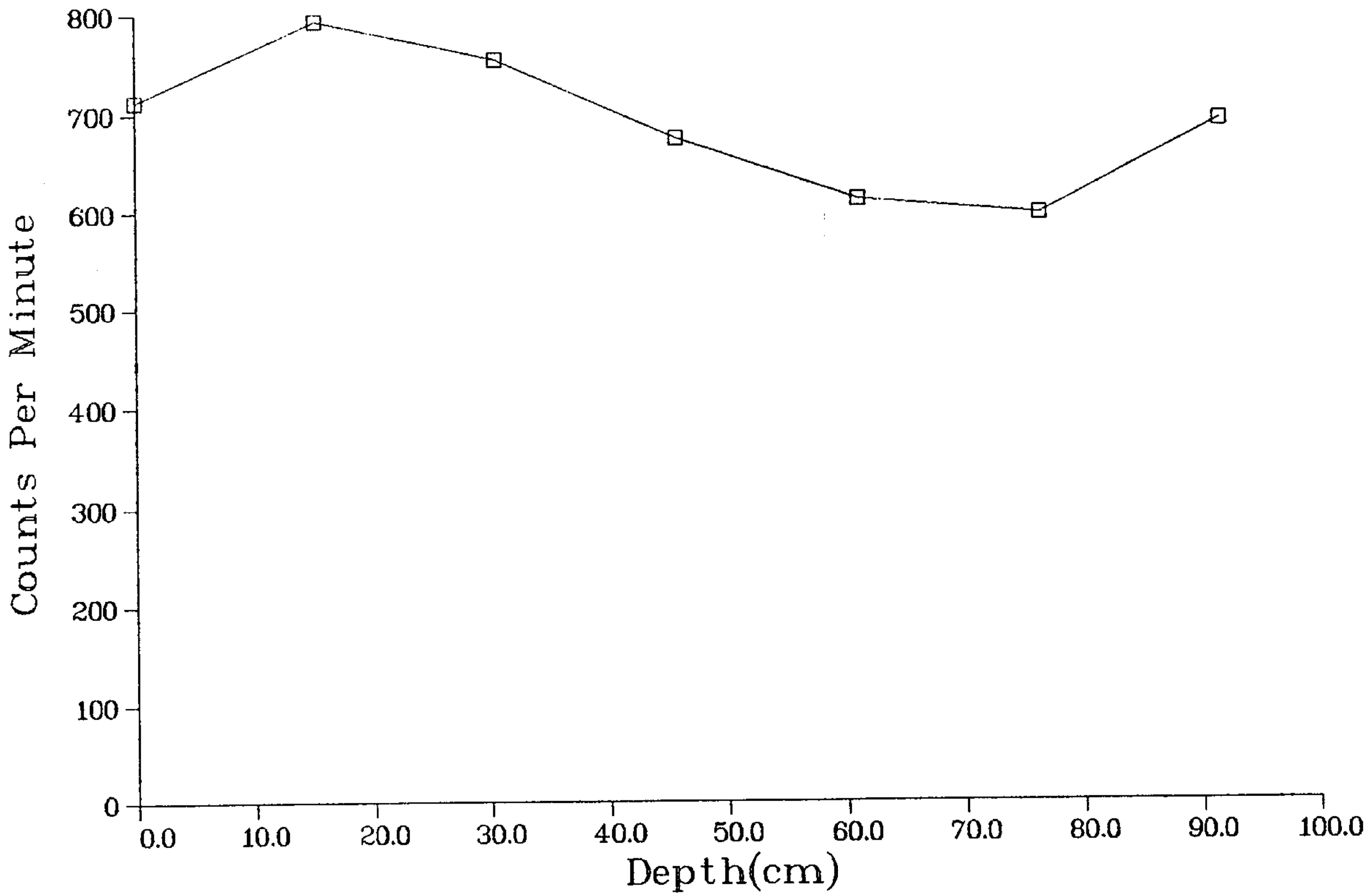

Fig. II–16. Gamma profile of core hole MJC16 (see Fig. 6)

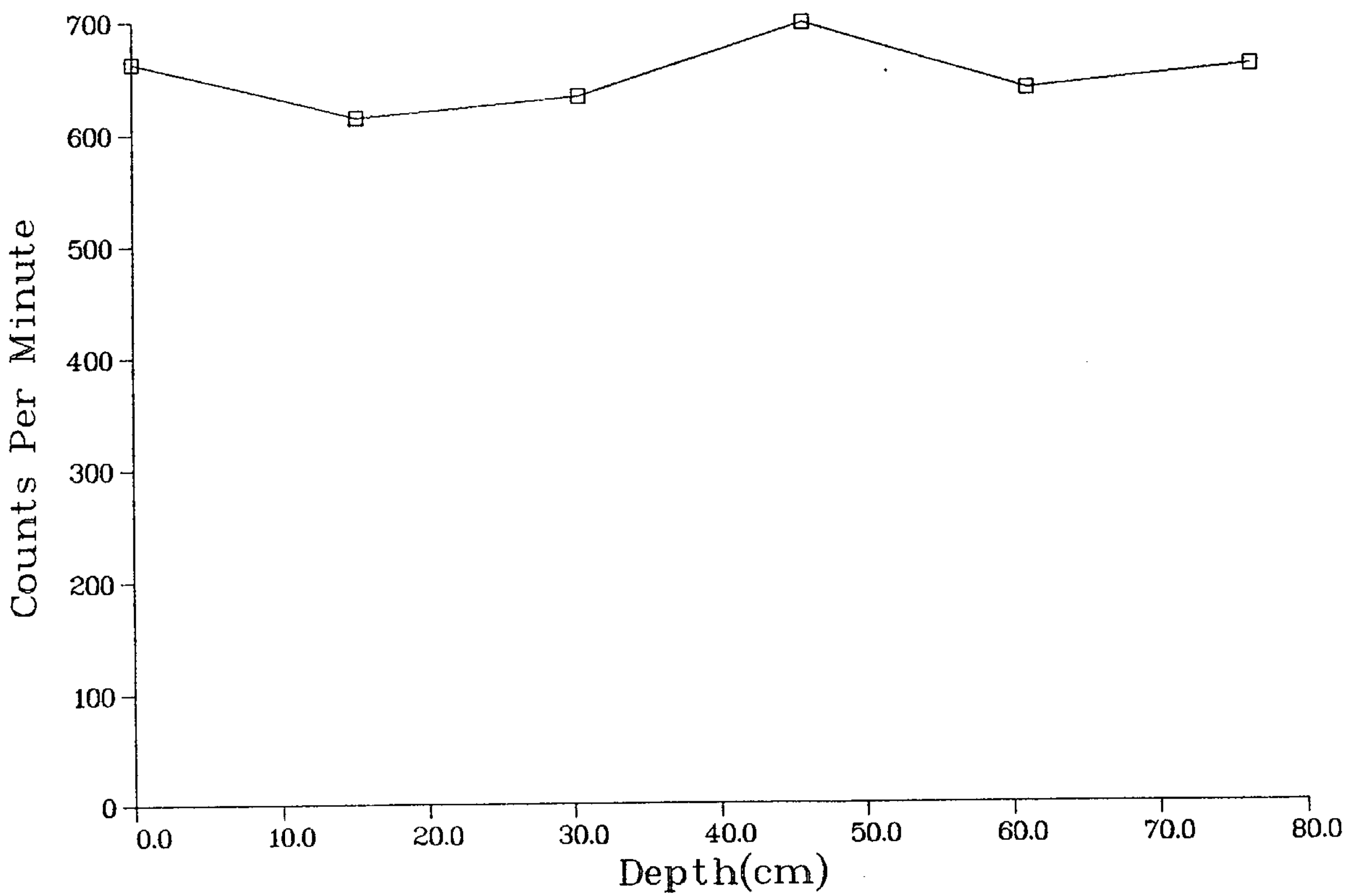

Fig. II–17. Gamma profile of core hole MJC17 (see Fig. 6)

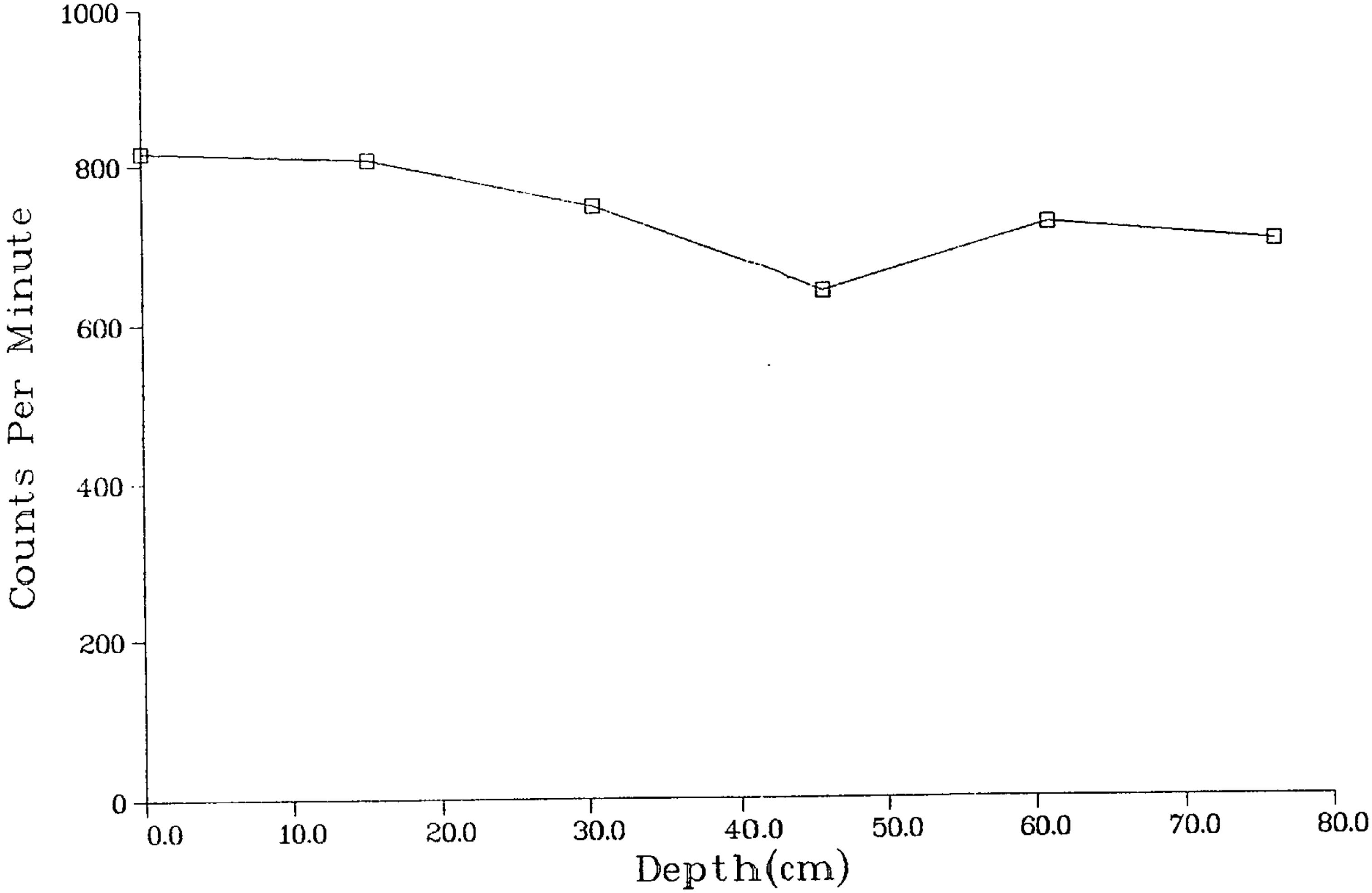

Fig. II-18. Gamma profile of core hole MJC18 (see Fig. 6)

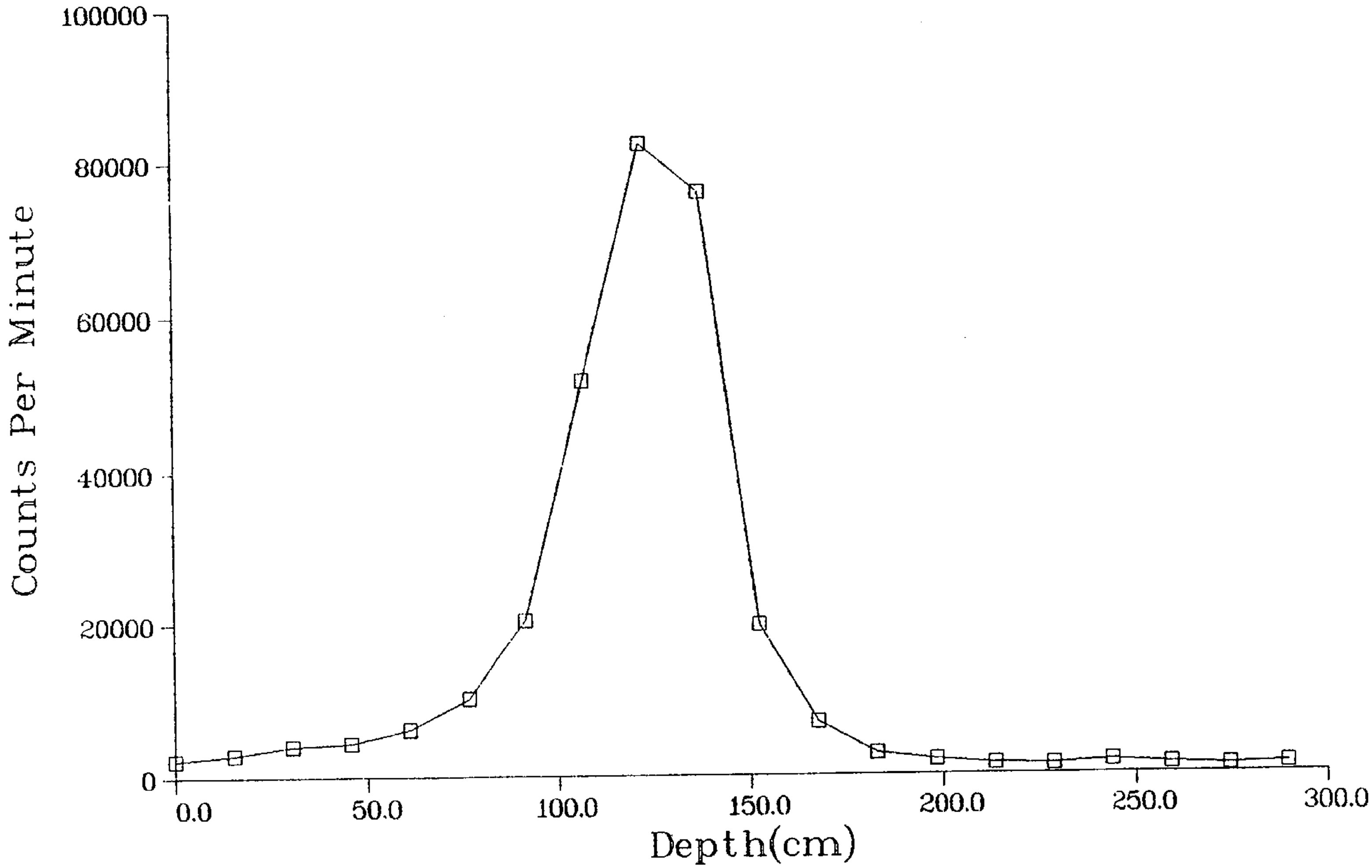

Fig. II–19. Gamma profile of core hole MJC43 (see Fig. 6)

APPENDIX III

EVALUATION OF RADIATION EXPOSURES AT
468 DAVISON AVENUE IN MAYWOOD, NEW JERSEY

EVALUATION OF RADIATION EXPOSURES AT 468 DAVISON AVENUE 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 much of the exterior property was contaminated with radioactive material of the naturally occurring thorium and uranium decay chains. The contaminated material was found: (1) along a 10-foot wide strip in the back yard on the west border (to a depth of about 1.5 feet); (2) along the entire east border of the property in a 10-foot wide strip (to a depth of about 4 feet); and (3) in the shrubbery beds in the front yard (to a depth of about 1.5 feet). No radioactive contamination was found in 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 III-1 until stable lead is formed. The "decay product" listed in Table III-1 is the radiation produced as the parent decays. Radioactive decay started by thorium-232 continues as shown in Table III-2 until stable lead is also formed.

RADIATION EXPOSURES AT 468 DAVISON AVENUE

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 radioactive 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 468 Davison Avenue is described, based on the radiological conditions determined from the recent radiation survey. A summary of this radiation exposure data is given in Table III-3 along with a listing of the normal

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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.

background levels for this area and the applicable guideline values for comparison.

Direct Gamma-Ray Exposures

As shown in Tables III-1 and III-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 8 to 200 microroentgens* per hour, with an average of 38 microroentgens per hour. Inside the house, the exposure rates ranged from 11 to 22 microroentgens per hour, with an average value of 15 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 330 milliroentgens, a value below the guideline limit. Exposures above the guideline could occur only at isolated areas outdoors on the property, and only under continuous exposure conditions. Indoors, the continuous annual exposure from the average radiation levels would be 130 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.

*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.

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 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 outdoors 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 house was determined to be 8.9 picocurie* per liter downstairs and 3.8 picocuries per liter upstairs, values above 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 radon daughter concentrations in the house were determined to be 0.06 and 0.05 working level† downstairs and 0.02 working level upstairs. These concentrations are above the normal background range for the New Jersey area (0.004 to 0.008 working levels), and are above 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.§

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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).

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 exposure of the respiratory tract. Guidelines for acceptable concentrations of radionuclides in air have been developed and are presented in 10 CFR 20. At 468 Davison, 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. On this property, under present land use conditions, consumption of produce from a small garden could produce long-term radiation exposures, but these exposures would be small compared to direct gamma-ray and inhalation of radon and radon daughters exposure pathways.

If land use changes (e.g., to large scale food production), the potential for long-term radiation exposures to individuals ingesting significant quantities of food grown in the contaminated soil would require careful evaluation.

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 III-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 468 Davison Avenue was calculated to be 0.56%.* Thus, for persons living for a lifetime at 468 Davison, 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 chance of 24.96% 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 19.3% for the United States.

SUMMARY

A summary of radiation exposure data at 468 Davison Avenue is presented in Table III-3. Of the four primary radiation exposure pathways, only two may be 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. Exposures to gamma radiation outdoors on this property could approach the guidelines for exposure to individuals in the general public. This pathway is, therefore, a significant exposure mechanism at this site under current conditions of property use. Exposure to radon and radon daughters could exceed the guideline exposure to individuals in the general public making this pathway also a significant exposure pathway at this property.

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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.

Table III-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 III-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	0.3 millionth of a second ($\frac{3}{1,000,000}$)	alpha	lead-208
or			
Thallium-208	3.1 minutes	beta, gamma	lead-208
Lead-208	stable	none	none

Table III-3. Summary of exposure data at 468 Davison 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: 38 microRoentgens per hour at one meter
	Indoors: 8 microRoentgens per hour at one meter	Indoors: 60 microRoentgens per hour	Indoors: 15 microRoentgens per hour at one meter
Radon in indoor air	Basement: 1.7 picocuries per liter	3 picocuries per liter	Basement: 8.9 picocurie per liter
	Upstairs: 0.8 picocuries per liter		Upstairs: 3.8 picocuries per liter
Radon daughters in indoor air	Basement: 0.008 working level	Basement: 0.01 working level	Basement: 0.056 working level
	Upstairs: 0.004 working level	Upstairs: 0.01 working level	Upstairs: 0.019 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.