DOE/EV-0005/29
ORNL-5734
Dist. Category UC-70

Contract No. W-7405-eng-26

Health and Safety Research Division

RADIOLOGICAL SURVEY OF THE FORMER KELLEX RESEARCH FACILITY, JERSEY CITY, NEW JERSEY

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Worked performed as part of the

Remedial Action Survey and
Certification Activities

Date Published: February 1982

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

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ACKNOWLEDGEMENTS

Research for this project was sponsored by the Division of Environmental and Safety Engineering (then Environmental Control Technology), U. S. Department of Energy, under contract W-7405-eng-26 with Union Carbide Corporation. The authors wish to acknowledge the continued support and encouragement of William E. Mott, Director, Environmental and Safety Engineering Division, and members of his staff. Appreciation is extended to J. F. Emory and Joe Northcutt, ORNL Analytical Chemistry Divsion for their careful analysis of environmental samples for uranium, to P. T. Perdue for his gamma-ray spectral analysis of soil samples, to B. S. Ellis for her management of samples analysis records, and to Roxanne Rabe and Wilma Minor for their manuscript typing. The authors wish to acknowledge the valued radiation survey work of their deceased co-author, William M. Johnson. This report is dedicated to him.

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ABSTRACT

A radiological survey has been conducted at the site of the former Kellex Corporation Research Facility in Jersey City, New Jersey. Kellex played a major role in the Manhattan Project, particularly in the area of engineering research in gaseous diffusion for uranium enrichment. As a result of those operations and subsequent work with radioactive materials, this site was selected for a radiological survey by the Department of Energy (DOE) [then Energy Research and Development Administration (ERDA)] in its program aimed at reviewing and documenting the radiological status of properties associated with early source material contracts. The survey included measurement of external gamma radiation, beta-gamma surface dose rates, alpha and beta surface contamination, concentrations of selected radionuclides in surface and subsurface soil and water on the site, and background radiation in the northern part of New Jersey. The results of the radiological survey indicate radionuclide concentrations in the soil and water on the former Kellex property are within background levels, with the exception of nine isolated and well-defined areas on the site of the former Kellex Laboratory.

*Deceased.

INTRODUCTION

At the request of the Department of Energy (DOE) [then Energy Research and Development Administration (ERDA)], a radiological survey was conducted at the former M. W. Kellogg Company in Jersey City, New Jersey.* The site, located at the intersection of New Jersey Route 440 and Kellogg Street, was an industrial park which included the Kellex Corporation Research Facility. Figures 1-5 are aerial photographs of the Kellex site between 1940 and 1966. The photographs reflect the changing on-site conditions with time. A diagram of the Kellex site indicating the location and orientation of the on-site buildings at the time the facility was operational (1943-1952) is shown in Fig. 6. All of these buildings have been removed since that time.

Kellex was formed by Kellogg in 1943 to carry out engineering research in gaseous diffusion for uranium enrichment as a part of the Manhattan Project. The main research activities of Kellex involved component testing with uranium hexafluoride.

According to sparse records of early (1951-1953) radiological surveys conducted by the AEC's New York Operations Office, it was believed that all of Kellex's operations were initially conducted in a single building on the site. This building was designated Building 11 and contained several laboratories, offices, weighing facilities, toilets, change rooms, and a shielded counting room. The radioactive materials handled in this building included material from a "purex" uranium recovery process, natural uranium, and some pitchblende. There was no information regarding any other radioactive material which might have been handled in this building, nor was there any information regarding the relative quantities of such materials from the purex process, uranium, or pitchblende.

In early 1943, uranium hexafluoride research was transferred from Building 11 to Building A on the western edge of the site[1] (Fig. 6).

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*The survey was carried out in two phases. Initial work was done in March 1977. Additional survey work was conducted in the summer of 1979.

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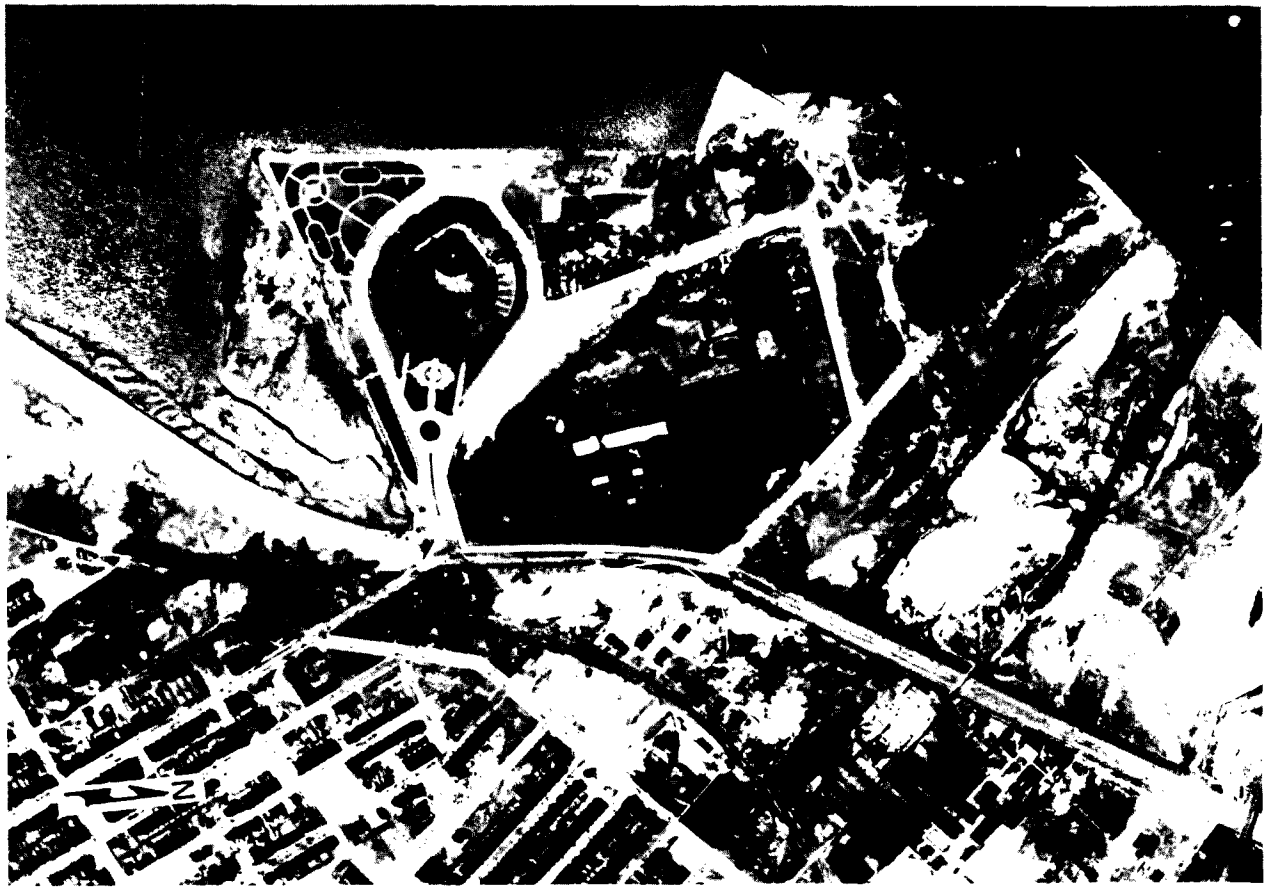

Fig. 1. Aerial photograph of the Kellex site and surrounding area in April, 1940.

ORNL-Photo 4329-79

Fig. 2. Aerial photograph of the Kellex site and surrounding area in January, 1944.

ORNL-Photo 5191-79

Fig. 3. Aerial photograph of the Kellex site and surrounding area in April, 1951.

ORNL-Photo 5192-79

Fig. 4. Aerial photograph of the Kellex site and surrounding area in April, 1961.

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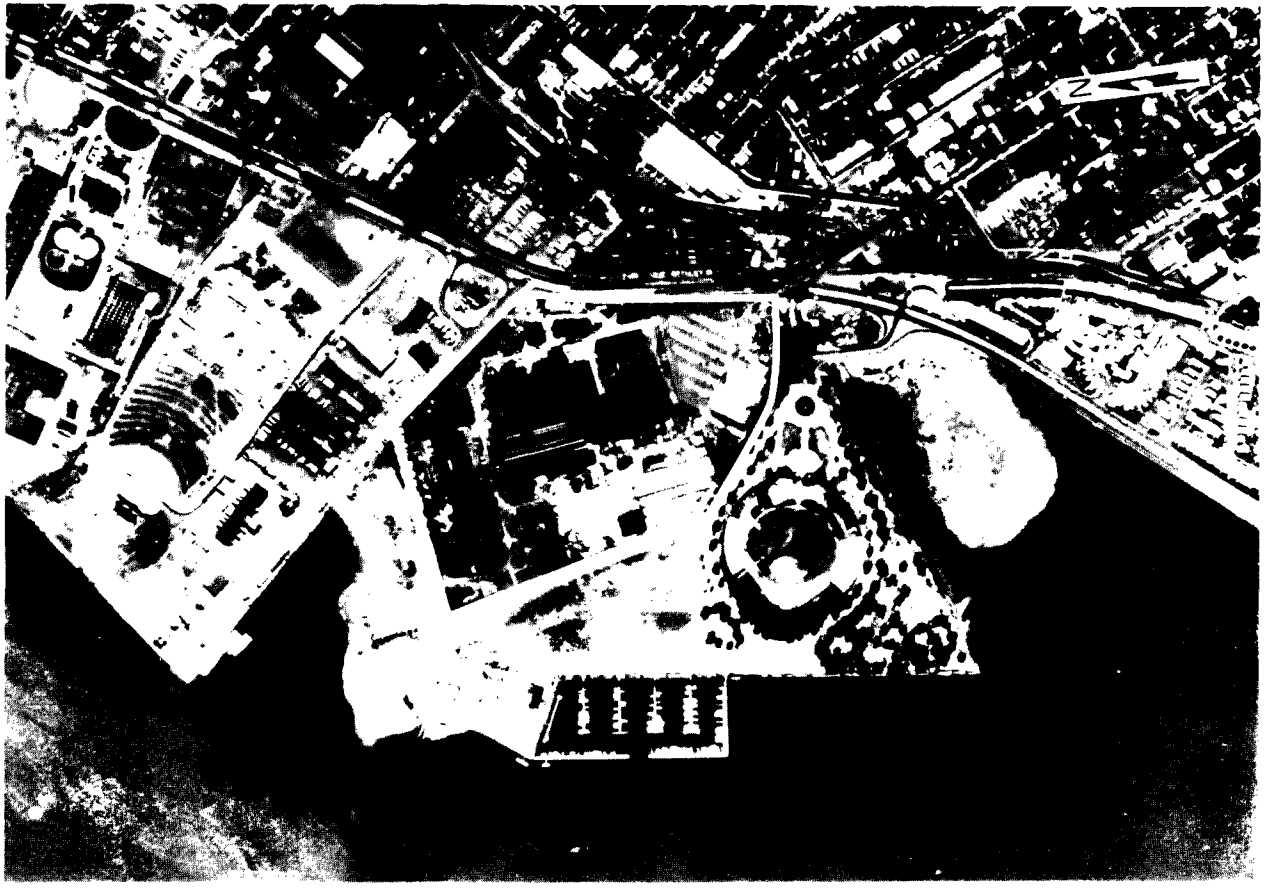

Fig. 5. Aerial photograph of the Kellex site and surrounding area in June, 1966.

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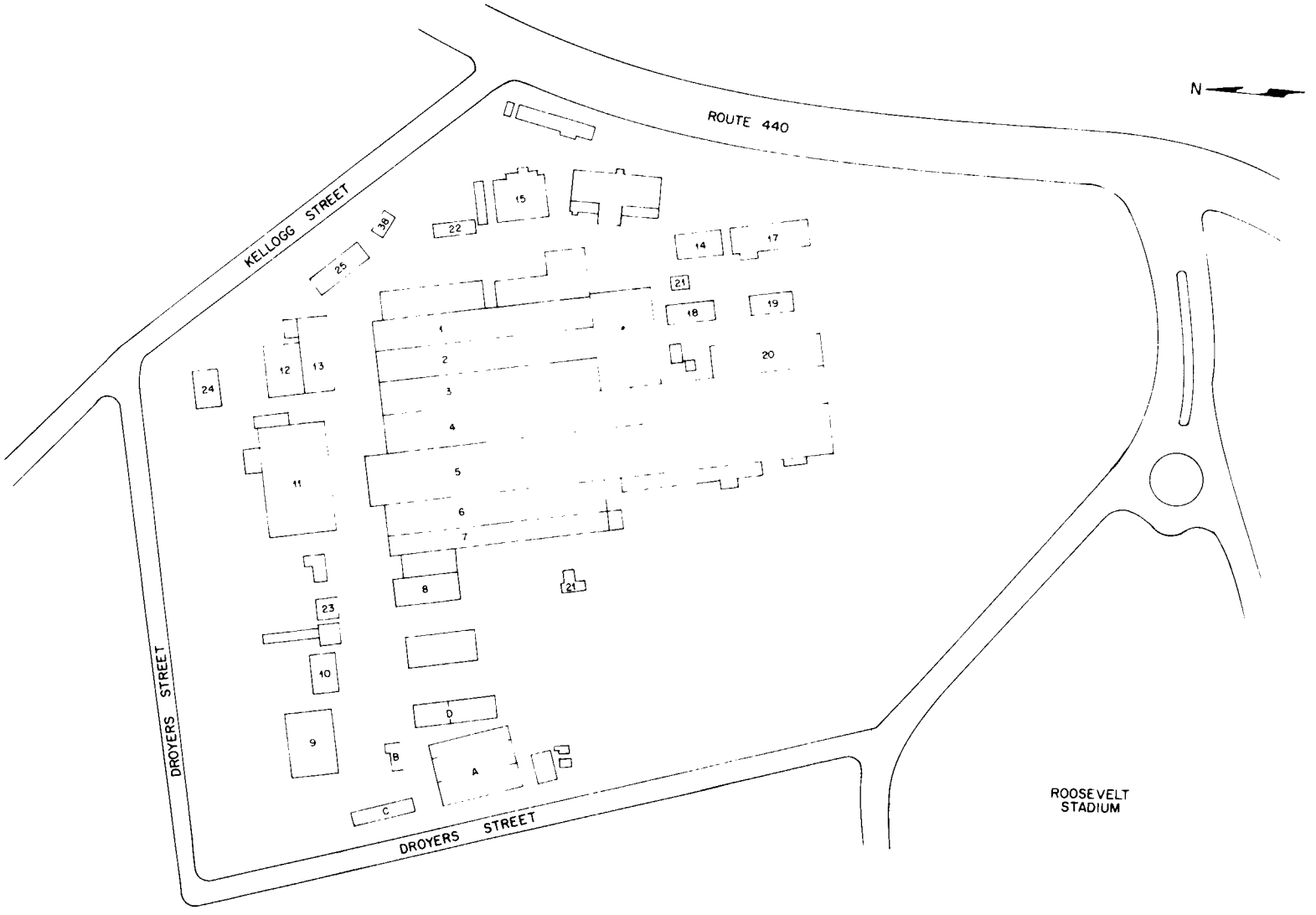

Fig. 6. Location and orientation of the buildings at the Kellex site during operations (1943 to 1952).

In 1945, all gaseous diffusion equipment was removed and relocated to the Oak Ridge Gaseous Diffusion Plant (K-25) in Oak Ridge, Tennessee.

On June 25, 1953, a *Contamination Status Report* was published by the Vitro Corporation of America and detailed the findings of a "final radiation and contamination survey" of the Jersey City Laboratory (Appendix I). In this report, it was indicated that most external gamma radiation readings were less than 100 μR/h*, and no transferable alpha or beta-gamma contamination was observed in any of the accessible areas. Some elevated gamma-ray readings were noted in a duct used for exhausting hoods in two of the laboratories in Building 11. One reading equivalent to 600 μR/h was observed on a wall in the chemical storage area. Since 1953, Building 11 has been demolished. Its location was estimated from a sketch of the property which was made in the 1960s and is shown by a dotted outline in Figs. 7 and 8. In the above report, there was no mention of the gaseous diffusion research which was conducted in Building A (Fig. 6) nine years earlier, and no measurements were taken in that building.

Ownership and use of the property have also changed since 1953. The site of the laboratory is currently owned by Pierpont Associates, Incorporated, and managed by Harborside Management Company. Approximately 17 ha (43 acres) of the original property have been sold. A portion of the Pierpont Associates property is occupied by a Pathmark supermarket and its parking lot. Approximately 10 ha (25 acres) remain under Pierpont ownership, including the laboratory site where radioactive materials were handled. A large portion of this property is currently occupied by Stadium Plaza, a new shopping center with associated parking lots (Fig. 9).

A preliminary survey of the Kellex site was made by a DOE representative and an Oak Ridge National Laboratory (ORNL) health physicist on October 21, 1976. This cursory survey of the property revealed average external gamma-ray readings of 5 to 6 μR/h. For the northeastern part of the United States, this is approximately equivalent to natural background radiation levels. However, it was decided that a

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*Conversion for SI units are located in Appendix II.

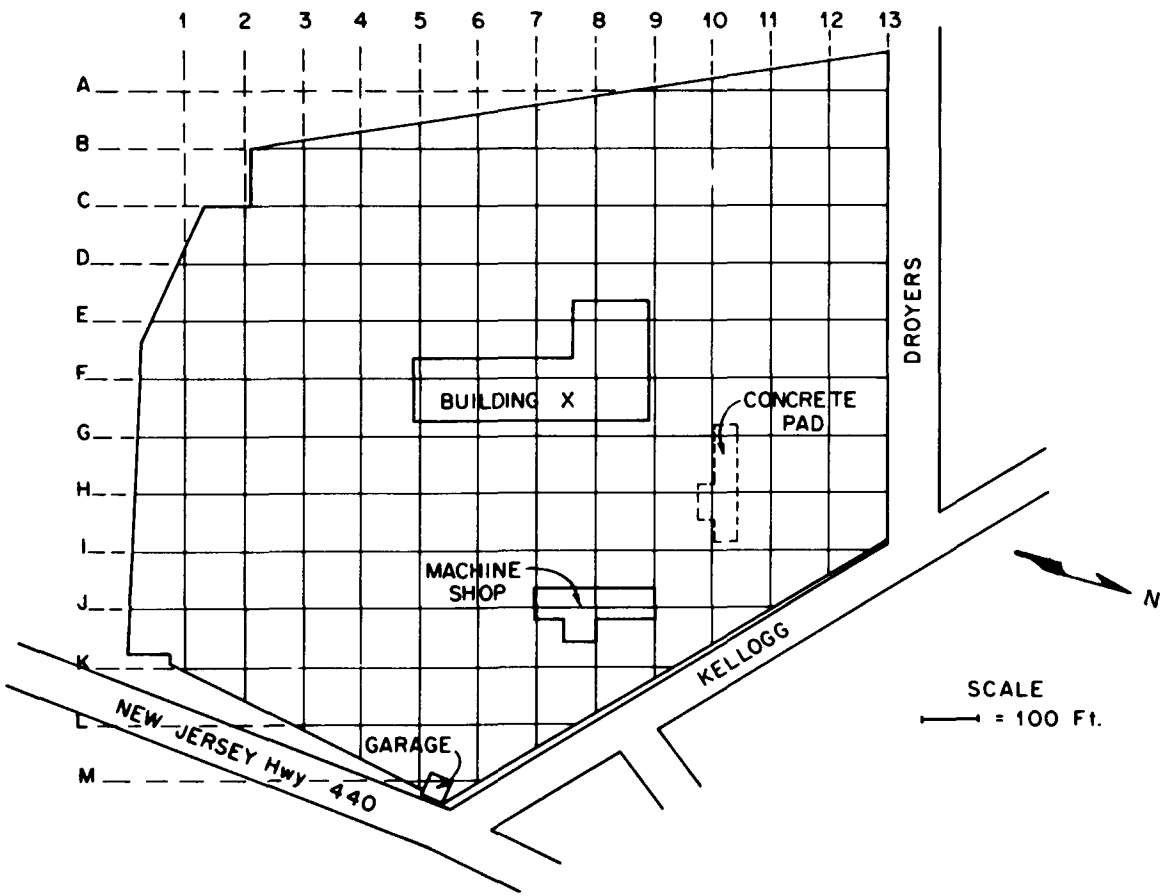

Fig. 7. Extent of former Kellex site as surveyed in 1977 radiological assessment. (Building X was a portion of Building 11; the machine shop was a portion of Building 1.)

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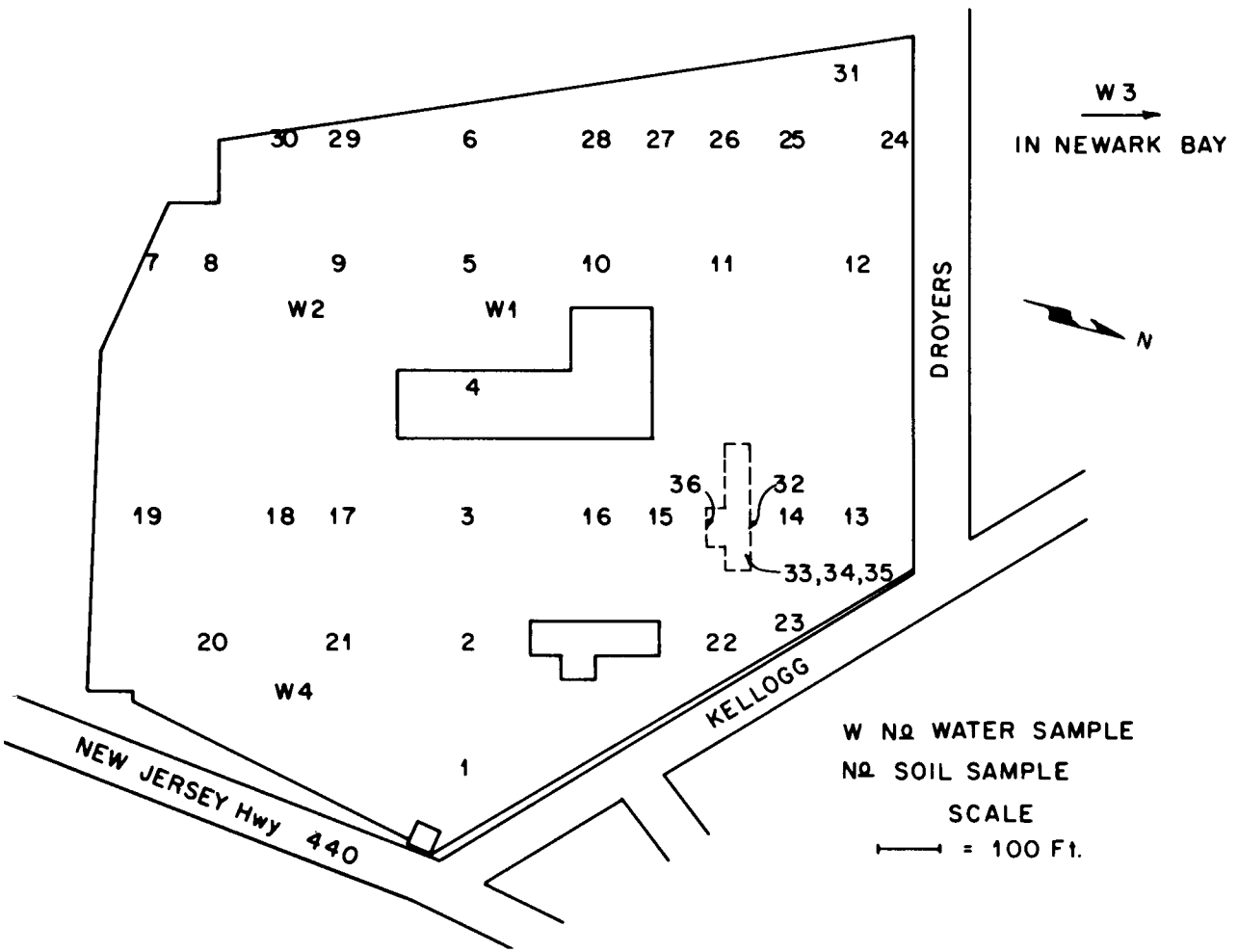

Fig. 8. Site plan and location of surface soil and water samples taken at the former Kellex site.

formal survey should be conducted due to the size of the property and uncertainty as to the exact location and extent of Kellex operations.

In addition to the concrete pad of the old laboratory, three buildings were still standing on the property at the time of the October, 1976, visit but were later demolished. One of these was most likely the remains of the original Buildings 6, 7, and 8 (Fig. 6) which were contiguous. This structure was vacant and will be referred to as Building X in Fig. 7. Another building was probably the remains of the structure immediately east of Building 1 in Fig. 6. This building was used at the time of the 1977 survey as a machine shop and will be so identified in this report. The third and final remaining structure during the 1977 survey was a small building fronting Route 440 which was used as the Plymouth-Chrysler garage (Fig. 7). This building will be referred to as the "garage" in this report.

SURVEY PLAN

A series of surveys were undertaken to characterize the existing radiological status of the Kellex site. They were conducted by members of the Health and Safety Research Division of ORNL. The first formal survey, performed on March 28-30, 1977, included the following measurements:

1. measurement of external gamma radiation levels at 1 m above the surface at grid points of an approximate 30-m grid over the entire property as shown in Fig. 7;
2. measurement of beta-gamma dose rates at 1 cm above the surface using the same grid;
3. measurement of the concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in surface soil samples located as shown in Fig. 8;
4. measurement of the concentrations of ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U in surface (including drainage) water samples located as shown in Fig. 9;

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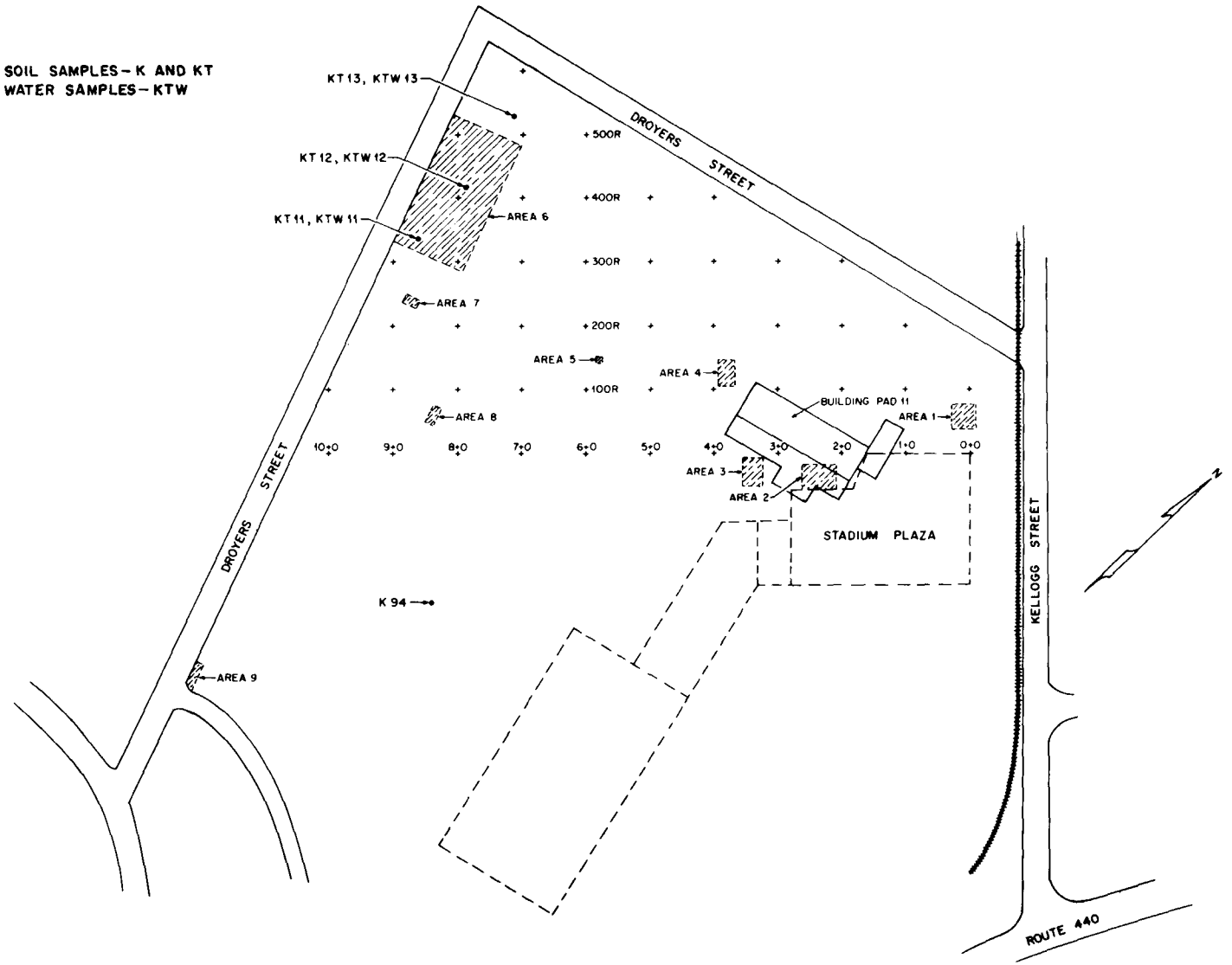

Fig. 9. Site plan and location of grid system and selected sample areas on the Kellex site.

5. measurement of fixed alpha contamination levels, beta-gamma dose rates at 1 cm, and gamma radiation levels at 1 m above the surfaces on an approximate 3-m grid on the concrete pad at Building 11 as shown in Fig. 10;
6. measurement of transferable alpha and beta contamination on the concrete pad of former Building 11;
7. measurement of the concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in scale samples taken from floor drains in the concrete pad of Building 11;
8. measurement of external gamma radiation levels at 1 m, beta-gamma dose rates at 1 cm above the surfaces, and alpha contamination by direct reading in the three buildings remaining on the site: the garage, the machine shop, and the large empty building designated as Building X in Fig. 7; and
9. background measurement of external gamma radiation levels and concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in surface soil and ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U in surface water samples at points near, but assumed not influenced by, the former Kellex Corporation operations.

Several additional surveys were performed at the Kellex site during 1979 (March 27, May 10-11, June 2, July 21, August 1-4, and August 30-31).

The additional surveys in 1979 included the following:

1. measurement of external gamma exposure rates at the ground surface in walk-over traverses less than 3 m apart over the property shown in Fig. 11;
2. measurement of concentrations of ^{238}U, ^{226}Ra, and ^{232}Th in soil at variable depths in Areas 1-9 identified in Fig. 9 ;
3. measurement of concentrations of ^{226}Ra, ^{238}U, ^{232}Th, ^{230}Th, and ^{210}Pb in three groundwater samples at locations shown in Fig. 9; and

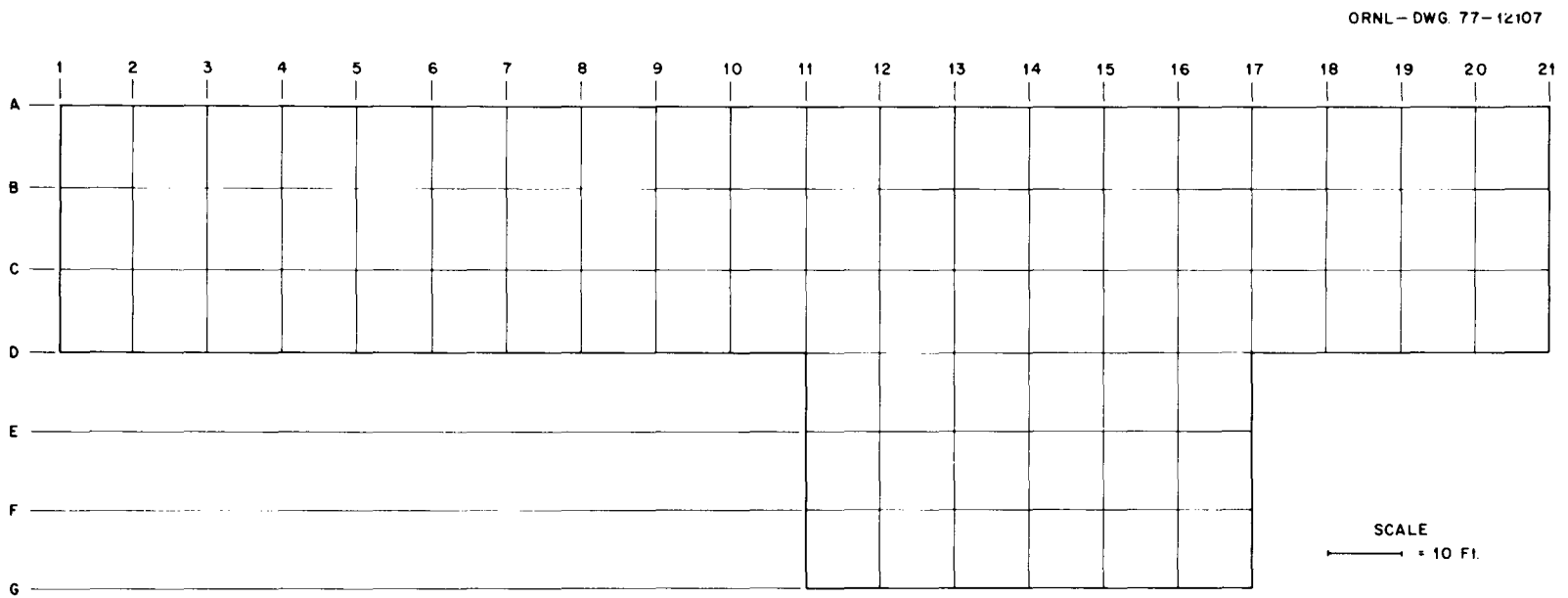

Fig. 10. Grid used for external gamma radiation measurements on the concrete pad of former Building 11.

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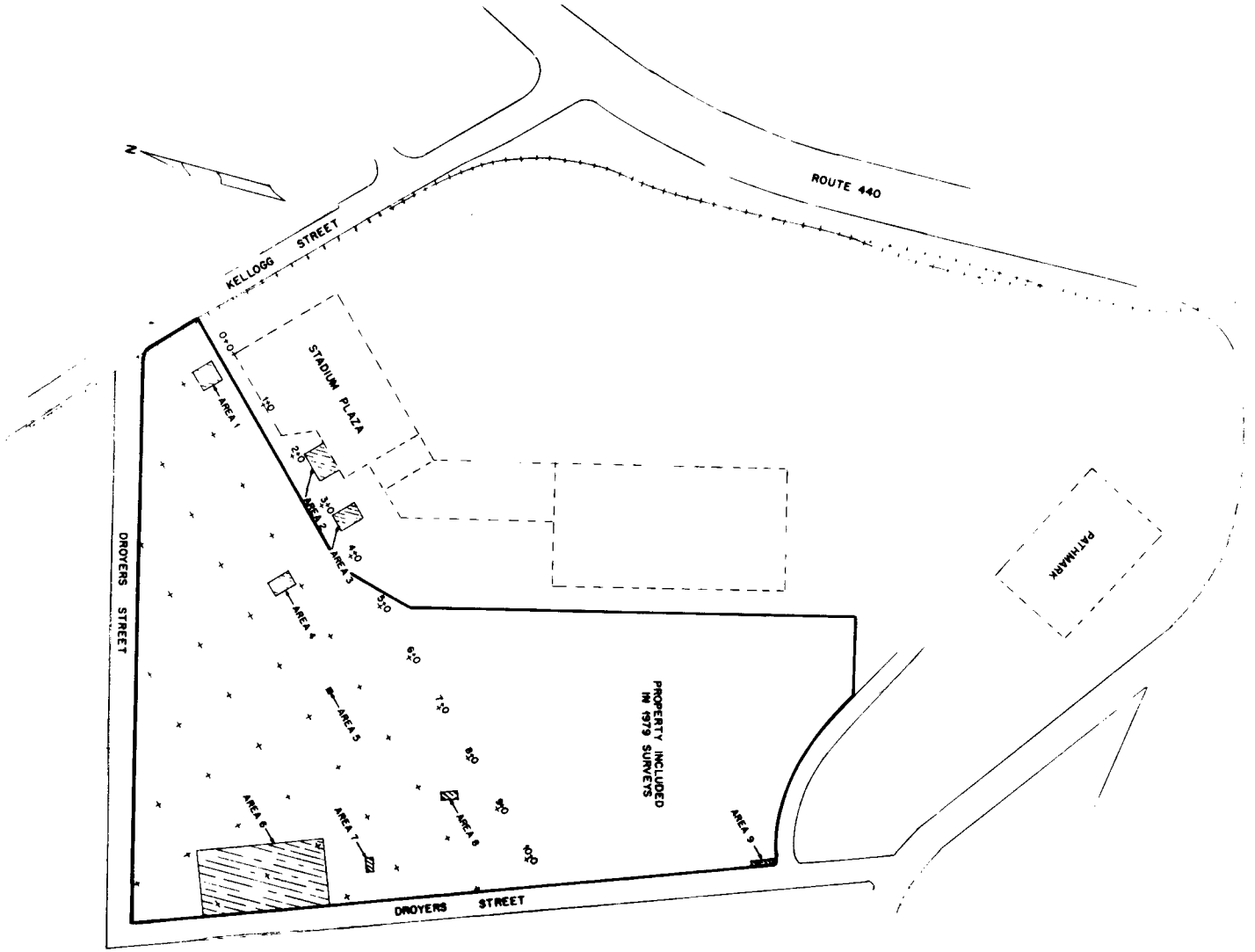

Fig. 11. Property on the Kellex site included in the 1979 surveys with identification of the nine areas where elevated external gamma exposure rates were elevated.

4. drilling and gamma logging of 27 holes on the Kellex site as a means to estimate the ^{226}Ra concentration in soil as a function of depth at locations identified in Fig. 12.

RADIOLOGICAL SURVEY TECHNIQUES

This section describes the instrumentation and techniques used to carry out the radiological surveys of the Kellex site.

External Gamma Radiation

During March, 1977, external gamma radiation level measurements were made at 1 m above the surface using NaI(Tl) scintillation survey meters which are described in Appendix III. Also, external gamma radiation levels were measured inside the machine shop, the garage, and Building X using the same type of instrument.

During the 1979 surveys, external gamma exposure rates were measured at the ground surface in that area indicated in Fig. 11. The gamma-ray scan was made in 3-m-interval traverses.

Scintillation survey meter measurements are indicative of the instantaneous exposure rates at the point of measurement. Because the response of these meters is highly energy dependent, the meter reading was normalized in the field to the exposure rate given by a Geiger-Mueller (G-M) counter[2] equipped with a filter of tin and lead to provide an instrument response nearly independent of photon energy.

Beta-Gamma Dose Rates

In March, 1977, beta-gamma dose rates of 1 cm above the surface were measured at most of the grid locations where external gamma radiation levels were measured. In the 1979 surveys, beta-gamma dose rates were measured only at those locations where low-level radioactive contamination existed. All measurements were made with G-M survey meters, which are described in Appendix III. These meters were

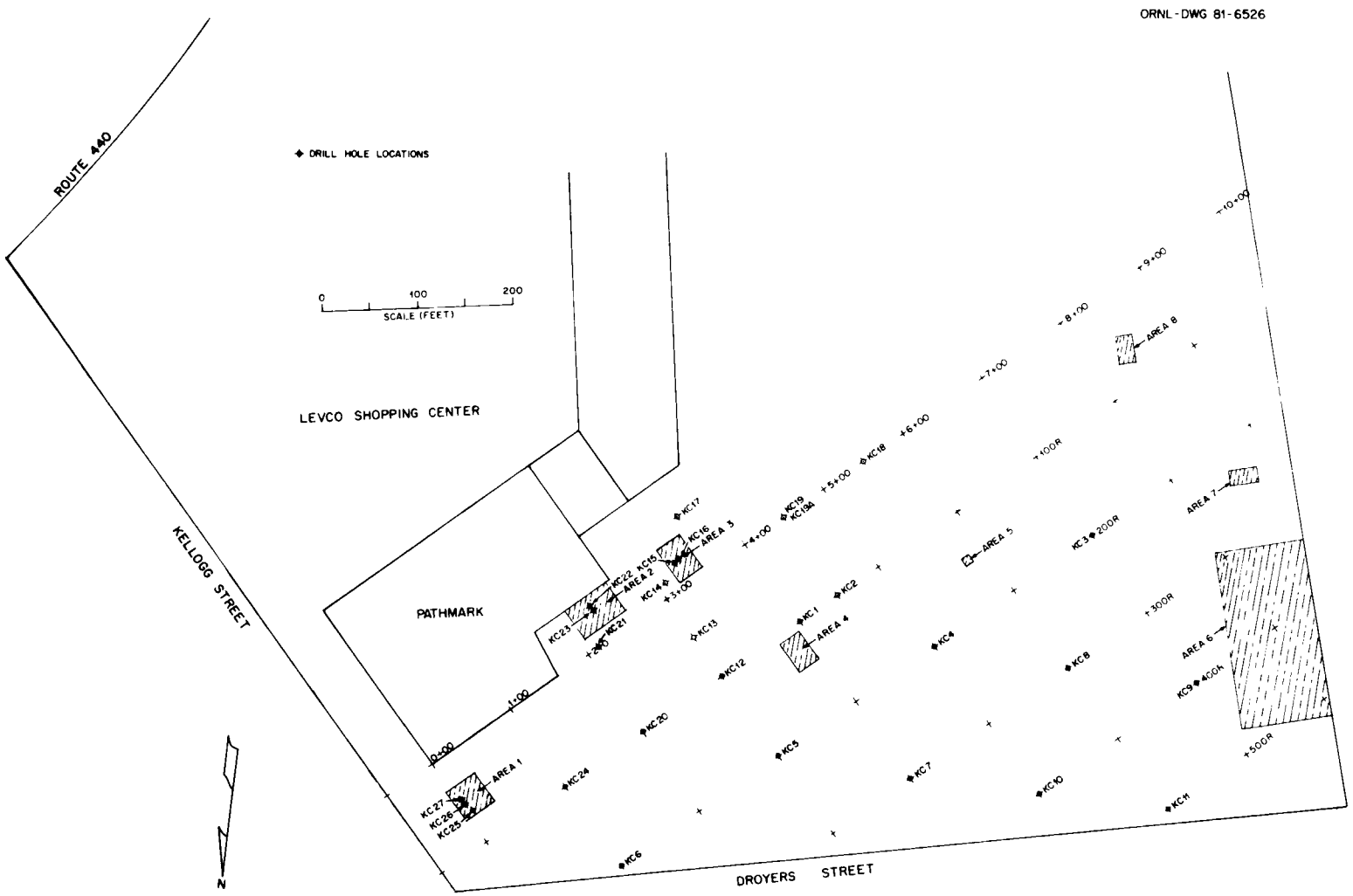

Fig. 12. Location of auger holes on the former Kellex site.

field calibrated by comparison with a Victoreen Model 440 ionization chamber to obtain beta-gamma dose rates.

Alpha and Beta Contamination

Alpha contamination levels were measured during the March, 1977, survey on the concrete pad of Building 11 and in the three buildings left standing: the garage, machine shop, and Building X. Direct readings of alpha contamination levels were made with ZnS(Ag) scintillation survey meters, which are described in Appendix III. Standard smears* were taken on an approximate 3-m grid on the concrete pad of Building 11 and counted using the smear counters described in Appendix III in order to assess the transferable alpha and beta contamination levels. No alpha or beta contamination measurements were made in the 1979 surveys since only open land was surveyed.

Soil Sampling and Analysis

Surface soil samples were taken at locations throughout the property and in drains of former Building 11 as shown in Fig. 8 during the March, 1977, survey. During the 1979 surveys, soil samples were primarily taken at those locations where elevated levels of external gamma exposure rates were observed.

The samples were packaged in plastic bags and returned to ORNL where they were dried for 24 h at 110°C and then pulverized to a particle size no greater than 500 μm in diameter. Next, aliquots from each sample were transferred to plastic bottles, weighed, and stored for approximately one month to allow the ^{226}Ra daughter products to attain secular equilibrium. The samples were counted using a Ge(Li) detector, and the spectra obtained were analyzed by computer techniques. A description of the Ge(Li) detector and soil counting techniques is given in Appendix IV. The concentrations of ^{226}Ra and ^{232}Th

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*A standard smear consists of wiping 100 cm^2 of a surface with filter paper or soft absorbent paper and counting this medium with appropriate alpha and beta detectors.

were determined for these samples. A neutron absorption technique was used to determine the concentration of ^{235}U in these samples.

Subsurface Soil Sampling

During the 1979 surveys, 27 holes were drilled in soil from the ground surface to depths between 1.5 and 3 m (5 and 10 ft) with a motorized rig using a 20-cm-diam auger. A plastic pipe (10-cm inside diameter) was placed in each hole, and a NaI(Tl) scintillation probe was lowered inside the pipe. The probe was encased in a lead shield with a horizontal row of narrow collimating slits on the side. This arrangement allowed measurements of gamma radiation intensities resulting from gamma-ray activity within small sections of the hole depth. Measurements were usually made at 31-cm (1-ft) intervals. This "logging" of the auger holes was performed in order to define the profile of radioactivity underground and to estimate the ^{226}Ra concentration as a function of depth.

The NaI(Tl) probe readings are displayed as counts per minute (cpm). It was empirically determined that a conversion factor of 2.0×10^{-3} pCi/g·cpm will yield an approximate estimate (±50%) of ^{226}Ra concentration in soil at the depth the reading was made.

Six soil samples at two drilling locations were obtained for analyses at ORNL.

Water Sampling and Analysis

Surface water samples were taken at the locations shown in Fig. 8 during the March, 1977, survey. Three groundwater samples were collected during the 1979 surveys at locations shown in Fig. 9. The samples were collected in plastic bottles and returned to ORNL for processing. The concentrations of ^{210}Pb, ^{226}Ra, ^{230}Th, ^{232}Th, and ^{238}U were determined using radiochemical techniques.

Background Measurements

External gamma radiation levels were measured at locations near, but not influenced by, former Kellex operations and at 14 locations throughout the northern section of New Jersey (Fig. 13, NJ9 through NJ23). At those locations where undisturbed soil was found, surface soil samples were taken and analyzed for ^{226}Ra, ^{232}Th, and ^{238}U using the techniques described above. Also, a water sample (W3) was taken from Newark Bay and was analyzed for ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U using standard radiochemical techniques at the ORNL Analytical Chemistry laboratory.

SURVEY RESULTS

Background Measurements

Background levels of external gamma exposure rates and radionuclide concentration in soil were measured at several locations in northern New Jersey (Fig. 13, location NJ9 through NJ23). The average external gamma exposure rate at 1 m above the surface was 6.1 μR/h and the range of measurements was 4 to 12 μR/h. Soil samples were taken at the same locations and the radionuclide concentrations averaged 1.0 pCi/g of ^{226}Ra, 1.0 pCi/g of ^{232}Th, and 1.2 pCi/g of ^{238}U.

Site Survey*

External gamma radiation

The exposure rate from external gamma radiation measurements during the March, 1977, survey at 1 m above the surface of the site averaged 6.6 μR/h, with a range of 4 to 11 μR/h. These values are the result of 133 individual measurements taken on the site on the grid points as shown in Fig. 8. The individual measurements are given in Table 1. The measurements were not significantly different from normal background for this region of the United States.

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*All values presented in this report include background radiation levels and concentrations.

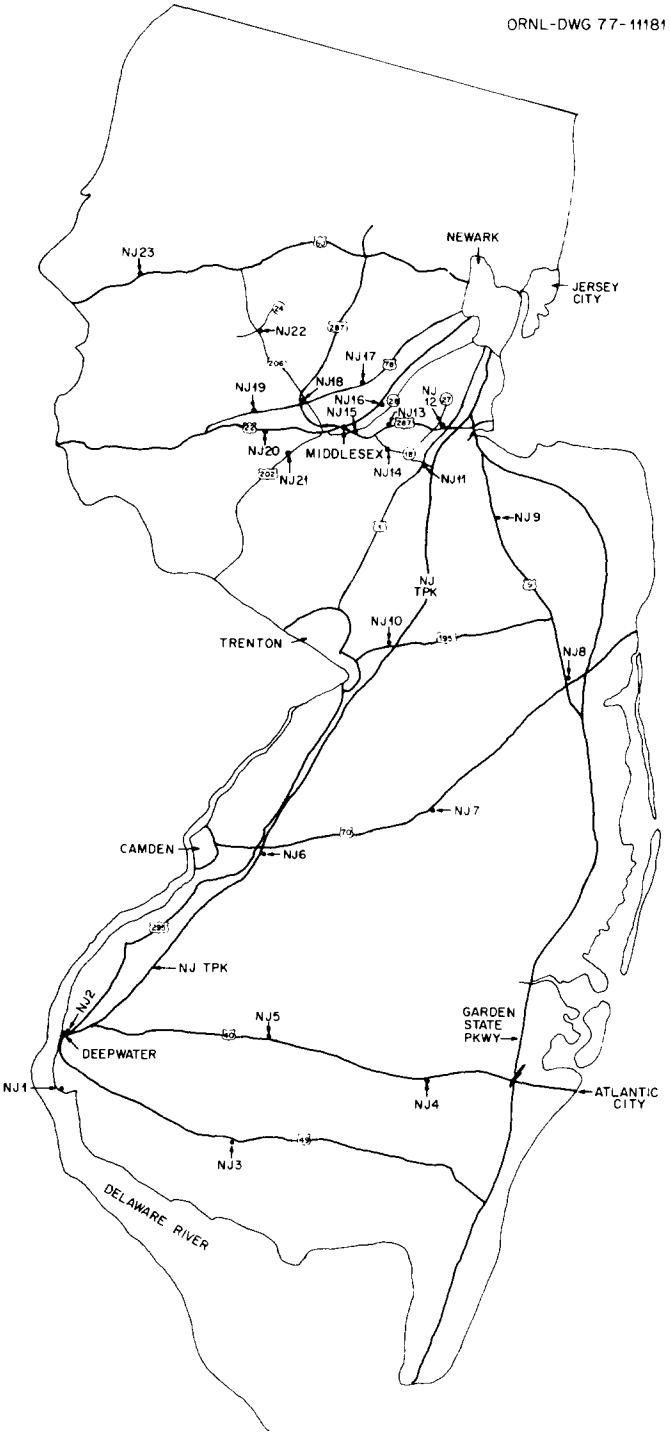

Fig. 13. Location of background measurements in the state of New Jersey.

Table 1. External gamma radiation levels at 1 m above the surface of the Kellex site during March, 1977, survey

Grid location[a]	Exposure rate (μR/hr)	Grid location[a]	Exposure rate (μR/h)	Grid location[a]	Exposure rate (μR/h)
A10	7	F 1	7	I 1	7
A11	7	F 2	8	I 2	8
A12	7	F 3	8	I 3	8
A13	8	F 4	8	I 4	4
		F 5	7	I 5	4
B 3	6	F 6	5	I 6	4
B 4	8	F 7	4	I 7	4
B 5	9	F 8	4	I 8	4
B 6	8	F 9	9	I 9	4
B 7	5	F10	7	I10	5
B 8	5	F11	8	I11	5
B 9	10	F12	7	I12	6
B10	10	F13	8	I13	8
B11	8				
B12	9	G 1	7	J 1	7
B13	8	G 2	4	J 2	6
		G 3	5	J 3	5
C 3	9	G 4	4	J 4	6
C 4	6	G 5	4	J 5	6
C 5	6	G 6	4	J 6	5
C 6	8	G 7	4	J 7	6
C 7	5	G 8	4	J 8	4
C 8	6	G 9	5	J 9	6
C 9	7	G10	7	J10	4
C10	7	G11	5	J11	6
C11	6	G12	6	J12	6
C12	8	G13	8		
C13	8			K 1	7
		H 1	7	K 2	8
D 1	7	H 2	6	K 3	7
D 2	10	H 3	6	K 4	7
D 3	11	H 4	6	K 5	7
D 4	11	H 5	6	K 6	8
D 5	9	H 6	6	K 7	6
D 6	9	H 7	4	K 8	7
D 7	9	H 8	6	K 9	7
D 8	6	H 9	6		
D 9	8	H10	6	L 3	7
D10	7	H11	6	L 4	7
D11	7	H12	6	L 5	7
D12	9	H13	8	L 6	7
D13	8			L 7	8
E 1	7			M 5	7
E 2	8			M 6	7
E 3	7				
E 4	7				
E 5	6				
E 6	6				
E 7	7				
E 8	6				
E 9	7				
E10	5				
E11	7				
E12	7				
E13	8				

[a]See Fig. 7 for grid location on site property.

External gamma exposure rate measurements were made at the ground surface in the 1979 surveys so that areas having exposure rates significantly above background were more easily identified. The property that was gamma-ray scanned during the 1979 surveys is shown in Fig. 11. Exposure rates at the ground surface ranged from approximately 6.7 μR/h to 16 μR/h and averaged approximately 11 μR/h. Large areas on the site were covered by a cinder-type fill material. Exposure rates over these areas averaged higher than on other site locations (approximately 15 μR/h) and values as high as 19 μR/h were observed.

During the March, 1977, survey, external gamma-ray measurements revealed only two areas (Area 1 and Area 2, see Fig. 11) of significant contamination on the concrete pad where Building 11 existed (see section on Survey of Building 11 Concrete Pad). During the 1979 surveys, seven additional areas were found (Areas 3-9) having significantly higher-than-background external gamma exposure rates. The location, size, and maximum external gamma exposure rate at ground surface for all nine areas found during 1977 and 1979 surveys are listed in Table 2.

The following description relates the nine areas of interest with buildings that were present during MED/AEC operations on the former Kellex site (refer to Figs. 6 and 9 for locations). Area 1 is situated on or near the former Building 24. Areas 2, 3, and 4 are situated on or adjacent to the location of former Building 11. Area 5 is situated on or near former Building 10, and Area 6 is located to the north of former Building C including the north half of that building. Area 7 is located where the south part of Building C was located. Area 8 is located between the former Buildings A and D, and Area 9 is located southeast of former Building A where no buildings were located. Only Buildings 11 and A reportedly contained the experimental gaseous diffusion operations.*

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*The use of Buildings B, C, and D is unknown but they may have been used in supporting functions for gaseous diffusion research. Thus, Areas 1, 5, and 9 could have become contaminated by post-MED use of the facilities, or by demolition and relocation of material from other contaminated structures or soils.

Table 2. Location, size, and maximum gamma exposure rate measurement (at ground surface) in areas of low-level contamination

Area[a]	Size (m)	Maximum external gamma exposure rate observed on ground surface (μR/h)
1	11 x 13	53
2	12 x 16	210
3	9 x 13	160
4	7.3 x 11	110
5	1.0 x 1.0	40
6	30 x 91	130
7	6.1 x 6.1	27
8	3.7 x 9.1	27
9	1.8 x 7.6	53

[a]Location of areas at Kellex site shown on Fig. 9.

Beta-gamma dose rates

During the March, 1977, survey, the beta-gamma dose rates at 1 cm above the surface averaged 0.02 mrad/h over the site with a range of 0.01 to 0.09 mrad/h. These values are the result of 113 individual measurements taken on most of the grid points shown in Fig. 7. The individual measurements are given in Table 3. The values obtained were not significantly different from expected background beta-gamma dose rates for this region of the United States. During the 1979 surveys, beta-gamma measurements were made to assist in defining the location and extent of those areas containing low-level contamination.

Radionuclide concentrations in surface soil

Soil samples were obtained from the site at the locations shown in Fig. 8 during the March, 1977, survey. The results of the radionuclide analyses of these samples are given in Table 4. A total of 31 samples were obtained from the general site; samples 32 through 36 were from the concrete pad area of former Building 11. Samples 32 and 36 were from old building drains, while samples 33 through 35 were scrapings from areas giving elevated radiation readings on the survey meters. The results of samples taken on the concrete pad will be discussed in the section dealing with the survey of this structure. A discussion of the results of the other samples follows.

In the 31 samples which were representative of the general site, the ^{226}Ra concentration averaged 1.2 pCi/g with a range of 0.29 to 2.4 pCi/g. The concentration of ^{232}Th averaged value 1.2 pCi/g with a range of 0.50 to 2.3 pCi/g, and the ^{238}U concentration averaged 1.2 pCi/g with a range of 0.34 to 3.3 pCi/g.

During the 1979 surveys, soil samples (and one concrete sample – K45) were obtained exclusively from Area 1 through Area 9 where elevated external gamma-ray measurements were observed. The single exception being sample K94 (Fig. 9), which was a cinder sample. This sample was obtained because elevated external gamma-ray measurements were observed above those locations covered by the cinder material.

Table 3. Beta-gamma dose rates at 1 cm above the surface of the Kellex site

Grid location[a]	Dose rate (mrad/h)	Grid location[a]	Dose rate (mrad/h)	Grid location[a]	Dose rate (mrad/h)
A12	0.02	E 6	0.01	I 1	0.02
		E 7	0.02	I 2	0.02
B 3	0.01	E 8	0.01	I 3	0.02
B 4	0.03	E 9	0.01	I 4	0.01
B 5	0.02	E10	0.01	I 5	0.01
B 6	0.04	E11	0.02	I 6	0.02
B 7	0.09	E12	0.03	I 7	0.02
B 8	0.02			I 8	0.02
B 9	0.03	F 1	0.02	I 9	0.01
B10	0.04	F 2	0.03	I10	0.03
B11	0.03	F 3	0.03	I11	0.02
B12	0.04	F 4	0.03	I12	0.02
		F 5	0.03		
C 3	0.02	F 6	0.02	J 1	0.02
C 4	0.02	F 7	0.02	J 2	0.02
C 5	0.02	F 8	0.02	J 3	0.02
C 6	0.02	F 9	0.02	J 4	0.02
C 7	0.01	F10	0.03	J 5	0.03
C 8	0.01	F11	0.02	J 6	0.02
C 9	0.02	F12	0.03	J 7	0.02
C10	0.02			J 8	0.02
C11	0.02	G 1	0.02	J 9	0.03
C12	0.03	G 2	0.02	J10	0.01
		G 3	0.01	J11	0.02
D 1	0.02	G 4	0.02		
D 2	0.02	G 5	0.02	K 1	0.02
D 3	0.02	G 6	0.02	K 2	0.03
D 4	0.02	G 7	0.01	K 3	0.05
D 5	0.03	G 8	0.02	K 4	0.03
D 6	0.02	G 9	0.02	K 5	0.02
D 7	0.03	G10	0.02	K 6	0.01
D 8	0.02	G11	0.01	K 7	0.02
D 9	0.04	G12	0.02	K 8	0.02
D10	0.03			K 9	0.02
D11	0.04	H 1	0.02		
D12	0.03	H 2	0.02	L 3	0.02
		H 3	0.02	L 4	0.03
		H 4	0.02	L 5	0.02
		H 5	0.02	L 6	0.02
		H 6	0.02	L 7	0.02
		H 7	0.02		
		H 8	0.02		
		H 9	0.02		
		H10	0.02		
		H11	0.02		
		H12	0.02		

[a]See Fig. 7 for grid location on the site property.

Table 4. Radionuclide concentrations in soil and drain pipe scale samples from the March, 1977, survey

Sample	Depth (cm)	Radionuclide concentrations (pCi/g)		
		^{238}U	^{226}Ra	^{232}Th[a]
K1	0-7.5	1.8	1.7 ± 0.04	1.5 ± 0.35
K2	0-2.5	0.64	0.69 ± 0.01	0.74 ± 0.01
K3	0-1	0.57	0.75 ± 0.06	0.69 ± 0.02
K4	0-1	0.70	0.72 ± 0.02	0.91 ± 0.03
K5	0-7.5	0.34	0.29 ± 0.03	0.50 ± 0.01
K6	0-7.5	1.8	2.0 ± 0.03	2.0 ± 0.04
K7	0-7.5	0.73	0.74 ± 0.01	0.98 ± 0.02
K8	0-7.5	0.54	0.50 ± 0.02	0.64 ± 0.03
K9	0-7.5	1.3	1.2 ± 0.03	1.3 ± 0.04
K10	0-5	0.85	0.79 ± 0.02	1.0 ± 0.02
K11	0-5	0.80	0.87 ± 0.05	0.8 ± 0.06
K12	0-7.5	0.99	0.92 ± 0.03	1.0 ± 0.03
K13	0-7.5	0.47	0.50 ± 0.04	0.50 ± 0.01
K14	0-7.5	1.1	1.2 ± 0.03	1.3 ± 0.03
K15	0-7.5	0.70	0.65 ± 0.02	0.85 ± 0.03
K16	0-5	0.45	0.23 ± 0.02	0.55 ± 0.02
L17	0-5	0.71	0.57 ± 0.02	0.75 ± 0.10
K18	0-7.5	1.1	1.2 ± 0.02	1.3 ± 0.05
K19	0-5	0.86	1.1 ± 0.08	0.91 ± 0.01
K20	0-7.5	1.9	2.4 ± 0.09	1.0 ± 0.04
K21	0-5	1.1	0.75 ± 0.02	0.83 ± 0.01
K22	0-7.5	1.6	1.9 ± 0.08	1.7 ± 0.05
K23	0-5	1.7	1.5 ± 0.05	1.5 ± 0.05
K24	0-7.5	1.6	1.8 ± 0.06	1.9 ± 0.04
K25	0-7.5	1.2	1.2 ± 0.04	1.3 ± 0.04
K26	0-5	1.2	1.3 ± 0.05	1.2 ± 0.04
K27	0-5	1.2	1.4 ± 0.03	1.3 ± 0.05
K28	0-7.5	1.6	1.9 ± 0.08	1.4 ± 0.35
K29	0-7.5	1.3	1.3 ± 0.04	1.5 ± 0.04
K30	0-7.5	3.3	1.6 ± 0.02	1.7 ± 0.04
K31	0-7.5	2.2	2.4 ± 0.04	2.3 ± 0.03
K32	Drain pipe	0.64	1.1 ± 0.12	0.82 ± 0.08
K33	0-5	11	110 ± 1.2	110 ± 1.5
K34	0-5	29	150 ± 5.1	[b]
K35	0-5	14	54 ± 0.81	270 ± 1.8
K36	Drain pipe	0.58	0.83 ± 0.04	1.3 ± 0.08

[a]Indicated statistical counting errors associated with these concentrations are two standard deviations (95% confidence interval).

[b]Radionuclide concentration was below minimum detectable concentration.

Results of the soil sample radionuclide analyses for the 1979 surveys are listed in Table 5. Maximum radionuclide concentrations observed on the Kellex site for ^{238}U, ^{226}Ra, and ^{232}Th were 2,100 pCi/g (K80 - Area 6), 340 pCi/g (K39 - Area 2), and 4,300 pCi/g (K41A - Area 1), respectively.

Radium-226 concentrations in subsurface soil

In the 1979 surveys, 27 holes were drilled at various locations on the Kellex site so that estimates of subsurface concentrations of ^{226}Ra in soil could be made. The ^{226}Ra concentration estimates for each of the 27 holes are listed in Table 6. The location of the holes is shown in Fig. 12. The estimates ranged from 0.45 pCi/g (KC27 at 0 cm depth) to 7.7 pCi/g (KC23 at 46 cm depth) of ^{226}Ra in soil, and averaged 1.5 pCi/g.

In two holes (KC19 and KC23) core soil samples were collected and analyzed for radionuclide content. The results of these analyses are listed in Table 7, for grid locations again identified in Fig. 12. Most radionuclide concentrations were elevated above background activity, but not significantly so, with the exception of sample KC19D with a ^{238}U concentration of 8.5 pCi/g of soil.

Three trenches were dug by heavy equipment in and around Area 6. Soil samples were collected at variable depths and analyzed for radionuclide content. Results of analyses are listed in Table 8 and locations of sampling sites are indicated in Fig. 9. Higher-than-background concentrations of ^{238}U or ^{226}Ra were observed in all three trenches at varying depths.

Radionuclide concentrations in water

Water samples were obtained during the March, 1977, survey from three locations on the site as shown in Fig. 8. In addition, one sample (W3) was taken from Newark Bay in the vicinity of the former Kellex site. The results of the radionuclide analyses are presented in Table 9. For the sake of comparison, the Radiation Concentration

Table 5. Radionuclide concentrations in soil samples taken during the 1979 surveys

Sample	Location[a]	Sample type	Depth (cm)	Radionuclide concentrations (pCi/g)[b]		
				^{238}U	^{226}Ra	^{232}Th
K37	Grid D7 (Area 3)	Soil	0-8[c]	5.7	270 ± 2.5	7.4 ± 1.3
K38	Grid A19 (Area 2)	Soil	Beneath 20 cm of concrete	0.71	0.68 ± 0.054	0.61 ± 0.030
K39	Grid A17 (Area 2)	Soil	0-8	11	340 ± 2.4	98 ± 1.3
K40	Area 1	Soil	10	41	*d*	2500 ± 38
K41	Area 1	Soil	15	56	*d*	3000 ± 35
K41A	Area 1	Soil	15	72	*d*	4300 ± 47
K42	Area 1	Soil	20	9.1	0.77 ± 0.050	16 ± 0.14
K43	Area 1	Soil	0-8	2.2	1.7 ± 0.080	21 ± 0.22
K44	Area 1	Soil	0-8	0.91	*d*	15 ± 0.28
K45	Area 2	Concrete	--	1.2	0.98 ± 0.018	1.8 ± 0.034
K46	4+00, 100R (Area 4)	Soil	0-8	1.5	2.6 ± 0.15	1.3 ± 0.040
K47	Area 4	Soil	0-8	2.4	13 ± 0.20	1.6 ± 0.080
K48	Area 4	Soil	0-8	2.2	4.0 ± 0.20	1.5 ± 0.080
K49	Area 4	Soil	0-8	2.7	3.4 ± 0.030	2.4 ± 0.050
K50	Area 4	Soil	0-8	2.0	4.1 ± 0.12	4.1 ± 0.12
K51	Area 4	Soil	0-8	2.2	9.2 ± 0.27	1.4 ± 0.18
K52	Area 4	Soil	0-8	1.7	2.6 ± 0.67	2.0 ± 0.60
K53	Area 4	Soil	0-8	1.7	1.4 ± 0.24	1.0 ± 0.12
K74	8+25, 430R (Area 6)	Soil	0-8	1.1	*d*	58 ± 0.73
K75	8+25, 320R (Area 6)	Soil	0-8	930	1.5 ± 0.26	1.5 ± 0.16
K76	7+50, 400R (Area 6)	Soil	0-8	5.6	*d*	94 ± 1.2
K77	8+30, 330R (Area 6)	Soil	0-8	79	1.7 ± 0.040	2.0 ± 0.010
K78	8+30, 330R (Area 6)	Soil	0-8	66	1.2 ± 0.040	1.2 ± 0.040
K79	8+30, 345R (Area 6)	Soil	0-8	810	2.0 ± 2.8	1.8 ± 0.63
K80	8+40, 398R (Area 6)	Soil	0-15	2100	*d*	*d*
K85	5+80, 145R (Area 5)	Soil	0-8	4.5	*d*	210 ± 2.4
K89	8+50, 350R (Area 6)	Soil	0-8	1300	2.0 ± 0.18	2.1 ± 0.18
K90	8+53, 48R (Area 8)	Soil	13-38	870	*d*	*d*
K91	8+75, 230R (Area 7)	Soil	0-8	110	2.3 ± 5.3	2.2 ± 7.8
K92	8+85, 235R (Area 7)	Soil	20	2.4	2.8 ± 0.027	2.9 ± 0.041
K93	Area 9	Soil	0-15	1.2	100 ± 0.65	1.8 ± 0.25
K94	8+40, 230L	Cinders	0-15	2.1	2.4 ± 0.94	2.5 ± 0.09

[a]Sample and area location is shown in Fig. 9.

[b]Indicated errors associated with these concentrations are two standard deviations (95% confidence interval).

[c]A depth of 0-8 cm was considered a surface sample.

[d]Radionuclide concentration was below minimum detectable concentration.

Table 6. Estimated ^{226}Ra concentration in soil as a function of depth at drill hole locations at the Kellex site

Sample	Grid location[a] (ft)	Estimated ^{226}Ra concentration in soil (pCi/g) Depth (m) 0	0.30	0.61	0.91	1.2	1.5	1.8	2.1	2.4	2.7	3.0	Remarks
KC 1	4+00, 100R[b]	0.95	2.1	1.9	1.8	0.76	0.83	0.92	0.85	0.79	0.80		
KC 2	5+50, 100R	1.3	1.6	1.8	2.2	1.8	1.7						
KC 3	7+00, 200R	1.6	2.1	2.5	1.8	1.1	1.4						
KC 4	5+00, 200R	1.0	1.1	1.0	1.4	1.3	1.5	1.6	1.2	1.1	1.1		
KC 5	3+00, 200R	1.2	1.6	1.7	1.7	1.1	0.83	0.93					
KC 6	1+00, 200R	1.7	1.9	1.7	1.2	1.2	1.2	1.3	1.6	1.7	1.7		
KC 7	4+00, 300R	1.2	1.6	1.5	1.3	1.0	0.95	0.49	1.1				
KC 8	6+00, 300R	1.1	1.6	1.5	1.1	1.1	0.93	1.4					
KC 9	7+00, 400R	1.3	2.2	2.1	1.5	1.7	1.7	1.7	1.8	1.4			
KC10	5+00, 400R	0.92	1.1	1.1	0.95	1.0	1.1	0.93	0.94				
KC11	6+00, 500R	1.4	2.0	1.2	1.3	1.1	1.2	1.0					
KC12	3+00, 100R	0.95	1.1	1.4	2.0	1.7	1.6	1.3	1.1	0.89	0.87		
KC13	3+00, 50R	0.55	1.1	1.4	1.2	1.2	1.4	1.4					Below concrete of Bldg. 11 pad
KC14	3+15, 15L	1.4	2.6	2.4	2.0	1.7	1.4	1.3	1.6				
KC15	3+30, 30L	1.0	1.6	1.7	1.6	1.5	1.6	1.4	1.3				
KC16	3+36, 30L	1.2	1.7	2.0	1.7	1.7	1.5	1.5	1.1	0.86			
KC17	3+65, 70L	0.75	1.1	1.1	1.3	1.1	1.0	0.99	1.5	1.7			
KC18	5+50, BL	1.1	1.9	1.7	1.6	1.8	1.2	1.7	1.9	2.0			
KC19	4+50, BL	0.95	1.4	2.2	2.2	1.9	1.6	1.6	1.3	1.1			
KC19A	4+50, BL	0.93	1.6	2.4	2.1	1.8	1.8	1.8					Core hole 1.5 m right of KC19
KC20	2+00, 100R	1.0	1.7	1.3	1.7	1.7	1.6	1.8					
KC21	2+10, BL	1.1	1.5	1.6	2.1	2.2	1.9	1.6	1.5	1.6	1.4	1.2	
KC22	2+30, 40L	1.4	1.8	1.4	1.9	1.9	1.8	1.9	1.9	1.6	1.4		
KC23	2+30, 32L	1.6	5.2	3.3	2.8	2.6	2.3	2.3	1.6	1.6			
KC23	2+30, 32L	@ 0.5 ft: 2.6 pCi/g; @ 1.5 ft: 7.7 pCi/g; @ 2.5 ft: 2.8 pCi/g											
KC24	1+00, 100R	0.90	1.2	1.2	1.1	1.3	1.2	1.2	1.4				
KC25	0+ 8, 65R	0.69	0.94	1.0	0.96	0.87	1.3	1.4	1.1	0.92	1.0	1.3	Below concrete of Bldg. 24 pad
KC26	0+ 5, 55R	0.91	1.5	1.1	0.90	0.89	1.1	1.4	1.4	1.5	1.3	1.0	
KC27	0+ 5, 50R	0.45	0.91	1.0	1.1	0.88	0.96	1.6	1.5	1.2	1.1	1.2	

[a]Location is identified in Fig. 12.

[b]R = right of base line; L = left of base line; BL = on base line.

Table 7. Radionuclide content of core samples from the Kellex site

Sample	Location[a]	Depth (cm)	Radionuclide concentrations (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
KC19A	4+50, BL	0-3	0.69	0.61 ± 0.010	0.82 ± 0.030
KC19B	4+50, BL	3-5	0.84	1.1 ± 1.5	1.2 ± 4.9
KC19C	4+50, BL	5-8	1.9	2.1 ± 0.030	2.1 ± 0.040
KC19D	4+50, BL	8-10	8.5	3.6 ± 0.060	2.0 ± 0.040
KC19E	4+50, BL	10-13	2.0	2.1 ± 0.030	2.1 ± 0.040
KC19F	4+50, BL	13-18	1.7	1.8 ± 0.030	1.7 ± 0.040
KC23A	2+30, 32L	0-46	0.70	0.67 ± 0.010	0.82 ± 0.020

[a]Grid location may be identified in Fig. 12.

[b]Indicated errors associated with these concentrations are two standard deviations.

Table 8. Radionuclide concentrations in soil taken from trenches on Kellex site during 1979 surveys

Sample[a]	Depth (cm)	Radionuclide concentrations (pCi/g)[b]		
		^{238}U	^{226}Ra	^{232}Th
KT11A	0-20	5.4	1.4 ± 0.020	1.4 ± 0.020
KT11B	90	2.2	2.4 ± 0.030	2.3 ± 0.040
KT11C	180	0.31	0.37 ± 0.010	0.57 ± 0.020
KT12A	0-30	5.1	1.8 ± 0.020	1.6 ± 0.040
KT12B	90	1.9	1.6 ± 0.030	1.6 ± 0.030
KT12C	180	0.34	0.43 ± 0.010	0.54 ± 0.020
KT13A	0-30	1.6	1.7 ± 0.027	1.6 ± 0.035
KT13B	30-46	4.6	9.1 ± 0.090	4.0 ± 0.060
KT13C	180	0.55	0.52 ± 0.020	0.66 ± 0.020

[a]Locations are shown in Fig. 9.

[b]Indicated errors associated with these concentrations are two standard deviations.

Table 9. Radionuclide concentrations in water samples during March, 1977, survey

Sample	Radionuclide concentrations (pCi/L)[a]			
	^{210}Pb	^{226}Ra	^{230}Th	^{238}U
W1	1.1 ± 0.58	0.032 ± 0.036	0.086 ± 0.036	1.2 ± 0.09
W2	<0.77	0.13 ± 0.09	0.022 ± 0.022	0.63 ± 0.22
W3	0.18 ± 0.67	0.027 ± 0.045	0.045 ± 0.045	0.90 ± 0.045
W4	<0.86	0.13 ± 0.09	0.045 ± 0.022	0.21 ± 0.01
RCG_w	100	30[b]	2,000	40,000

[a]Indicated errors associated with these concentrations are two standard deviations.

[b]The EPA drinking water standard for radium is 5 pCi/L, including both ^{226}Ra and ^{228}Ra.

Guide in water* (RCG_w) for nonoccupational exposure[3] is also given in Table 9. The concentrations of ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U are all at least an order of magnitude less than the corresponding RCG_w. The radium concentrations are also at least an order magnitude lower than the Environmental Protection Agency's (EPA) drinking water standard for radium.[4]

Three water samples were obtained during the 1979 surveys from locations shown in Fig. 9. Results of radionuclide analyses are listed in Table 10. All concentrations were one to several orders of magnitude less than the radiation concentration guides for these radionuclides in water.

Building surveys

A radiological survey was conducted in the machine shop (Fig. 7) during the March, 1977, survey. For 29 readings of external gamma radiation, the average exposure rate was 5 μR/h and the average beta-gamma dose rate was 0.03 mrad/h. These levels were nearly uniform throughout the building. All direct measurements of alpha contamination indicated <100 dpm/100 cm^2.

The radiological survey of the garage (Fig. 7) yielded gamma-ray exposure rates of 5 to 6 μR/h at 1 m and an average beta-gamma dose rate of 0.03 mrad/h at 1 cm for 12 measurements of each. The direct alpha contamination levels were all <100 dpm/100 cm^2.

Radiation measurements were made at 88 locations in Building X (Fig. 7). The average gamma exposure rate at 1 m was 6 μR/h and the average beta-gamma dose rate at 1 cm was 0.02 mrad/h. Both the exposure rates and dose rates were nearly uniform throughout the building. Again, all direct readings of alpha contamination indicated <100 dpm/100 cm^2.

At the time of the 1979 surveys, the buildings indicated in Fig. 7 had been removed from the site.

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*This is also commonly referred to as maximum permissible concentration (MPC_w) (c.f. NCRP Report No. 22, 1959).

Table 10. Radionuclide concentrations in water samples collected during the 1979 surveys

Sample[a]	Radionuclide concentrations (pCi/L)[b]				
	^{210}Pb	^{226}Ra	^{230}Th	^{238}U	^{232}Th
KTW11	<9.0	0.45 ± 0.45	0.90 ± 0.90	9.3 ± 1.9	0.90 ± 0.90
KTW12	<9.0	0.45 ± 0.45	0.45 ± 0.45	3.3 ± 1.7	0.45 ± 0.45
KTW13	<9.0	0.45 ± 0.45	1.4 ± 1.4	1.0 ± 1.0	1.4 ± 1.4
RCG_w	100	30[c]	2,000	40,000	2,000

[a]Locations of samples shown in Fig. 9.

[b]Indicated errors associated with these concentrations are two standard deviations.

[c]The EPA drinking water standard for radium is 5 pCi/L, including both ^{226}a and ^{228}Ra.

Survey of Building 11 concrete pad

A thorough radiological survey was conducted in the area formerly occupied by Building 11, the old Kellex Laboratory, during the March, 1977, survey. All that remained of this structure was a concrete pad, located as shown in Fig. 7. During the 1979 surveys, much of this concrete pad had been removed as a result of site development.

The results of the alpha and beta-gamma contamination surveys are given in Table 11. The survey locations for these measurements are shown by the grid blocks in Fig. 10. The direct readings of alpha contamination, when averaged over 1 m^2, were all less than 30 dpm/100 cm^2. One spot of 100 cm^2 in grid block A19 (Fig. 10) gave an alpha reading of 3,000 dpm/100 cm^2. The beta-gamma dose rates when averaged over 1 m^2 were generally less than 0.03 mrad/h. Three exceptions were grid blocks B19, E5, and F6 which had beta-gamma dose rates of 0.14, 0.05, and 0.05 mrad/h, respectively. Significantly higher activity was found in one area of 100 cm^2 in grid block A19 where a beta-gamma dose rate of 0.6 mrad/h was measured. Also, one area in grid block B6 had a beta-gamma dose rate of 0.04 mrad/h.

The results of measurements of transferable alpha and beta contamination are also given in Table 11. The transferable alpha contamination, when averaged over 1 m^2, was always less than 20 dpm/100 cm^2, and the beta contamination was always less than 200 dpm/100 cm^2 when averaged in the same manner. One area of 100 cm^2 in grid section A19 had smear readings (smear located by an asterisk in Fig. 14) of 330 dpm/100 cm^2 alpha and 310 dpm/100 cm^2 beta-gamma.

The external gamma radiation level was measured at 1 m above the floor surface at each of the grid intersections in Fig. 10. For the total of 105 readings, the average exposure rate was 6.6 μR/h, with a range of 5 to 12 μR/h. The individual gamma-ray measurements are presented in Table 12.

Most of the grid sections identified in Fig. 14 had radiation and contamination levels near background. However, readings from a few grid sections were elevated. In grid section B6, maximum readings of 23 μR/h gamma and 0.04 mrad/h beta-gamma at 1 cm above the surface were

Table 11. Alpha and beta-gamma levels on the concrete pad of former Kellex Laboratory Building 11

Grid location[a]	Direct reading[b]		Transferable contamination[c]	
	Alpha (dpm/100 cm^2)	Beta-gamma (mrad/h)	Alpha (dpm/100 cm^2)	Beta-gamma (dpm/100 cm^2)
A 1	<30	<0.03	4	0
A 2	<30	<0.03	0	34
A 5	<30	<0.03	4	34
A 7	<30	<0.03	0	86
A 9	<30	<0.03	0	86
A11	<30	<0.03	0	69
A13	<30	<0.03	0	69
A15	<30	<0.03	9	17
A17	<30	<0.03	0	0
A19	<30 3000[d]	<0.03 0.6[d]	0 326[d]	17 310[d]
B 2	<30	<0.03	0	52
B 4	<30	<0.03	0	172
B 6	<30	<0.03 0.04[d]	4	0
B 8	<30	<0.03	0	103
B10	<30	<0.03	0	0
B12	<30	<0.03	4	0
B14	<30	<0.03	0	0
B16	<30	<0.03	0	0
B18	<30	<0.03	4	0
B19	<30	0.14	--	--
B20	<30	<0.03	0	0
C 1	<30	<0.03	4	0
C 3	<30	<0.03	9	0
C 5	<30	<0.03	0	103
C 7	<30	<0.03	4	138
C 9	<30	<0.03	0	0
C11	<30	<0.03	0	0
C13	<30	<0.03	0	0
C15	<30	<0.03	4	86
C17	<30	<0.03	4	52
C19	<30	<0.03	0	0
D12	<30	<0.03	0	34
D14	<30	<0.03	0	0
D16	<30	<0.03	0	0
E 5[e]	<30	0.05	--	--
E11	<30	<0.03	0	34
E13	<30	<0.03	0	0
E15	<30	<0.03	0	0
F 6[e]	<30	0.05	--	--
F12	<30	<0.03	0	0
F14	<30	<0.03	0	52
F16	<30	<0.03	0	120

[a]See Fig. 10 for grid locations.

[b]Direct readings are averaged over 1 m^2 (unless otherwise indicated) in the respective grid block. Beta-gamma dose rates are measured at 1 cm above the surface.

[c]Transferable contamination measurements are averaged over 1 m^2 (unless otherwise indicated) in the respective grid block. A zero measurement indicates a smear count less than or equal to background.

[d]This represents a maximum reading averaged over not more than 100 cm^2

[e]This location is not on the concrete pad proper but is on the ground near the pad.

Table 12. External gamma-ray exposure rate at 1 m above the concrete pad of former Kellex Laboratory Building 11

Grid location[a]	Exposure rate (μR/h)	Grid location[a]	Exposure rate (μR/h)	Grid location[a]	Exposure rate (μR/h)
A 1	6	C 1	6	E11	6
A 2	6	C 2	5	E12	5
A 3	6	C 3	6	E13	5
A 4	6	C 4	6	E14	5
A 5	6	C 5	6	E15	5
A 6	5	C 6	5	E16	5
A 7	6	C 7	5	E17	5
A 8	6	C 8	5		
A 9	6	C 9	6	F11	5
A10	5	C10	5	F12	6
A11	5	C11	5	F13	6
A12	5	C12	5	F14	5
A13	5	C13	5	F15	5
A14	5	C14	5	F16	5
A15	5	C15	5	F17	6
A16	5	C16	5		
A17	6	C17	6	G11	5
A18	7	C18	7	G12	5
A19	9	C19	7	G13	5
A20	5	C20	12	G14	6
A21	5	C21	7	G15	5
				G16	5
B 1	6	D 1	7	G17	6
B 2	6	D 2	7		
B 3	6	D 3	6		
B 4	5	D 4	6		
B 5	6	D 5	6		
B 6	5	D 6	5		
B 7	5	D 7	5		
B 8	5	D 8	6		
B 9	5	D 9	6		
B10	5	D10	6		
B11	5	D11	6		
B12	5	D12	5		
B13	5	D13	5		
B14	5	D14	5		
B15	5	D15	5		
B16	5	D16	5		
B17	8	D17	5		
B18	9	D18	6		
B19	8	D19	6		
B20	9	D20	6		
B21	7	D21	7		

[a]See Fig. 10 for grid point locations.

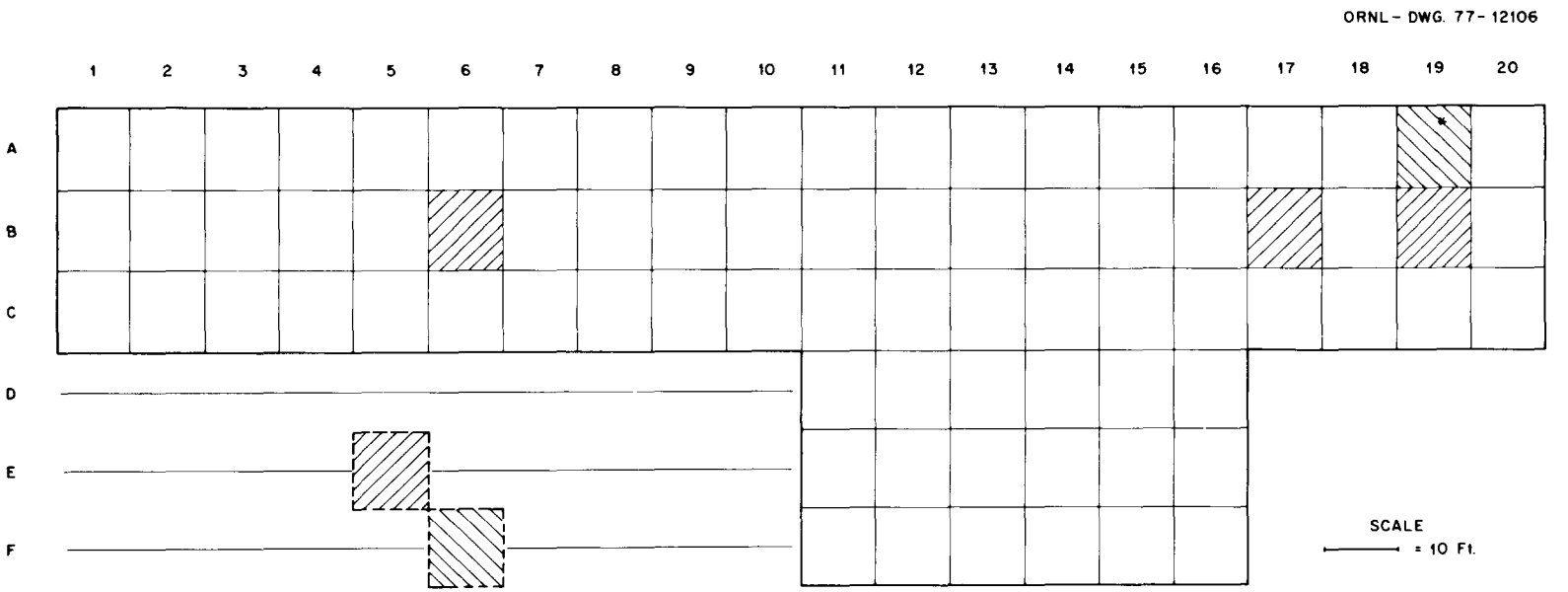

Fig. 14. Concrete pad areas of former Building 11 (contaminated areas are shaded).

measured. The readings in grid section B17 indicated a maximum gamma-ray exposure rate of 72 μR/h at the surface. In grid section B19, the beta-gamma dose rate averaged 0.14 mrad/h over a 1-m^2 area, and the maximum gamma-ray exposure rate was 110 μR/h at the surface. The highest radiation measurements on the concrete pad were found in grid section A19. The maximum readings here were 3,000 dpm/100 cm^2 alpha, 0.6 mrad/h beta-gamma, and 136 μR/h gamma at the surface. Three samples of dirt (samples 33 to 35 in Table 4) were scraped from section A19. These samples had elevated concentrations of the measured radionuclides. The fact that these measurements are at elevated levels indicates that some kind of uranium- and thorium-bearing materials were probably stored or handled at this isolated spot of section A19 at some previous time. The drain pipe scale samples (K32 and K36) showed no elevated radionuclide concentrations.

Radiation measurements taken in the area surrounding the concrete pad for former Building 11 were essentially background, with the exception of one small area located in grid sections E5 and F6 (Fig. 14). In section E5, the beta-gamma dose rate averaged 0.05 mrad/h and gamma exposure rates averaged 18 μR/h at the surface over a 1-m^2 area. In section F6, maximum readings of 0.8 mrad/h beta-gamma and 80 μR/h gamma were measured at the surface.

The two areas where elevated activity was observed during the March, 1977, survey were redesignated in the 1979 surveys. Grid section A19 was enlarged and called Area 2, and grids E5 and F6 were consolidated into Area 3.

SUMMARY AND CONCLUSIONS

A summary of the survey results is provided in Table 13. Excluding the nine areas noted earlier in this report and identified in Fig. 9, the mean external gamma-ray exposure rates observed on the Kellex site (6.6 μR/h) were similar to those mean background exposure rates observed in northern New Jersey (6.1 μR/h). The exposure guideline for an individual in the general public is 500 mrem/y,[2] which is considerably higher than any conceivable exposure that an individual might receive on the Kellex site.

Table 13. Summary of survey results at the former Kellex Research Facility in Jersey City, New Jersey

Survey technique	Number of measurements or samples taken	Range of values	Arithmetic mean and standard deviaion[a] $\bar{x} \pm s$	Geometric mean and geometric standard[a] deviation $\bar{x}_g : s_g$
Grid point measurements				
Gamma exposure rate at 1 m (μR/h)[b]	133	4-11	6.6 ± 1.6	6.4:1.3
Beta-gamma dose rate at 1 cm (mrad/h)[c]	113	0.01-0.09	0.02 ± 0.01	0.02:1.5
Soil sampling				
1977 survey (excluding Areas 4-9)[d]				
^{238}U (pCi/g)	34	0.45-29	2.7 ± 5.4	1.3:2.6
^{226}Ra (pCi/g)	34	0.29-150	10 ± 32	1.5:4.1
^{232}Th (pCi/g)	33	0.50-270	13 ± 50	1.5:3.7
1979 survey (Areas 1-9)[e]				
^{238}U (pCi/g)	31	0.71-2100	210 ± 480	12:12
^{226}Ra (pCi/g)	23	0.68-340	33 ± 89	4.1:5.6
^{232}Th (pCi/g)	31	0.61-4300	330 ± 1000	8.0:12
Water sampling				
(1977 and 1979 surveys)[f]				
^{238}U (pCi/L)	7	0.21-1.3	2.4 ± 3.2	1.2:3.4
^{230}Th (pCi/L)	7	0.022-1.4	0.42 ± 0.54	0.16:5.2
^{226}Ra (pCi/L)	7	0.027-0.45	0.24 ± 0.20	0.14:3.4
^{210}Pb (pCi/L)	2	0.18-1.1	[g]	[g]
Concrete pad at location of formerly Building 11[h]				
Direct alpha (dpm/100 cm^2)	42	<30-3000	[g]	[g]
Beta-gamma dose rate at 1 cm (mrad/h)	44	<0.03-0.6	[g]	[g]
Gamma exposure rate at 1 m (μR/h)	105	5-12	6.6 ± 8.7	5.8:1.4
Transferable alpha contamination (dpm/100 cm^2)	40	0-326	9.6 ± 51	[g]
Transferable beta-gamma contamination (dpm/100 cm^2)	40	0-310	42 ± 63	[g]

[a] Standard deviations are 1 σ (± 68%).

[b] See Table 1 for data.

[c] See Table 3 for data.

[d] See Table 4 for data.

[e] See Tables 5 and 8 for data.

[f] See Tables 9 and 10 for data.

[g] Too few values to adequately analyze.

[h] See Tables 11 and 12 for data.

Results of soil and water samples show the radionuclide concentrations are at normal background levels on the site except for samples originating from the nine contaminated areas. The average soil concentrations of radionuclides found on the site, excluding those nine areas, were 1.2 pCi/g of ^{226}Ra, 1.2 pCi/g of ^{232}Th, and 1.2 pCi/g of ^{238}U. These were not statistically different from the background levels found in the northern part of the state of New Jersey. From the nine areas, maximum radionuclide concentrations of ^{238}U, ^{226}Ra, and ^{232}Th in surface soil were 2,100 pCi/g (Area 6), 340 pCi/g (Area 2), and 4,300 pCi/g (Area 1), respectively. Radionuclide concentrations in on-site water samples were at least an order of magnitude below accepted concentration guidelines for drinking water.

The nine areas containing higher-than-background concentrations of radioactive material constitute a total area of approximately 3,350 m^2 (0.83 acre). These areas contain varying mixtures of radionuclides from the uranium and thorium decay chains in concentrations significantly above background exceeding federal guidelines (Appendix V). An evaluation of potential hazard relative to the contamination present in these nine areas is presented in Appendix VI.

REFERENCES

1. Personal communication, Jack Terrel, Oak Ridge Y-12 Plant, Oak Ridge, TN (February 1981).
2 E. B. Wagner and G. S. Hurst, "A Geiger-Mueller Gamma-Ray Dosimeter with Low Neutron Sensitivity," *Health Phys.* 5, 20 (1961).
3. *Code of Federal Regulations,* Title 10, Part 20, "Standards for Protection Against Radiation."
4. *Code of Federal Regulations,* Title 40, Part 141, "Interim Primary Drinking Water Regulations."

APPENDIX I

PREVIOUS RADIOLOGICAL SURVEY OF KELLEX SITE

VITRO CORPORATION OF AMERICA

June 25, 1953

Contamination Status Report
Jersey City Laboratory

A final radiation and contamination survey of the Jersey City Laboratory was made with the purpose of determining the amount of residual contamination remaining after extensive decontamination procedures had been undertaken. Results indicate that the laboratory is free from excessive contamination.

Two (2) reports issued by the New York Office of the Commission, namely, "Status of Building Contamination at Kellex Laboratories" and "Second Contamination and Radiation Survey at Kellex Laboratory" dated September 29, 1949, and December 19, 1949, respectively, were used as guides for establishing standards of radioactive contamination which would not be considered significant as potential health hazards.

A set of specific maximum permissible limits were obtained from an AEC report (NYO-1536), "Decontamination and Survey of Uranium Refinery Plant" as follows:

0.9 mrep/hr - worst contact,
9.6 mrep/hr - worst operating position,
0.3 mrep/hr - average at 3 ft from the floor.

The MPCs for transferable contamination in accessible areas were chosen as 0 alpha d/m/sm* and 1,000 beta d/m/sm.

Summary

With but two exceptions (0.6 mrep/hr in chemical storage area and 0.2 mrep/hr in Laboratory 3), the radiation level in the Jersey City Laboratory is below that reported in "Second Contamination and Radiation Survey at Kellex Laboratory" dated December 19, 1949. In neither instance is the maximum permissible limit of 0.9 mrep/hr at point of worst contact exceeded.

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*Authors believe original report to mean smear where "sm" is an abbreviation.

No transferable alpha or beta-gamma contamination was observed in any of the accessible areas.

The ductwork (not included in Commission survey reported December 1949) leading from the laboratory exhaust hoods in Laboratories 3 and 5 gave evidence of transferable alpha ranging from 300 to 500 d/m/smear, whereas beta-gamma contamination was negligible. However, we understand from Commission personnel that the ductwork should not be considered an accessible area; therefore, the stringent requirement of "no transferable alpha" would not be applicable.

The contamination in the ductwork is virtually 100% normal uranium. It may be estimated that each contaminated duct contains approximately 100 mg of normal uranium as compared with the established maximum allowable amount of 30 mg of normal uranium within the body.

Survey Methods and Instruments

Each laboratory was surveyed by a random method. The rooms were divided into imaginary squares (ca. 3 ft x 3 ft), and a smear test was made in order to determine levels of transferable contamination. Smears were counted both in an alpha scintillation counter and a beta-gamma geiger counter (end window).

The model 2610 IDL beta-gamma survey meter was used for the radiation survey. Since the only alpha active materials ever used in the laboratory were in normal uranium and pitchblende, the IDL meter, by showing no beta-gamma contamination also indicated no alpha contamination. This instrument was chosen mainly because of its good sensitivity and fast reaction which allowed us to scan large areas in order to spot any localized contamination. All recorded measurements are readings made at the point of worst contact unless otherwise specified.

Survey Results

Laboratories 1 and 2. These laboratories were surveyed on March 6, 1953, previous to occupancy by the M. W. Kellogg Company personnel. The maximum radiation levels observed within the ductwork showed a maximum beta-gamma count of 150 d/m, whereas alpha contamination was found to be negligible. Since the tolerance level of beta-gamma smears is 1,000 β-γ d/m/sm, the beta-gamma contamination

recorded may be considered insignificant. All other radiation readings taken in accessible areas, such as floors, desks, hood surfaces, and fixtures approached normal background of 0.02 mrep/hr. Smears yielded insignificant counts.

Laboratory 3. A final survey in this laboratory indicated a maximum radiation level of 0.2 mrep/hr in hood section B. All smear tests yielded negative results. Ductwork in Laboratory 3 showed maximum transferable contamination levels of 500 α d/m/sm; β-γ contamination within the ductwork was negligible.

Laboratory 4. The maximum radiation level in this laboratory was found in hood section C (0.05 mrep/hr). This area was used as the analytical section where levels of activity handled were very low and where, since April, 1952, no radioactive material had been processed.

Laboratory 5. Hood sections A and C indicated the highest radiation level of 0.1 mrep/hr. Transferable alpha contamination was observed in the ductwork from hood section A (300 d/m/sm). The average radiation level measured off the floor approached 0.05 mrep/hr. All smears yielded negative results.

Laboratory 6. The maximum radiation level observed here was measured at 0.08 mrep/hr in hood section B. All other areas were found to approach normal background and were found to be free from transferable contamination. No significant transferable contamination was observed in the duct system.

Physics Laboratory. All radiation levels observed approached a normal background of 0.02 mrep/hr. All smear tests taken yielded negative results.

Pilot Area. A final survey of this area indicated radiation levels not exceeding 0.1 mrep/hr. Transferable alpha and beta-gamma contamination is negligible.

Chemical Storage Area. The maximum radiation level (0.6 mrep/hr) was observed off the wall immediately to the left of the entrance to the area. The average radiation level off the floor was ca. 0.01 mrep/hr with a maximum of 0.2 mrep/hr.

Fenced-In Area. There was evidence of some slight overall contamination here which showed background to approach a level of 0.05 mrep/hr (ca. two times normal background). The maximum level observed on the concrete matting did not exceed 0.1 mrep/hr.

Halls, Corridors, Counter Room, Closets, and General Office Area. All radiation levels observed approached a normal background of 0.02 mrep/hr. All smear tests taken yielded negative results.

APPENDIX II

STANDARD UNITS OF MEASUREMENT

The following table has been developed for use with this report in the conversion of units of measurement from those utilized in the text to the newly adopted International System of Units (SI). Units used in the text which do not appear in this table are considered as standard under the new system.

Table II-1. Standard units of measurement

To convert from	Into SI units	Multiply by
gallons (gal)	liters (L)	3.785
inches (in)	centimeters (cm)	2.540
square inches (in^2)	square centimeters (cm^2)	6.452
feet (ft)	meters (m)	0.3048
square feet (ft^2)	square meters (m^2)	0.0929
acres (a)	hectare (ha)	0.4047
miles (mi)	kilometer (km)	1.609
millirad (mrad)	microgray (μGy)	10.0
microroentgen (μR)	coulomb per kilogram (C/kg)	2.58×10^{-10}
disintegrations per minute (dpm)	becquerel (Bq)	0.02
picocurie (pCi)	becquerel (Bq)	0.037
microcurie (μCi)	becquerel (Bq)	3.7×10^{4}

APPENDIX III

DESCRIPTION OF RADIATION SURVEY METERS AND SMEAR COUNTERS

RADIATION SURVEY METERS

Alpha Survey Meters

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

The alpha scintillation survey meter consists of a large area (100 cm^2) ZnS(Ag) detector with a photomultiplier tube in the probe which is coupled to a portable scaler/ratemeter (Fig. III-A). The ZnS(Ag) detector is covered with a 0.03-mil aluminized mylar sheet in order to make the instrument light-tight. The mylar, in turn, is covered with a grid to prevent puncturing the detector when surveying over rough surfaces. This instrument is capable of measuring alpha surface contamination levels of a few dpm/100 cm^2 but must be used in the scaler mode for this purpose. It is highly selective for densely ionizing radiation such as alpha particles, and the instrument is relatively insensitive to beta and gamma radiation.

The gas-flow proportional counter uses propane gas as the detection medium. Through front panel meter readings, it can be used to measure alpha contamination levels from a few hundred dpm/100 cm^2 to several hundred thousand dpm/100 cm^2. If individual pulses are counted, this instrument can also be used for measurements down to a few dpm/100 cm^2. The probe has a surface area of approximately 61 cm^2 and has a 0.03-mil aluminized mylar covering with a protective grid. Due to the protective grid, the active area of the probe is 50 cm^2. It is relatively insensitive to other than alpha radiation. This instrument, shown in Fig. III-B, is manufactured by the Eberline Instrument Company as their model PAC-4G meter with a probe.

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

ORNL-Photo 6705-76

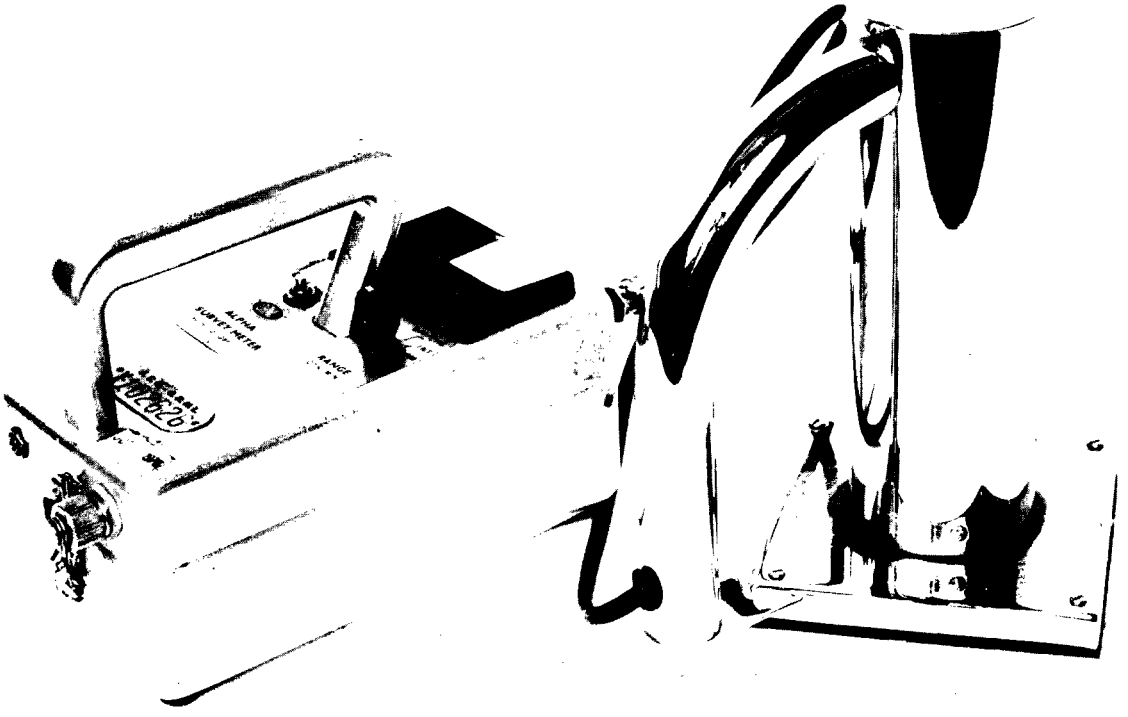

Fig. III-A. Alpha scintillation survey meter.

ORNL-Photo 6715-76

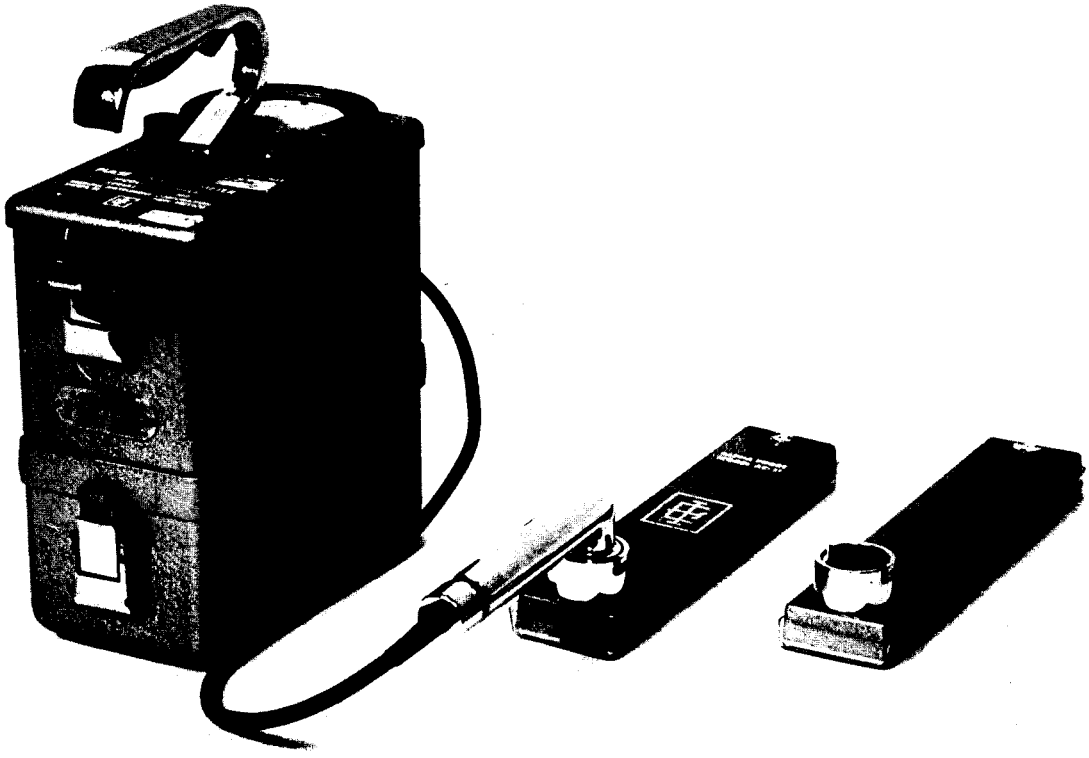

Fig. III-B. Gas-flow proportional alpha survey meter.

Beta Survey Meter

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

The G-M survey meter is calibrated at ORNL for gamma radiation using a National Bureau of Standard (NBS) standard Ra source. The gamma calibration factor is typically of the order of 3,200 cpm per mR/h.

In order to assess beta-gamma surface dose rates from uranium-contaminated surfaces using this instrument, a field calibration was performed. The G-M survey meter was compared with a Victoreen Model 440 ionization chamber (Fig. III-D) and was found to produce 2,300 cpm per mrad/h with a 25% standard deviation for a wide variety of surfaces, including concrete, wood, pavement, bricks, and steel beams.

Gamma Scintillation Survey Meter

A portable survey meter using an NaI scintillation probe is used to measure low-level gamma radiation exposure. The scintillation probe is a 3.2 x 3.8-cm NaI(Tl) crystal coupled to a photomultiplier tube. This probe is connected to a Victoreen Model Thyac III ratemeter (Fig. III-E). This unit is capable of measuring radiation levels from a few μR/h to several thousand μR/h. This instrument is calibrated at ORNL with an NBS standard ^{226}Ra source. Typical calibration factors are on the order of 500 cpm per μR/h. The response of this meter is highly energy dependent. In the field, a G-M detector

ORNL-Photo 6704-76

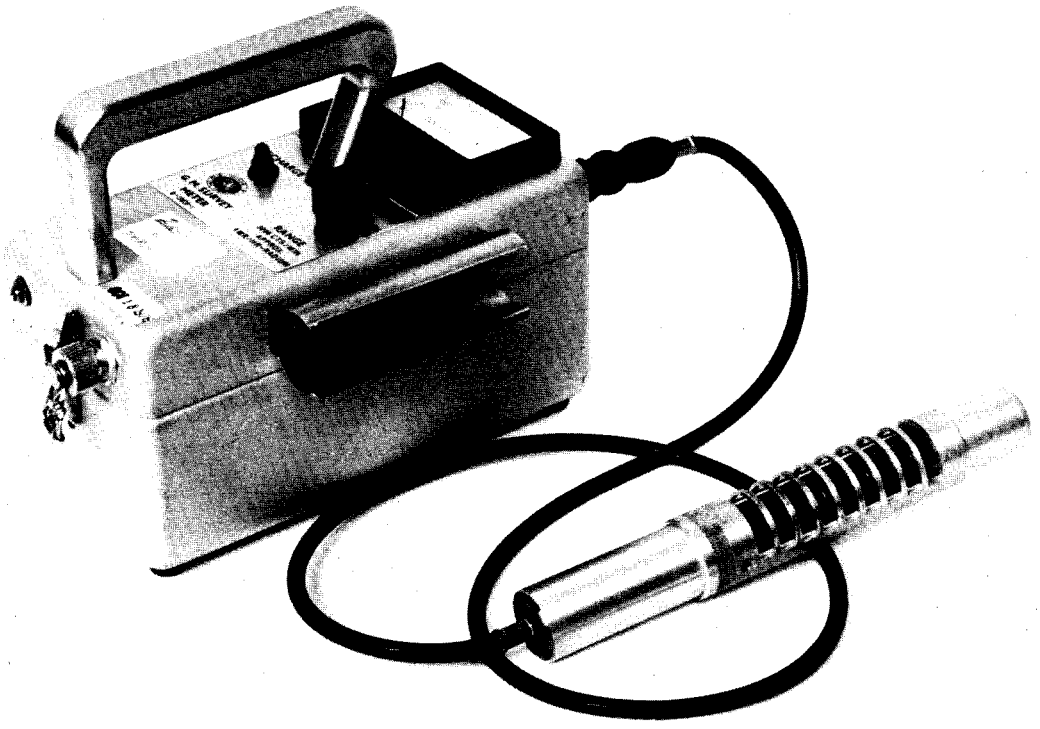

Fig. III-C. Geiger-Mueller survey meter.

ORNL-Photo 6710-76

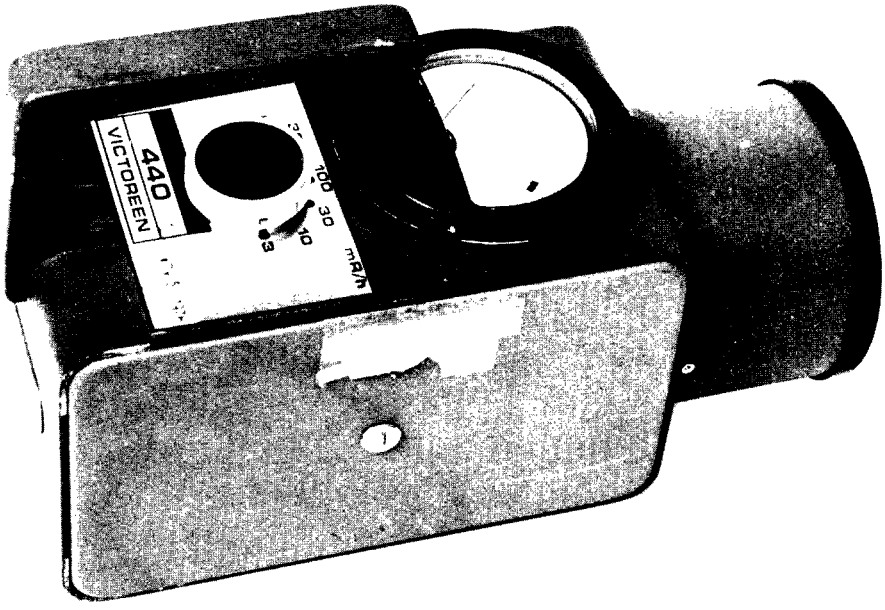

Fig. III-D. Victoreen Model 440 ionization chamber.

ORNL-Photo 6707-76

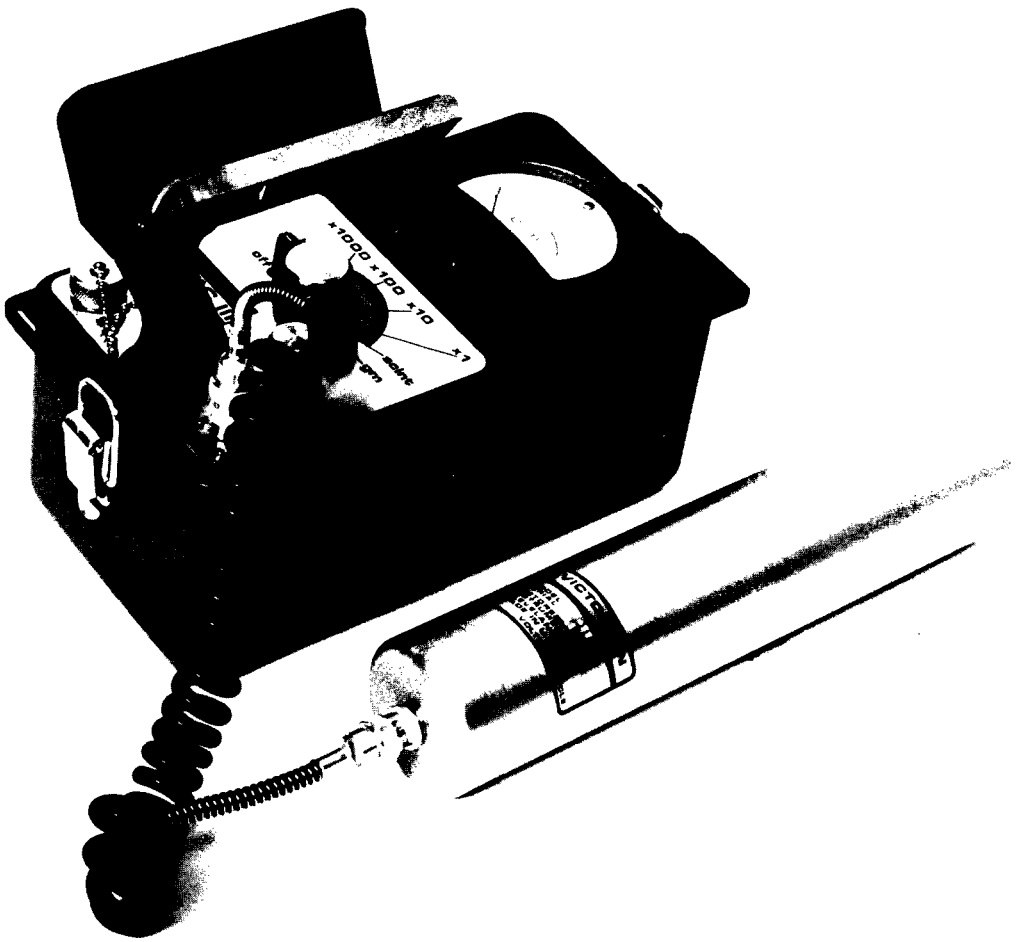

Fig. III-E. Gamma scintillation survey meter.

with a response nearly independent of photon energy is used to determine a correction factor for the scintillation meter.

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 Zns phosphor, and a photomultiplier tube. This detector assembly was used with electronic components housed in a portable NIM bin (Fig. III-F). 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 calibrated daily using an alpha source with a known disintegration rate.

Beta Smear Counter

The beta smear counter consisted of a thin mica window ($\sim$2 mg/cm^2) G-M tube mounted on a sample holder and housed in a 23-cm-diam x 35-cm-high lead shield. Located under the counter window is a slotted sample holder, accessible through a hinged door on the shield. An absorber can be interposed in the slot between the sample and the counter window to determine relative beta and gamma contributions to the observed sample counting rate. The electronics for this counter were housed in a portable NIM bin and consisted of a Tennelec TC 148 preamplifier, an ORTEC 456 high-voltage power supply and a Tennelec TC 545 counter-timer.

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

ORNL-Photo 1070-78

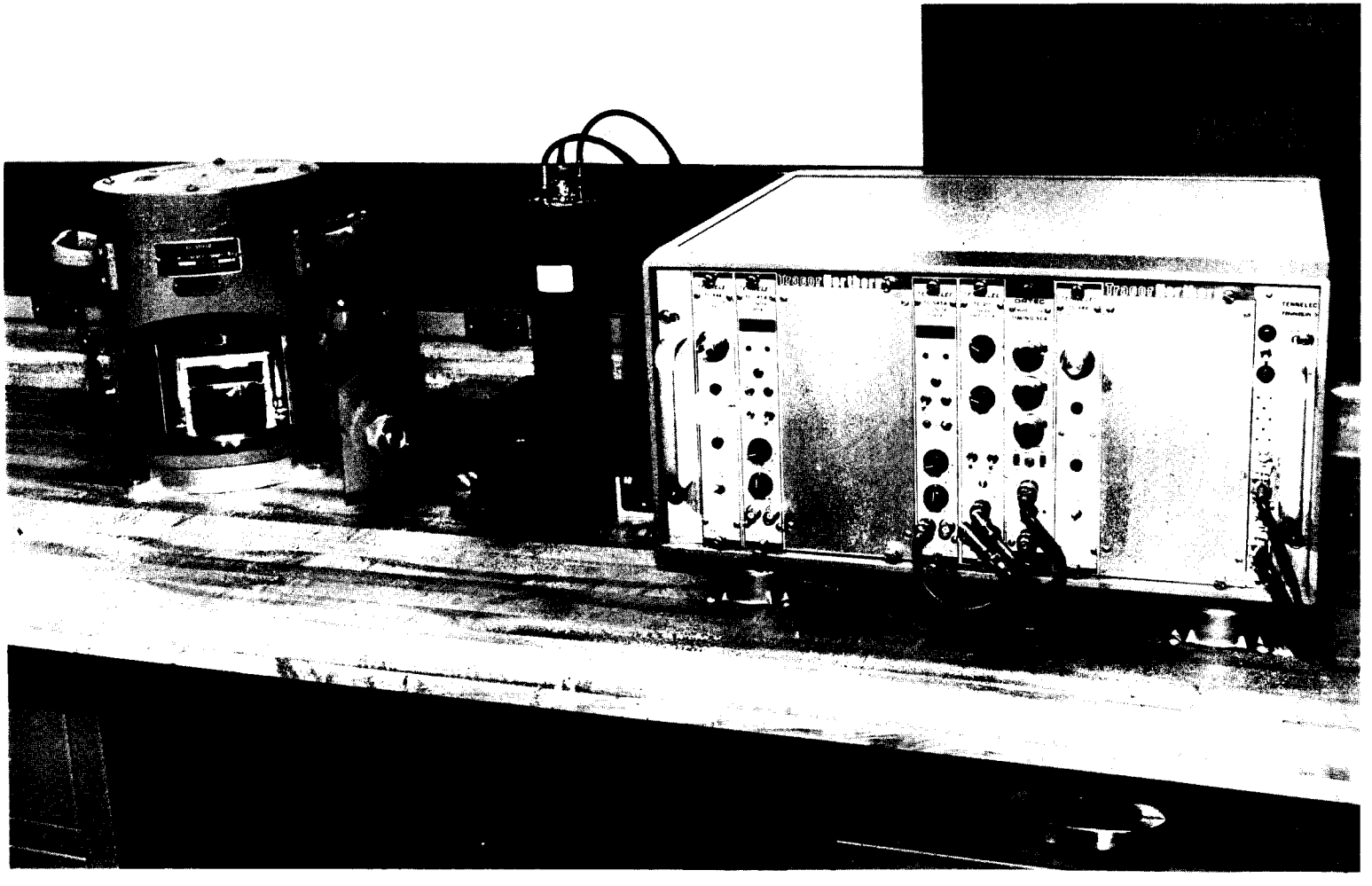

Fig. III-F. Smear counter and associated electronics. The beta counter is on the left and the alpha counter is on the right.

APPENDIX IV

SOIL ANALYTICAL PROCEDURES

ANALYSIS FOR ^{226}Ra AND ^{232}Th USING THE Ge(Li) DETECTION SYSTEM

Soil samples for ^{226}Ra and ^{232}Th analysis are dried for 24 h at 110°C and then pulverized to a particle size no greater than 500 μm in diameter (-35 mesh). Aliquots from this dried sample are transferred to 30-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-Lithium drifted [Ge(Li)] detector system of the Off-Site Pollutant Measurements Group at ORNL.

A holder for twelve of the polyethylene bottles and a background shield have been designed for use with a 50-cm^3 Ge(Li) detector system (Figs. IV-A, IV-B). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300-cm^3 sample and a graded shield developed for use with the system, it is possible to measure less than 1 pCi/g of ^{232}Th or ^{226}Ra with an error of ±10% or less. The minimal detectable concentration (MDC) for the system, considering the background of the counting system, is generally about 0.3 pCi/g.

Pulses produced by the Ge(Li) crystal are sorted by a 4096-channel analyzer (Fig. IV-C), stored on magnetic tape, and subsequently entered into a computer program, which uses a least-squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. The program, which is accessible through a remote terminal, relies on a library of radioisotopes, which contains approximately 700 isotopes and 2500 gamma-rays, and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ^{226}Ra, six principal gamma-ray lines are analyzed. Most of these are from ^{214}Bi and correspond to 295, 352, 609, 1120, 1765, and 2204 keV. For analysis of ^{232}Th, seven gamma lines of its daughters are analyzed (239, 338, 583, 795, 911, 969, and 2615 keV).

ORNL-Photo 2172-75

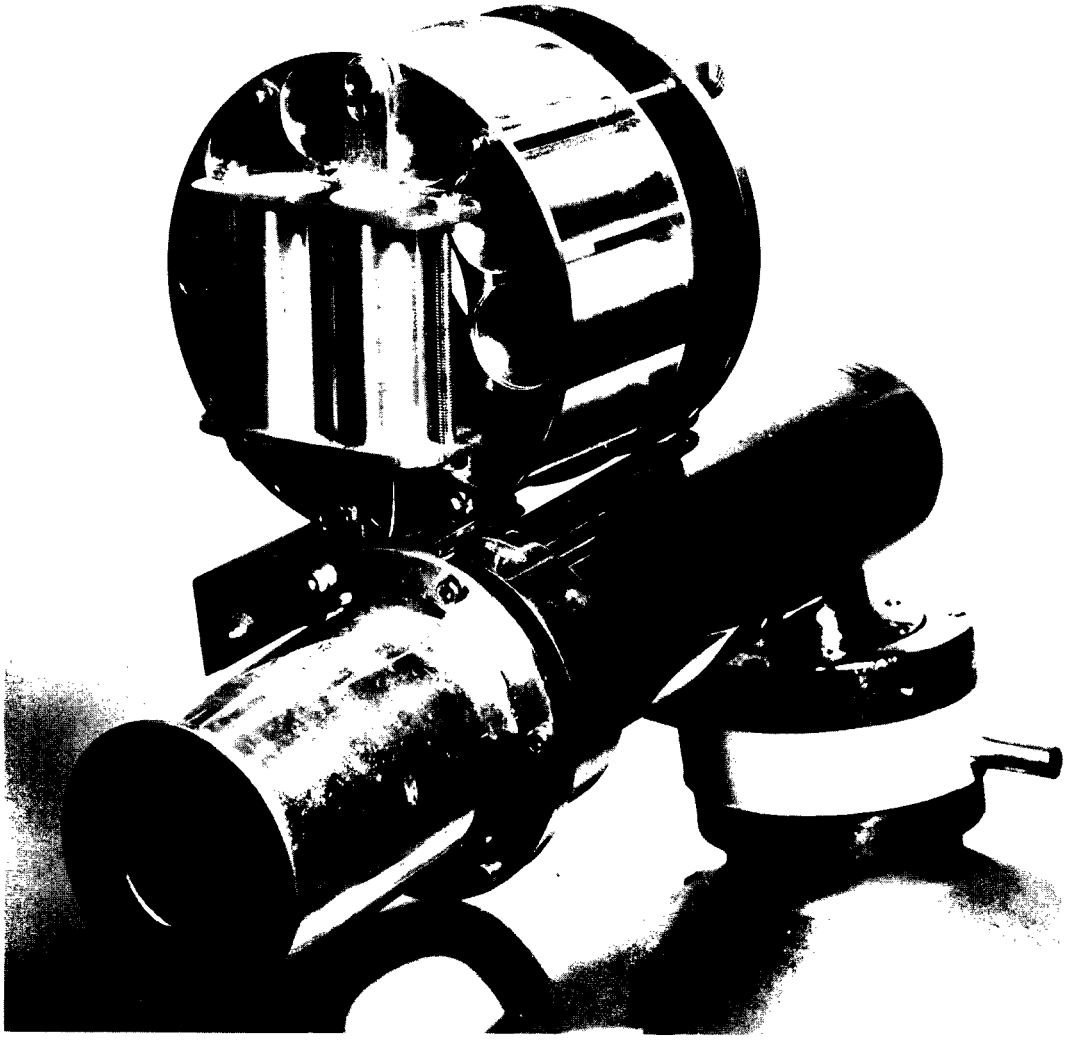

Fig. IV-A. Soil sample holder above the Ge(Li) detector system.

ORNL-Photo 2171-75

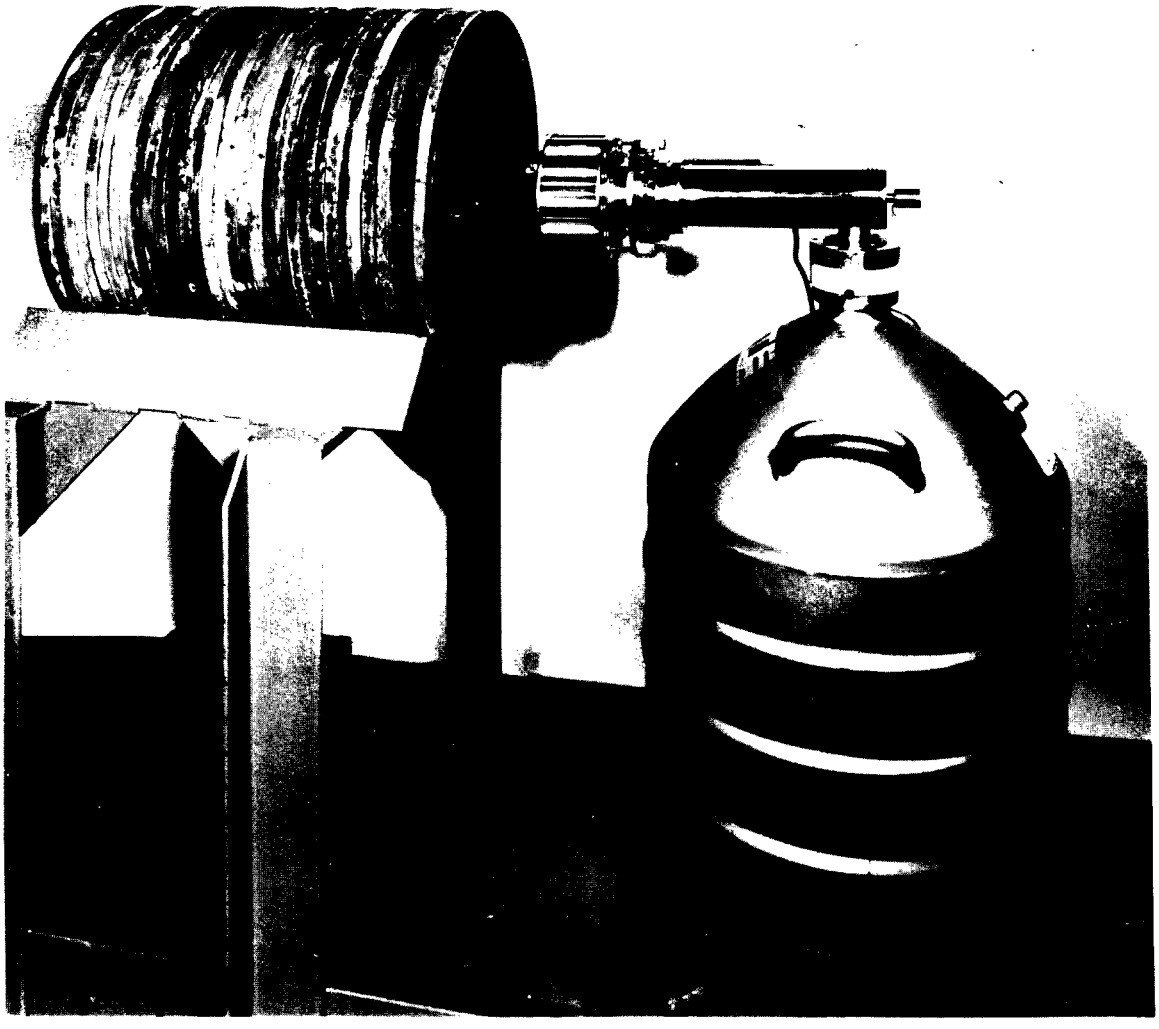

Fig. IV-B. Soil sample holder attached to Ge(Li) detector.

ORNL-Photo 6719-76

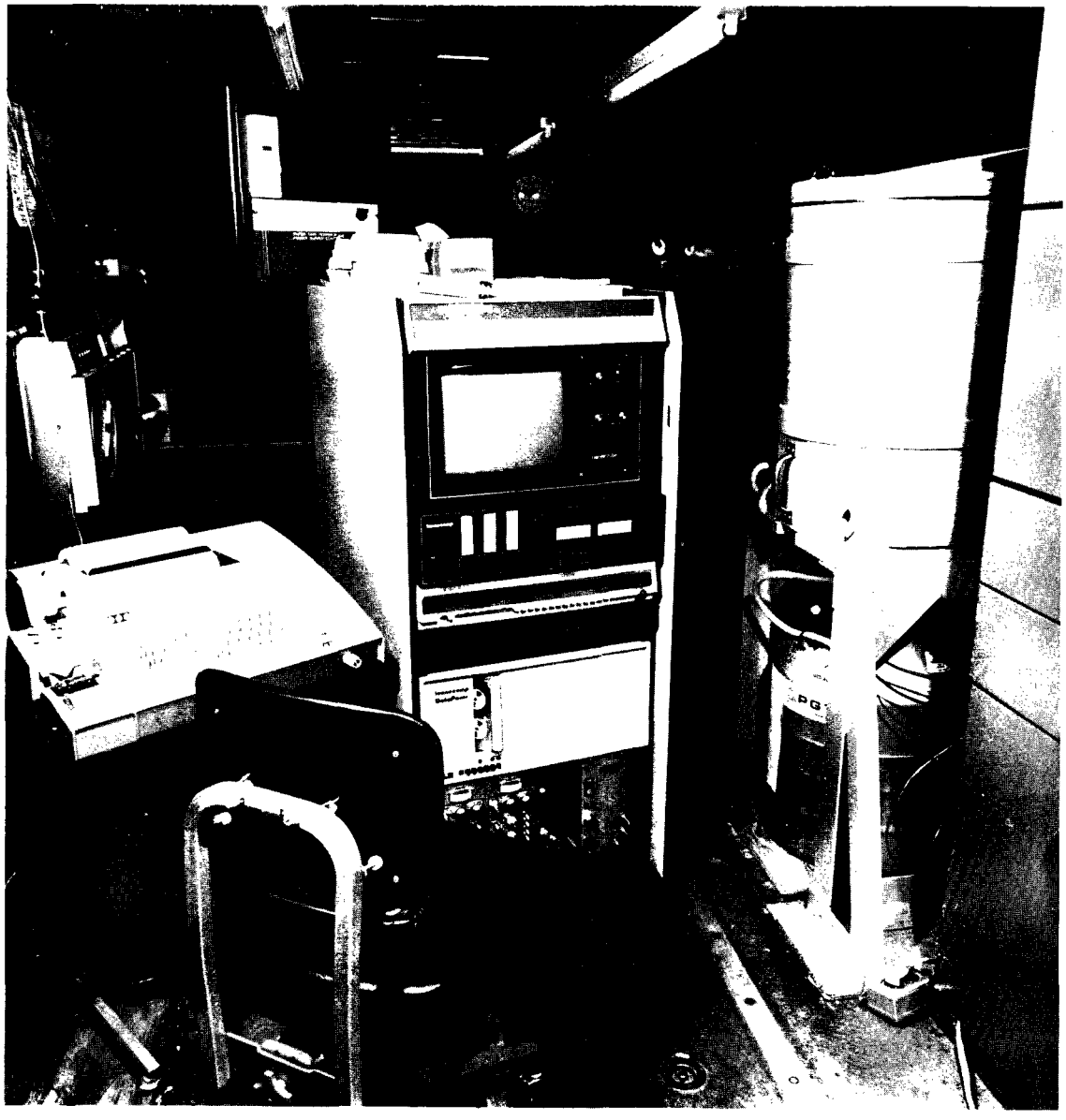

Fig. IV-C Ge(Li) detector and holder inside lead shield with associated multichannel analyzer.

NEUTRON ABSORPTION TECHNIQUE FOR ^{238}U ANALYSIS*

Following the initial soil sample drying and pulverizing, a 30 cm^3 aliquot is sent to the Analytical Chemistry Division of ORNL for ^{238}U analysis by neutron activation. 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} $n/(cm^2 \cdot s)$, 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 ±5% (expressed as the relative standard deviation for 2σ or 95% confidence intervals).

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*F. F. Dyer, J. F. Emery, and G. W. Leddicotte, *A Comparative Study of the Neutron Activation Analysis of Uranium by Delayed Neutron Counting*, Oak Ridge National Laboratory, ORNL-3342, October, 1962.

APPENDIX V

PERTINENT RADIOLOGICAL REGULATIONS, STANDARDS, AND GUIDELINES

A summary of applicable radiation guidelines for the former Kellex site

Mode of exposure	Exposure conditions	Guideline value	Guideline source
1. External gamma radiation[a]	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[a]	^{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[a]	Removable beta-gamma emitters	1000 dpm/100 cm^2	Same as number 2
4. Beta-gamma dose rates[a]	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[a]	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[a]	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. Uranium concentration in soil	Average concentration of ^{238}U in the top 20 cm of soil averaged over 400 m^2 (including background)	40 pCi/g	DOE letter from William E. Mott to Department of Environmental Protection, State of New Jersey dated June 13, 1980

[a] This appendix contains a complete listing of standard.