C. Mayes

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FORMERLY UTILIZED MED/AEC SITES **DRAFT**

REMEDIAL ACTION PROGRAM

RADIOLOGICAL SURVEY

of

THE ECKHART HALL
UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

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PREFACE

This is one of a series of reports resulting from a program initiated in 1974 by the Atomic Energy Commission (AEC) for determination of the condition of sites formerly utilized by the Manhattan Engineer District (MED) and the AEC for work involving the handling of radioactive materials. Since the early 1949's, the control of over 100 sites that were no longer required for nuclear programs has been returned to private industry of the public for unrestricted use. A search of MED and AEC records indicated that for some of these sites, documentation was insufficient to determine whether or not the decontamination work done at the time nuclear activities ceased is inadequate by current guidelines.

These reports contain the results of surveys of the current radiological condition of Eckhart Hall, University of Chicago, Chicago, Illinois.

This survey was performed by the following Health Physics personnel of the Occupational Health and Safety Division, Argonne National Laboratory, Argonne, Illinois: R. A. Wynveen, W. H. Smith, C. Boggs Mayes, P. C. Gray, D. W. Reilly.

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RADIOLOGICAL SURVEY OF THE ECKHART HALL,
UNIVERSITY OF CHICAGO, CHICAGO, ILLINOIS

INTRODUCTION

Much of the work involved in the Manhattan Engineer/Atomic Energy Commission (MED/AEC) Era was performed at the University of Chicago, The Eckhart Hall was one of the buildings in use at that time. Some radiochemistry and/or physics research for the MED/AEC project was performed in this building.

No reports o. radiation surveys or decontamination could be found concerning Eckhart Hall. It was, therefore, felt that a radiation survey should be undertaken. The survey of Eckhart Hall was performed from September 25 to March 22, 1977. The survey was performed on an intermittent basis during the quarter breaks to minimize the disturbance of the University's operations. The purpose of this survey was to determine if any detectable contamination remains as a result of the MED/AEC operations.

Eckhart Hall is presently in use as offices, laboratories and classrooms.

SURVEY TECHNIQUES

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General

All accessible original walls were surveyed to a height of 2 meters and all accessible floor areas were surveyed. In many areas, the floors and walls had been retiled or painted. Even though these were not the original surfaces, these areas were surveyed since the instrument capability was adequate to detect activity on the original structures underneath. A representative selective survey of overheads such as pipes, vents and light fixtures was performed in areas where the original structures were available. See Table 1 and Figures 1A through 1E for locations of accessible areas surveyed. (All measurements were originally taken using the English system. The SI units are to the nearest approximation. For example, 2 inches are equal to 5 cm.)

Instrumentation

Three types of survey instruments were used (Table 2). An Eberline floor monitor, Model FM-4G, having a detection area of 325 cm^2, utilizing the Eberline PAC-4G-3 electronics, was used to survey the pad. An Eberline PAC-4G-3 with a hand-held detector, 61 cm^2 in sensitive area, was used to survey the walls and other areas not accessible with the floor monitor. Double aluminized mylar (0.85 mg/cm^2) windows were used for both detectors. The thin window allows for low energy detection and, therefore, provides for increased instrument sensitivity. Both of these instruments were initially used in the beta mode. In the beta mode, the detector responds to alpha and beta particles and X and gamma rays. When areas were found which indicated a higher count rate than the instrument background, the instrument was then switched to the alpha mode which responds to particles with high specific ionization, such as alpha particles, and a reading of

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the alpha activity, if detectable, was obtained.

An End Window Geiger-Mueller (G-M) Detector, Eberline Model E-500B with a 2.2 cm diameter window held one meter above the floor, was used to determine general background radiation levels throughout the surveyed area. If an area was found that had an elevated count rate, a contact reading was obtained.

The End Window G-M Detector was calibrated using the gamma emissions from a Radium-226 (^{226}Ra) calibration source. The Eberline floor monitor and hand-held detector instruments were calibrated in the alpha mode using a flat plate, infinitely thin Plutonium-239 (^{239}Pu) standard and in the beta mode with a flat plate, infinitely thin Strontium-90-Yttrium-90 (^{90}Sr-^{90}Y) standard. The instruments were calibrated so as to provide an apparent 50% geometry.

It should be realized that the numerous isotopes which could be encountered will exhibit emission energies differing from that of ^{239}Pu and ^{90}Sr-^{90}Y utilized in the calibration. When detecting known nuclides that emit alpha and beta energies differing from that of the standards, a conversion factor for the particular radionuclide is developed to determine the appropriate yield. All readings of dis/min - 100 cm^2 as reported are equated to ^{239}Pu and ^{90}Sr-^{90}Y, unless otherwise stated.

When possible, the nuclides of contamination were identified. This was done by performing a gamma spectral analysis on a contaminated item or a representative sample from a contaminated area. A Nuclear Data Multichannel Analyzer Model ND-100, utilizing a 7.6 cm x 7.6 cm Sodium Iodide Thallium activated [NaI(Tl)] crystal was used for determining the gamma-ray spectrum. This instrument, along with all other survey and sampling devices, was housed in the mobile laboratory.

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Smear Surveys

Dry smears were taken throughout the entire area of Eckhart Hall. A standard smear is performed by applying moderate pressure by the tips of the first two fingers to the back of the filter paper. All smears were taken with No. 1 Whatman filter paper, 4.25 cm in diameter. Smears of 930 cm^2 were normally taken. If an area was found which has a higher than normal background, a smear of 100 cm^2 was taken. Smears of 100 cm^2 were also taken if the survey area showed excessive dirt loading. The smears were counted in groups of ten using a 10-Wire Flat Plate Gas Proportional Detector, developed at Argonne National Laboratory (ANL), utilizing an Eberline Mini Scaler Model MS-2. At least one smear of each group was removed and counted in the more sensitive Nuclear Measurement Corporation 2π Internal Gas Flow Proportional Counter, Model 3A (PC-3A) using a mylar spun top. (The mylar spun top is placed over samples to negate the dielectric effect when counting samples on non-conducting media such as paper.) This procedure was used as a more sensitive means of counting a selection of the smear samples. All smears of areas or objects with elevated direct readings were counted. In addition, any smears indicating above background levels in the 10-Wire Assembly, were also counted in the PC Counter. Smears were counted in both detectors for alpha and beta activity. Appendix 1 provides the instrumentation and smear count conversion factors used. All contamination on the smears is equated to ^{90}Sr-^{90}Y and ^{239}Pu, unless otherwise stated.

Table 1 includes the room survey results while the maps in Figure 1A through 1E indicate the location of the smear in the room. A number in a circle, (n), indicates a smear of an overhead structure. A number in a square, [n], indicates one of the following: an elevated direct reading, a smear of an area or object that had an elevated direct reading, or a smear that

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exhibited a greater than background count.

Air Samples

Air samples were collected using a Filter Queen air sampling device. The Filter Queen Princess Model is an air sampling device utilized for the sampling of radioactive particulate matter in the air. This unit was designed and constructed at Argonne National Laboratory. (See Figure 1A through 1E for locations of air samples.) The collection medium consisted of a 200 cm^2 sheet of Hollingsworth-Vose (HV-70-0.23 mm) filter paper which collects the particulates present in the air. A flow rate of 15 or 25 cubic meters per hour (m^3/h) was used. A 10% portion, 5 cm in diameter, was removed from the filter media after collection and counted for both alpha and beta activity in the PC Counter, utilizing a mylar spun top. The collection efficiency for 0.3μ particles at this flow rate is approximately 99.9%. Sampling results were used to determine radon concentrations and the presence of any long-lived activity. Air sample calculations are presented in Appendix 2.

Soil Samples

In addition to the survey inside the building, soil corings were taken at selected locations in undisturbed areas outside Eckhart Hall to determine the deposition if any, of nuclides that could have been spilled or released. (See Figure 1F for soil sample locations.) Radiochemical (fluorometric) and gamma-ray spectral analyses were conducted on these soil samples.

The corings were effected using a 10.1 cm in diameter by 15.2 cm in length right circular cylinder, commonly called a golf-green hole cutter. Each total core sample 30 cm in length, was divided into four segments. Starting from the surface, three separate 5 cm segments were cut, bagged, and marked A, B, and C respectively; the final segment, of 15 cm, was marked D.

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The reasons for the segmented coring is to determine what contaminant migration may have occurred, to reduce the dilution of lower level soil with the upper level segments with respect to the surface deposition of the contaminants or vice versa, and to reveal any overburden or backfill which may have occurred over the years.

Two soil samples were taken from the grounds adjacent to the Eckhart Hall. Figure 1F indicates the soil sample locations.

Background data for the soil sample analysis (Table 7) were obtained from a number of soil samples taken from the Chicago area. This information was obtained from the Environmental Monitoring Section of the Occupational Health and Safety (OHS) Division of ANL.

All soil samples were processed at ANL (Figure 2) and shipped to a commercial laboratory (LFE Environmental Analysis Laboratories) for radiochemical (fluorometric) and gamma specral analyses. Their soil analysis procedure is described in Appendix 3.

Sample preparation as depicted in Figure 2 consisted of weighing the samples in their entirety and then drying for approximately 24 hours at 80° Centigrade. All samples were then reweighed, placed into mill jars (8.7 ℓ) and milled until a sufficient amount of the soil sample would pass a No. 30 standard sieve. At no point were the rocks and heavy material ground or pulverized since this material would act as a diluent and hence lower the concentration per unit volume of deposited material. After sufficient milling, the material was sieved using a No. 30, 600 micron (μ) standard stainless steel sieve. The rocks and dross vs. sieved material (< 600 μ) was segregated, bagged, and weighed separately. Soil sample weights are given in Table 5. Aliquots of the sieved material were loaded into screw top plastic containers. The amount of sieved material varied

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according to the type of analysis to be performed; 100 grams for gamma and radiochemical (fluorometric) analysis and 10 grams for radiochemical (fluorometric) analysis only. Every effort was made throughout the sample preparation operations to reduce or eliminate cross contamination. Soil samples which were suspected of containing elevated amounts of radioactivity were processed in equipment separate from the soil samples considered to contain background levels. All items of equipment were scrubbed and air dried prior to the introduction of the next sample.

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ANALYSIS OF SURVEY RESULTS

General

All data, and diagrams of survey locations are in the attachments. This section discusses the results of the survey and the findings therin. Instrument readings and smear results were converted to units of disintegrations per minute per one hundred square centimeters (dis/min - 100 cm^2) using the factors in Appendix 1. All data is reported in net count, i.e., the background count rates have been subtracted from the gross count rates prior to converting from counts per minute per one hundred square centimeters (c/min - 100 cm^2) to dis/min - 100 cm^2. The beta mode readings are corrected to remove any alpha contribution. The room background levels varied somewhat due to the construction materials in them. Table 3 provides an average background reading for all modes of the different instruments used.

The areas accessible for survey varied from area to area. Areas accessible for survey are presented in Table 1. The average percent of the total accessible areas was 60% for the floors and 55% for the walls.

Instrument Surveys

Contamination was found in eight rooms throughout Eckhart Hall. This contamination consisted of small spots of activity, found mainly on the floors. See Table 1 and Figures 1A through 1E for the maximum readings and locations of the contaminated areas.

The highest level of activity was found at location 10 on the front stairs leading from the basement to the first floor. The beta-gamma reading was 3.5 x 10^5 dis/min - 100 cm^2 and the alpha reading was 3.9 x 10^4 dis/min - 100 cm^2. The G-M End Window reading was 2 mR/h at contact and background at one meter.

Smear Surveys

No contamination above background levels could be detected on any smears.

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Air Samples

The air sampling results are presented in Table 4. The variation of the data results do not appear to be a result of any MED/AEC operation, but rather the variation reflects various environmental factors such as wind, rain, and diurnal variation. Other factors such as the ventilation of the room can cause the radon concentrations to vary. All radon concentrations determined are below the maximum permissible concentration (MPC) for an uncontrolled area as listed in the "Standards of Protection Against Radiation," Code of Federal Regulations, Title 10, Part 20, Appendix B (April 30, 1975) (10 CFR 20). These concentrations are found to be within the normal expected levels of radon.

Soil Samples

Results submitted by LFE Environmental Analysis Laboratories, as listed in Table 6, are reported in picocuries per gram (pCi/g) for the Germanium (Lithium) [Ge(Li)] spectral analysis and in micrograms per gram (μg/g) for the uranium fluorometric analysis. The latter concentrations were coverted to pCi/g by means of the example calculation shown in Appendix 4.

The background data is presented in Table 7. The background samples indicate natural uranium concentrations ranging from 0.3 to 2.0 pCi/g. Results of soil samples taken at Eckhart Laboratory fall within the range of the concentrations found in the background samples.

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CONTAMINATION GUIDELINES

Both the ANSI Standard N13.12 for the control of radioactive surface contamination of facilities to be released for uncontrolled use and the NRC Guideline for the release of property for unrestricted use, were considered as guidelines (see Appendix 5).

Since none of the spots of contamination were easily chipped from their location, the spots could not be identified as to the radionuclide of contamination. It is known though, that plutonium, uranium, and radium were used in various buildings at the University of Chicago. Both plutonium and radium are considered Group 1 radionuclides in the ANSI Standard while uranium is in Group 3. Since radionuclide identification was impossible and it is feasible that plutonium and radium could have been the radionuclides of contamination, the limits for Group 1 radionuclides will be used. The NRC Guidelines for ^{226}Ra and ^{239}Pu are as follows: the average is 100 dis/min - 100 cm^2, the maximum is 300 dis/min - 100 cm^2 and the removable is 20 dis/min - 100 cm^2. The measurements for the average may not be averaged over more than one square meter and the maximum level applies to an area of not more than 100 cm^2. Also, the average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

The proposed ANSI Standard is more restrictive than the NRC guide when considering ^{226}Ra or ^{239}Pu. The allowable limits in the ANSI Standard for ^{226}Ra and ^{239}Pu is 20 dis/min - 100 cm^2 removable and the limits are such that the total (fixed plus removable) activity must be non-detectable and the instrument utilized for this measurement shall be calibrated to

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measure at least 100 pCi of the contaminant uniformly spread over 100 cm^2.

The areas of contamination which were found to be greater than the acceptable surface contamination levels for Group 1 radionuclides as given in the proposed ANSI Standard N13.12 are as follows:

Room 3 - Two spots on floor - Smear Location 3 and 4

9 - Spot on floor - Smear Location 7

12 - Spot on floor - Smear Location 7

19 - Spot on bench and floor - Smear Location 4 and 5

25 - Spot on floor - Smear Location 5

27 - Spot on wall - Smear Location 7

Basement Corridor and Stairs - Spots of floor and stairs - Smear Location 7, 8, 9, and 10

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HAZARD EVALUATION

In order to assess both the external and internal radiological hazard involved with Eckhart Laboratory, a hypothetical situation involving the basement stairs will be constructed. The highest level of contamination was found at Smear Location 10 on the basement stairs.

To assess the external radiological hazard, the highest G-M reading of 2 mR/h which was obtained at the above location, will be considered. The G-M reading at 1 meter away was not distinguishable above background. It is, therefore, concluded that this elevated reading does not pose an external radiological hazard.

Personnel involved with this facility during the MED/AEC era, recall that ^{226}Ra was used in this building. Since it was not possible to identify the radionuclide(s) of contamination and it was known that ^{226}Ra was used in the building, the activity will be equated to ^{226}Ra to determine the internal radiological hazard.

The level of activity found on the concrete stairs was 3.5×10^5 dis/min - 100 cm^2 $\beta\gamma$ equated to ^{90}Sr-^{90}Y and 3.9×10^4 dis/min - 100 cm^2 equated to ^{239}Pu. The beta-gamma activity in terms of ^{226}Ra would be determined as follows:

$$\frac{3.5 \times 10^5 \text{ dis/min } \beta\gamma(^{90}Sr\text{-}^{90}Y)}{100 \text{ cm}^2} \cdot \frac{4.7 \text{ dis/min } \beta\gamma(^{226}Ra)}{2 \text{ dis/min } \beta\gamma(^{90}Sr\text{-}^{90}Y)} =$$

$$\frac{8.2 \times 10^5 \text{ dis/min } \beta\gamma(^{226}Ra)}{100 \text{ cm}^2}^{(1)}$$

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The alpha activity would be:

$$\frac{3.9 \times 10^5 \text{ dis/min } \alpha(^{239}\text{Pu})}{100 \text{ cm}^2} \cdot \frac{1.6 \text{ dis/min } \alpha(^{226}\text{Ra})}{2 \text{ dis/min } \alpha(^{226}\text{Pu})} =$$

$$\frac{3.1 \times 10^5 \text{ dis/min } \alpha(^{226}\text{Ra})^{(1)}}{100 \text{ cm}^2}$$

Since the beta-gamma activity is greater than the alpha activity the estimate of

$$\frac{8.2 \times 10^5 \text{ dis/min } \beta\gamma^{(1)}(^{226}\text{Ra})}{100 \text{ cm}^2}$$

will be used.

A probable situation which could arise would involve the pneumatic jackhammering of the concrete stairs in a dry condition, thereby creating an aerosol. This appears to be a satisfactory situation to consider for the purpose of assessing a potential radiological hazard.

The spot of contamination found on the stairs encompassed an area no larger than 1000 cm^2. Thus, the total activity would be:

$$\frac{8.2 \times 10^5 \text{ dis/min}_{(ra)}}{100 \text{ cm}^2} \cdot 1000 \text{ cm}^2 = 8.2 \times 10^6 \text{ dis/min}_{(ra)}.$$

This is equal to:

$$8.2 \times 10^6 \text{ dis/min}_{(ra)} \cdot \frac{1 \ \mu\text{Ci}_{(ra)}}{2.22 \times 10^6 \text{ dis/min}_{(ra)}} = 3.7 \ \mu\text{Ci}_{(ra)}$$

It will be assumed that one person is operating a jackhammer to chip up some of the concrete on the stairs so that new concrete can be poured. It will be assumed that the entire contaminated area of 1000 cm^2 will be jackhammered.

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If the contaminant had not penetrated the concrete, the contamination should be confined to the near surface of the concrete. Therefore, it will be assumed that the radioactivity is confined to the top 0.3 cm of the concrete. If the concrete is jackhammered to a depth of 0.3 cm, the concentration of the radionuclide would be the following:

$$\frac{3.7\ \mu Ci_{(ra)}}{0.3\ cm \times 1000\ cm^2} = \frac{3.7\ \mu Ci_{(ra)}}{300\ cm^3} = 1.2 \times 10^{-2}\ \mu Ci_{(ra)}/cm^3 .$$

Since jackhammering results mainly in large pieces of concrete rather than small particles, the assumption will be made that only 10% of the concrete will become airborne respirable. Using this assumption, only 30 cm^3 of concrete and 0.37 $\mu Ci_{(ra)}$ would become airborne respirable.

The density of ordinary concrete is 3 g/cm^3[2]. Thus, the amount of contaminated concrete that would become airborne would be:

$$30\ cm^3 \cdot \frac{3\ g}{cm^3} = 90\ g.$$

One can assume that the concrete is dry and that a maximum dust burden would be created from the jackhammer disturbance. This maximum dust burden would, however, most probably be no greater than the Threshold Limit Value (TLV) for Nuisance Particulates. The TLV is 15 mg/m^3 or 1.5×10^{-2} g/m^3[3].

If an aerosol was generated which contained this TLV, the number of cubic meters of contaminated air would be the following:

$$90\ g \cdot \frac{m^3}{1.5 \times 10^{-2}\ g} = 6 \times 10^3\ m^3.$$

The total activity of 3.7×10^{-1} $\mu Ci_{(ra)}$ would be suspended in 6×10^3 m^3 of air which would result in the following concentration:

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$$\frac{3.7 \times 10^{-1}\ \mu Ci_{(ra)}}{6 \times 10^{3}\ m^{3}} = 6.17 \times 10^{-5}\ \mu Ci/m^{3} = 6.17 \times 10^{-11}\ \mu Ci/cm^{3}.$$

It should be realized that only a limited number of people would be directly involved in such a postulated environment for any length of time. In addition, the level of concrete dust described herein would probably be reduced at the height of a person's breathing zone due to the high density of the concrete. The Maximum Permissible Concentration in the air (MPCa) for radium in an uncontrolled area is $2 \times 10^{-12}\ \mu Ci_{(ra)}/ml$[4]. Comparing the postulated level to the MPC, the following value is obtained:

$$\frac{6.17 \times 10^{-11}\ \mu Ci/cm}{2 \times 10^{-12}\ \mu Ci/ml} = 30.8$$

In the preceding situation, we have generated an aerosol which is 30.8 times greater than the MPC.

Since the jackhammering of the small area would not take very long and the particles would soon fall out of suspension, the aerosol created is assumed to last only 10 minutes. A person involved in this operation for this period of time would inhale the following level of activity:

$$\frac{1.2\ m^{3}\ of\ air}{60\ min} \cdot 10\ min = 0.2\ m^{3}\ of\ air$$

or

$$0.2\ m^{3} \cdot \frac{6.17 \times 10^{-5}\ \mu Ci_{(ra)}}{m^{3}} = 1.23 \times 10^{-5}\ \mu Ci_{(ra)}^{(5)}.$$

The fraction reaching the organ of reference, which in this case is the bone, would be 0.03[6]. Therefore, the total reaching the bone would be:

$$1.23 \times 10^{-5}\ \mu Ci_{(ra)} \cdot 0.03 = 3.69 \times 10^{-7}\ \mu Ci_{(ra)}.$$

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The maximum permissible burden of radium for the bone in the total body $\left[q(K)\right]$ is 1×10^{-1} $\mu Ci_{(ra)}$ [7]. Comparing the total reaching the bone to the maximum permissible bone burden, the following is obtained:

$$\frac{3.69 \times 10^{-7}\ \mu Ci_{(ra)}}{1 \times 10^{-1}\ \mu Ci_{(ra)}} = 3.69 \times 10^{-6}.$$

Thus, the person would receive 3.69×10^{-6} or approximately 0.0004% of a bone burden from this operation. Even though these calculations are based on reasonable hypothesized values, it must be realized that the actual total activity could be less than but probably not greater than the hypothesized value.

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FOOTNOTES

1. The conversion factors for dis/min β-γ (^{90}Sr-^{90}Y) and dis/min α (^{239}Pu) to dis/min$_{(ra)}$ for the PAC-4G-3 as given in Appendix 1.
2. This value is taken from the Table, "Density of Elements and Common Material," as given in the Radiological Health Handbook, January, 1970.
3. The Threshold Limit Value is 15 mg/m^3 for Nuisance Particulates from the Occupational Safety and Health Standards Subpart Z - Toxic and Hazardous Substances, May 28, 1975.
4. The Maximum Permissible Concentration values are given in "Standards for Protection Against Radiation," Code of Federal Regulations, Title 10, Part 20, Appendix B (April 30, 1075) (10 CFR 20), for an insoluble radionuclide in air in an uncontrolled area.
5. This value is from the "Specifications for Standard Man" as given in the Radiological Health Handbook, January, 1970.
6. This value is taken from the Report of Committee II of Permissible Dose from Internal Radiation (1959), International Committee on Radiological Protection (ICRP).
7. This is the maximum permissible bone burden for ^{226}Ra as found in the Report of Committee II of Permissible Dose from Internal Radiation (1959), International Committee on Radiological Protection (ICRP).

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FINDINGS

A comprehensive radiological survey was completed at Eckhart Hall, University of Chicago, Chicago, Illinois. Some radiochemistry and/or physics was performed at Jones Laboratory for the MED/AEC project in the 1940's. This building is now in use as offices, laboratories and classrooms.

Instrument and smear surveys indicate that some contamination is still present throughout the building. Most of this contamination, consisted of small spots of activity on the floors and walls. No radionuclide identification could be performed on the spots.

Personnel involved with this facility during the MED/AEC recall that ^{226}Ra was used in Eckhart Hall. Since the activity found throughout Eckhart Hall could not be identified and it is known that ^{226}Ra was used, the acceptable surface contamination limits for ^{226}Ra as given in the proposed ANSI Standard N13.12 for the control of radioactive surface contamination of facilities will be used as guidelines. In accordance with the proposed ANSI Standard, 7 rooms were found to be in excess of the allowable limits. Smears of these areas indicate that the contamination is fixed and not removable.

Radon concentrations were determined at selected sites including areas where contamination was found. The air sample data indicates normal radon concentrations.

Soil samples were taken about the grounds of Eckhart Hall to determine the deposition of any radionuclides that could have been spilled or released. Results of the soil sample analyses show no elevated readings above the natural background levels in the soil.

FIGURE 1A

ECKHART HALL BASEMENT

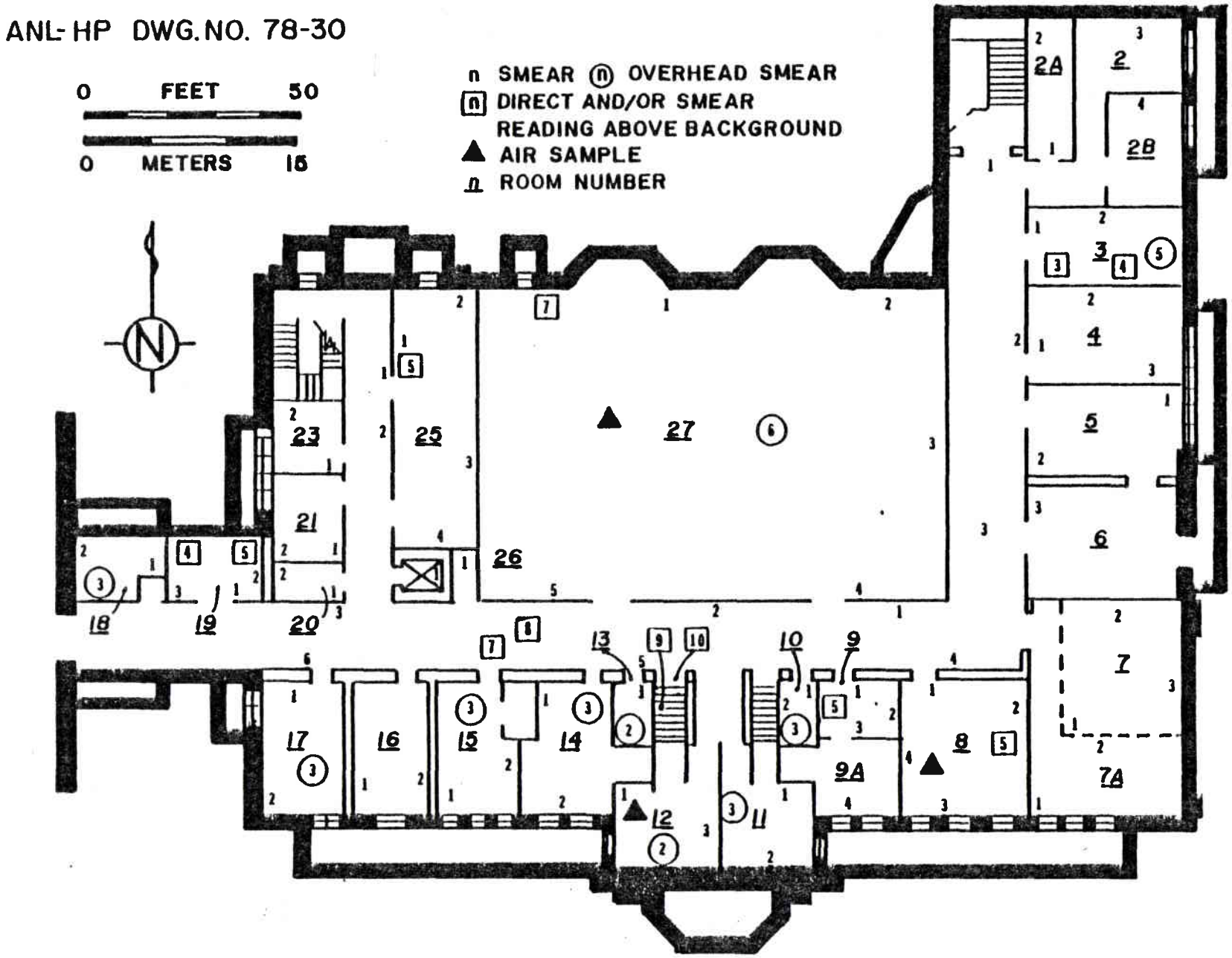

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FIGURE 1B

ECKHART HALL FIRST FLOOR

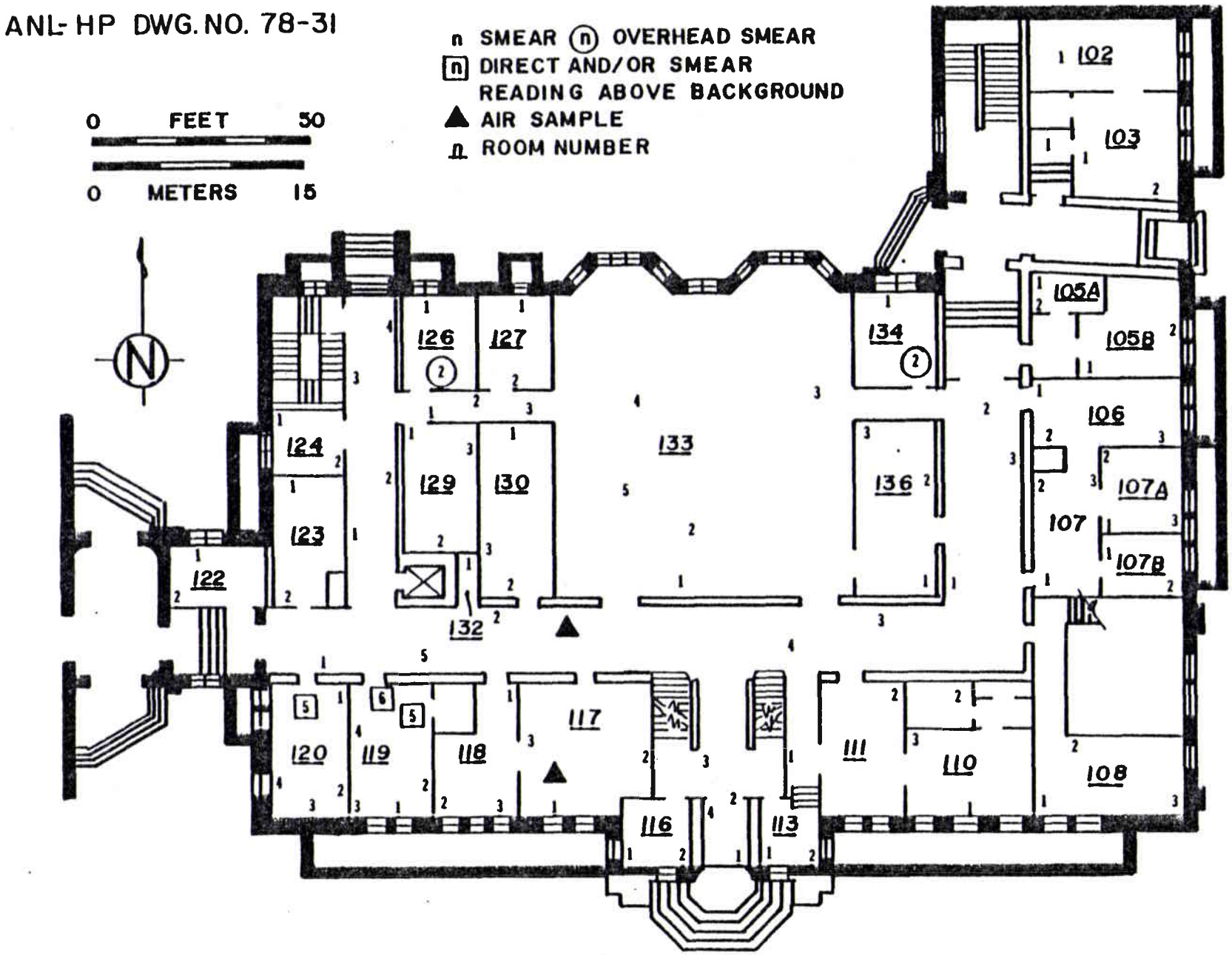

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FIGURE 1C

ECKHART HALL SECOND FLOOR

ANL-HP DWG. NO. 78-32

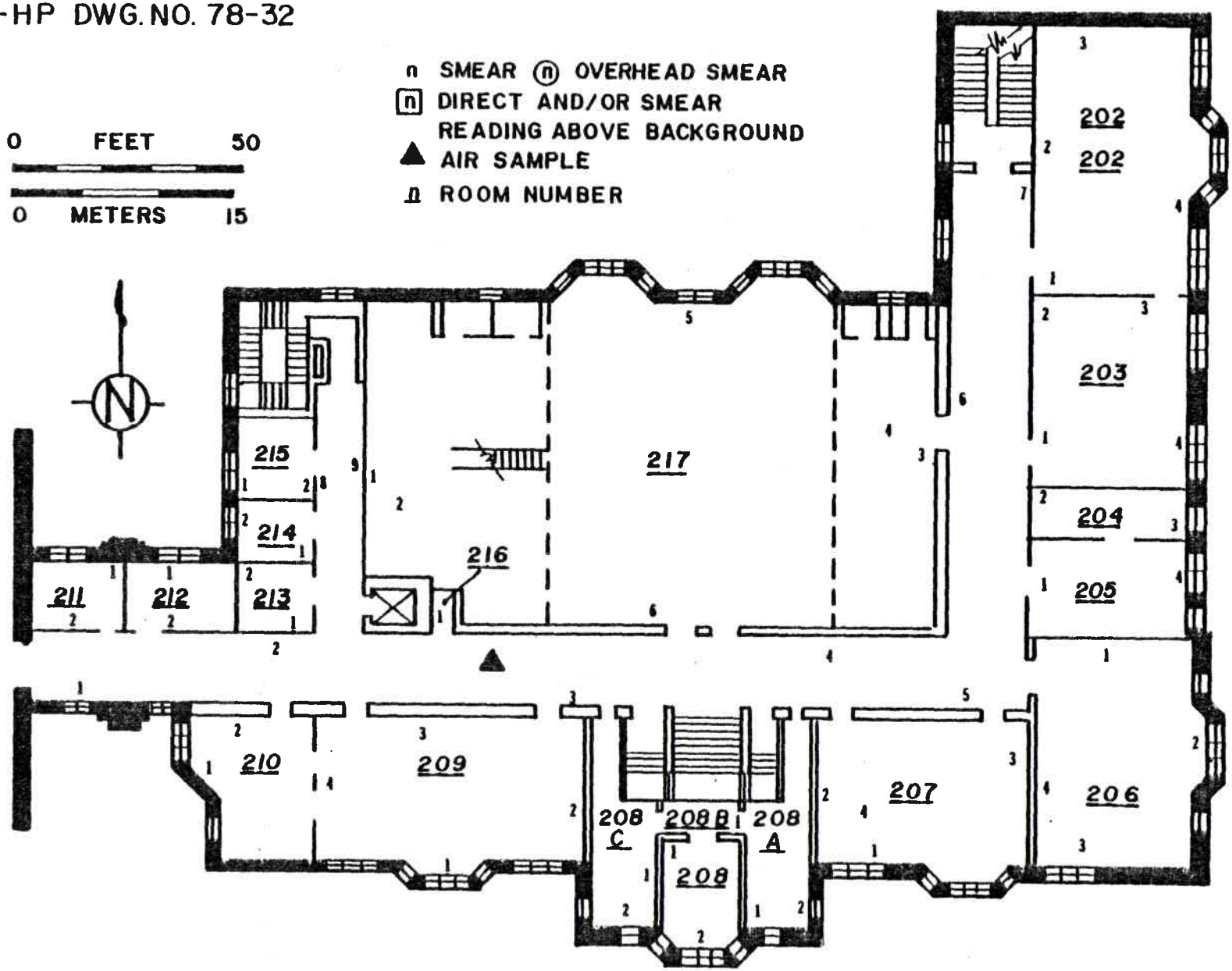

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FIGURE 1D

ECKHART HALL THIRD FLOOR

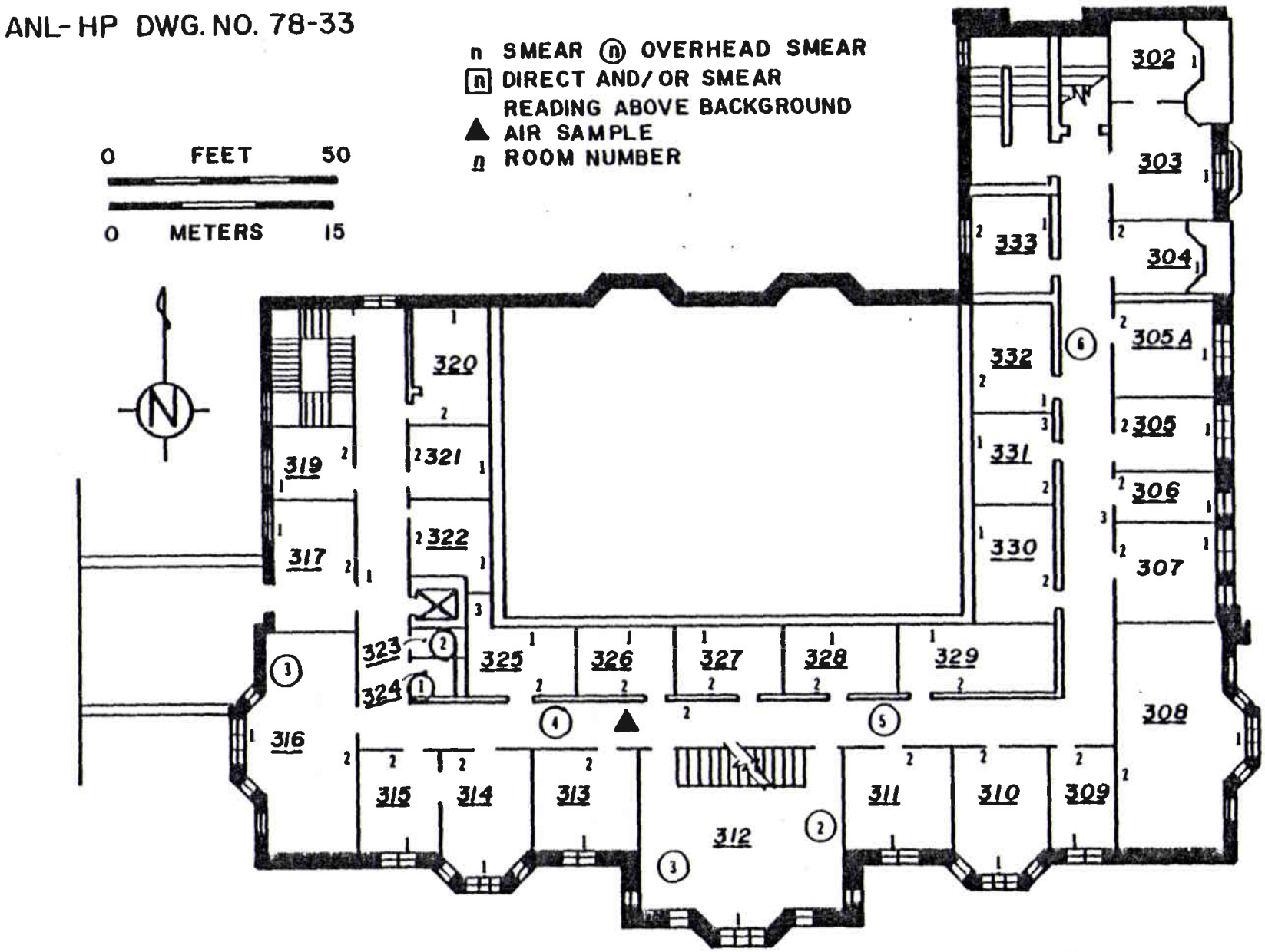

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FIGURE 1E

ECKHART HALL FOURTH FLOOR

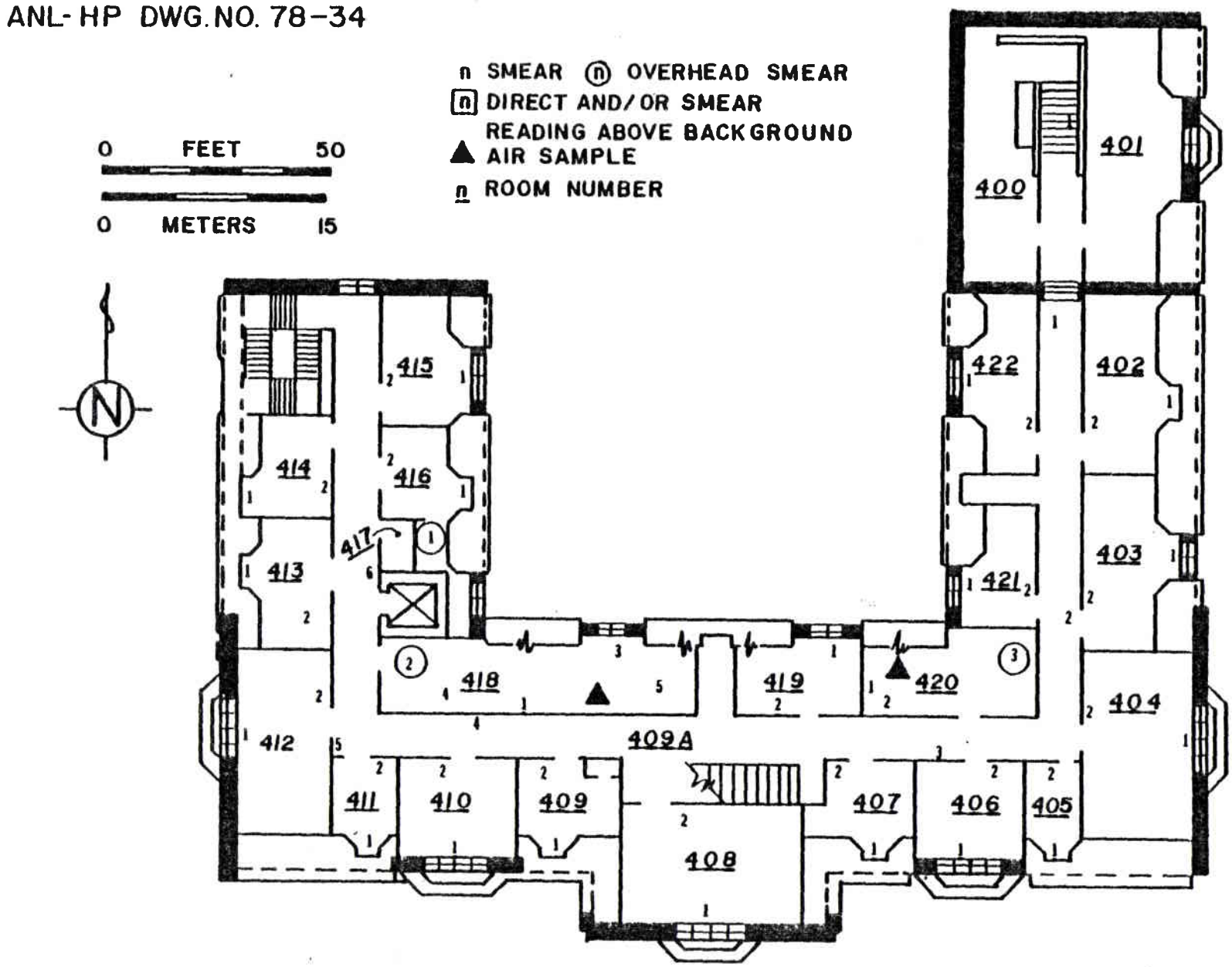

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FIGURE 1F

ECKHART HALL SOIL SAMPLES

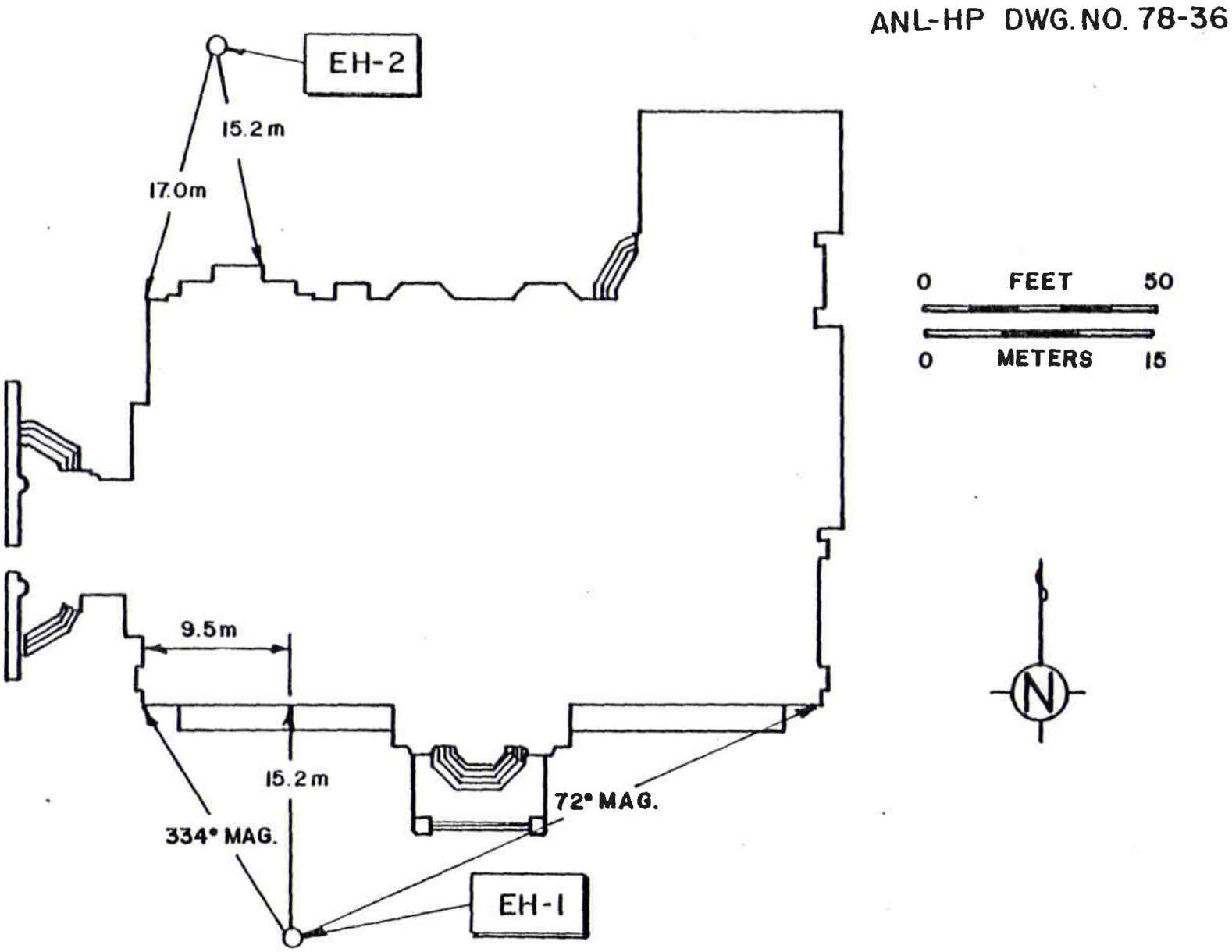

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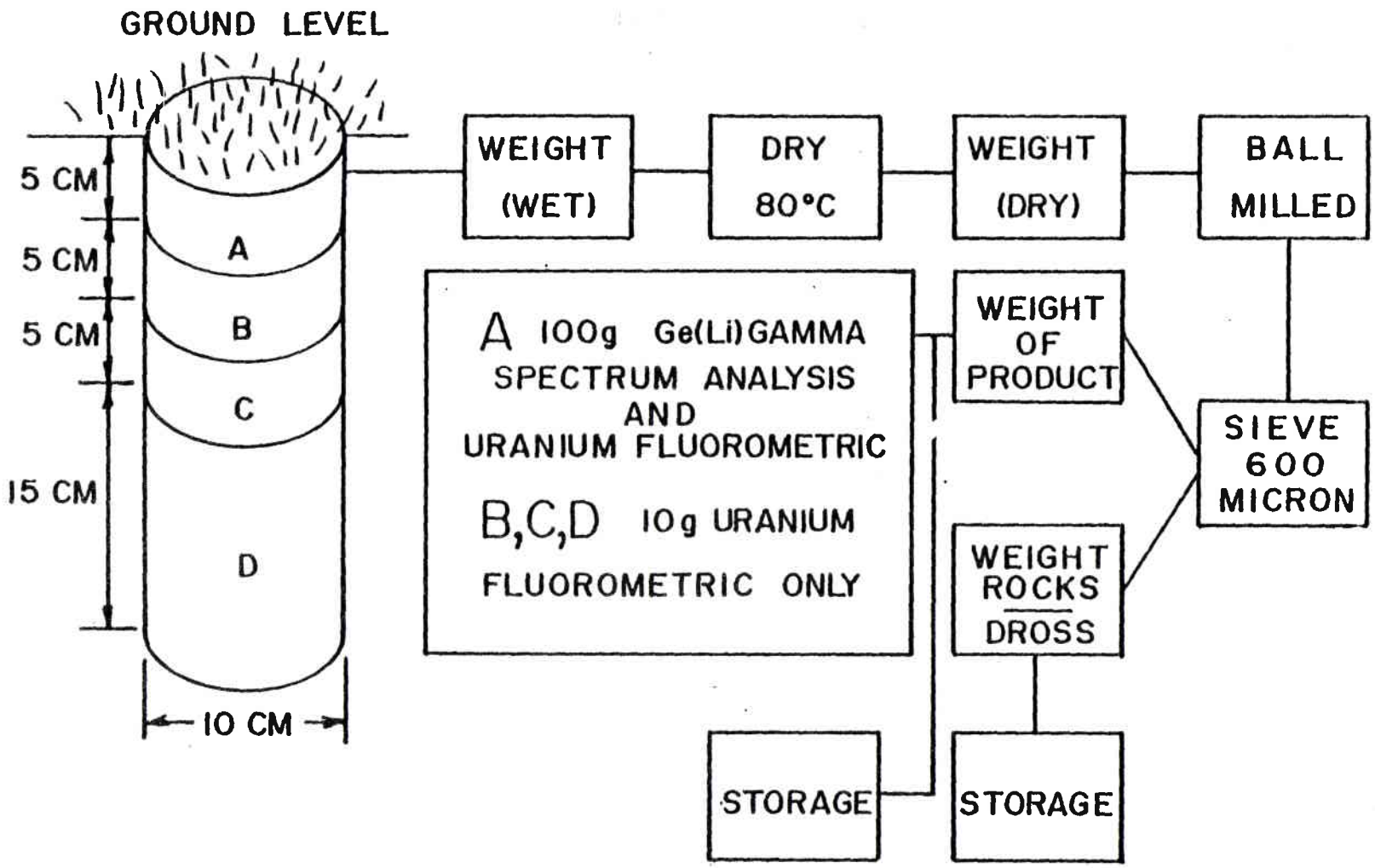
FIGURE 2

SOIL SAMPLING PROCEDURE AND PROCESSING DIAGRAM

ANL-HP-DWG. 78-2



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Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings (dis/min-100 cm²)				Alpha Mode Direct Readings dis/min-100 cm²				End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
Room 320	50	40	NS[2]	BKGD[3]	BKGD	OSU[4]	NE[5]	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
321	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
322	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
323	40	40	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
324	40	40	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
325	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
326	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
327	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
328	50	45	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
329	80	70	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
330	35	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
331	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
332	40	45	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
333	35	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
400	60	65	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
4th Floor Corridor	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
401	60	65	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
402	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

(1) Beta Mode detects both electromagnetic and particulate radiation. The beta mode readings are compensated for any alpha contribution.

(2) NS (Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm²	0-50 c/min-325 cm²
PAC-4G-3	150-200 c/min-61 cm²	0-50 c/min-61 cm²
PC Counter	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/hr at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish structures to reach original overhead surfaces.

(5) NE (Non-Existant) The locations did not contain structural items classified as "other" such as the following: ducts, louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

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TABLE I
DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings dis/min-100 cm²				Alpha Mode Direct Readings dis/min-100 cm²				End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
Room 303	50	45	NS[2]	BKGD[3]	BKGD	OSU[4]	NE[5]	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
304	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
305A	50	60	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
305	40	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
306	40	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
307	45	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
308	55	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
309	45	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
310	40	55	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
311	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
312	55	50	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
313	40	55	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
314	40	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
315	40	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
316	70	55	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
317	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
319	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS (Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm²	0-50 c/min-325 cm²
PC-4G-3	150-200 c/min-61 cm²	0-50 c/min-61 cm²
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following: ducts, louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

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TABLE I
DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings dis/min-100 cm²				Alpha Mode Direct Readings dis/min-100 cm²				End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
Room 405	40	50	NS[2]	BKGD[3]	BKGD	OSU[4]	NE[5]	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
406	60	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
407	60	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
408	70	60	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
409	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
410	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
411	50	55	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
412	70	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
413	55	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
414	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
415	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
416	50	55	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
417	70	50	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
418	10	20	0.52	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BGKD	
419	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
420	30	30	0.60	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
421	60	40	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
422	60	40	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS (Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm²	0-50 c/min-325 cm²
PC-4G-3	150-200 c/min-61 cm²	0-50 c/min-61 cm²
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following; ducts, louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

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DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/l)	Beta Mode[1] Direct Readings dis/min-100 cm^2				Alpha Mode Direct Readings dis/min-100 cm^2				End Window mR/h		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
Room 206	20	25	NS[2]	BKGD[3]	BKGD	OSU[4]	NE[5]	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
207	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
208A	90	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
208B	90	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
208C	90	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
208T	90	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
209	80	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
210	60	60	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
211	75	75	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
212	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
213	50	40	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
214	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
215	50	45	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
216	70	70	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
217 & Mezzanine	50	10	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
3rd Floor Corridor	100	100	0.58	BKGD	KBGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
302	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS (Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm^2	0-50 c/min-325 cm^2
PAC-4G-3	150-200 c/min-61 cm^2	0-50 c/min-61 cm^2
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following: ducts, louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

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TABLE I
DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings dis/min-100 cm² Floors	Walls	Overhead	Other	Alpha Mode Direct Readings dis/min-100 cm² Floors	Walls	Overhead	Other	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm²)	Comments
Room 120	50	50	NS[2]				4.8×10^4				BKGD[3]	50	BKGD	NST[8]	Cabinet containing sources
				BKGD	BKGD	OSU[4]		NA[6]	NA	NA		NN[7]	BKGD	BKGD	Location 5 Rest of survey was BKGD
122	50	25	NS	BKGD	BKGD	OSU	NE[5]	NA	NA	NA	NA	NN	BKGD	BKGD	
123	60	70	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
124	40	10	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
126	30	20	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
127	30	20	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
129	60	15	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
130	70	20	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
132	35	45	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
133	90	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
134	30	30	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
136	50	50	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	KBGD	
2nd Floor Corridor	95	95	2.0	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
202	30	20	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
203	40	30	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
204	90	75	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
205	90	75	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS (Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm²	0-50 c/min-325 cm²
PAC-4G-3	150-200 c/min-61 cm²	0-50 c/min-61 cm²
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following: ducts, louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

(8) NST (No Smear Taken)

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TABLE I
DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/l)	Beta Mode[1] Direct Readings dis/min-100 cm^2				Alpha Mode Direct Readings dis/min-100 cm^2				End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
Corridor by Room 102	100	100	NS[2]	BKGD[3]	BKGD	OSU[4]	NE[5]	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
Room 103	75	60	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
105A	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
105B	40	40	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
106	80	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
107A	75	75	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
107	60	80	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
107B	90	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
108	70	60	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
110	60	60	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
111	60	60	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
113	50	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
116	80	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
117	50	75	0.03	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
118	75	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
119	80	50	NS				2.3×10^4				BKGD	NRR[10]		NST[8]	Drawer containing sources Location 5
							2×10^4				BKGD	NRR		NST	Drawer containing thorium crucible Location 6
				BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	Rest of survey was BKGD

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS (Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Backgound Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm^2	0-50 c/min-325 cm^2
PAC-4G-3	150-200 c/min-61cm^2	0-50 c/min-61 cm^2
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following: ducts, louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

(8) NST (No Smear Taken)

(10) NRR (No Reading Recorded)

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TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings dis/min-100 cm²				Alpha Mode Direct Readings dis/min-100 cm²				End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
Basement Corridor and Stairs	100	95	NS[2]	NRR[10]				BKGD[3]				0.2	0.04	BKGD	Smear 7, Spot on floor
				NRR				BKGD				0.1	BKGD	BKGD	Smear 8, Spot of floor
				1.8×10^4				BKGD				0.03	BKGD	BKGD	Smear 9, Spot on stairs
					BKGD	OSU[4]	NE[5]	.	NA[6]	NA	NA	NN[7]	BKGD	BKGD	Smear 10, Spot on stairs Rest of survey was BKGD
Corridor by Room 23	100	95	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Stairway by Room 2	60	70	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Elevator	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Corridor by Rm 2-6	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Basement Stairs	100	100	NS	3.5×10^5				3.9×10^4				2	BKGD	BKGD	
					BKGD	OSU	NE		NA	NA	NA	NN	BKGD	BKGD	Rest of survey was BKGD
Corridor by Room 134				BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Main Corridor	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Main Entrance	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Corridor by Room 124	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Corridor by Room 124	100	100	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
Room 102	75	65	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS - (Not Selected) Air sample locations were chosen on a selcted basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm²	0-50 c/min-325 cm²
PAC-4G-3	150-200 c/min-61 cm²	0-50 c/min-61 cm²
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following: ducts, louvers, pipes and vents

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

(10) NRR (No Reading Recorded)

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TABLE 1
DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings dis/min-100 cm²				Alpha Mode Direct Readings dis/min-100 cm²				End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
14	50	50	NS[2]	BKGD[3]	BKGD	BKGD	NE[5]	NA [6]	NA	NA	NA	NN[7]	BKGD	BKGD	
15	40	40	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
16	60	50	NS	BKGD	BKGD	OSU[4]	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
17	50	50	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
18	20	20	NS	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
19	30	30	NS	6.8×10^3				1.1×10^3				NRR[10]	BKGD	BKGD	Spot on bench top, Smear 4
				6.2×10^3				BKGD				NRR	BKGD	BKGD	Spot on floor, Smear 5
					BKGD	BKGD	NE		NA	NA	NA	NN	BKGD	BKGD	Rest of survey was BKGD
20	40	25	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
21	95	90	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
23	40	30	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
25	45	70	NS	3.0×10^4				6.4×10^2				NRR[10]	BKGD	BKGD	Spot on floor, Smear 5
					BKGD	OSU	BKGD		NA	NA	NA	NN	BKGD	BKGD	Rest of survey was BKGD
26	60	45	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
27	50	20	0.68	2×10^3				BKGD				BKGD	BKGD	BKGD	Spot on wall, Smear 7
					BKGD	BKGD	NE		NA	NA	NA	NN	BKGD	BKGD	Rest of survey was BKGD

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS - (Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm²	0-50 c/min-325 cm²
PAC-4G-3	150-200 c/min-61 cm²	0-50 c/min61 cm²
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following: ducts, louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

(8) NST (No Smear Taken)

(10) NRR (No Reading Recorded)

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TABLE I
DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (pCi/t)	Beta Mode[1] Direct Readings dis/min-100 cm^2				Alpha Mode Direct Readings dis/min-100 cm^2				End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	1 meter		
2 & 2A & 2B	50	20	NS[2]	BKGD[3]	BKGD	BKGD	NE[5]	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
3	70	20	0.38	$1.2x10^3$				BKGD				BKGD	BKGD	BKGD	Smear 3 Spot on floor
				$2.4x10^3$				BKGD				BKGD	BKGD	BKGD	Smear 4 Spot on floor
					BKGD	BKGD	NE		NA	NA	NA	NN	BKGD	BKGD	Rest of Survey was BKGD
4	50	20	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
5 & 6	50	20	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
7	30	30	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
7A	30	30	NS	BKGD	BKGD	OSU[4]	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
8	65	75	0.15				$6.3x10^4$				BKGD	4.5	BKGD	NST[8]	Location 5, Cabinet containing sources
				BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	rest of survey was BKGD
9	40	20	NS	$7.4x10^3$				BKGD				NRR[10]	BKGD	BKGD	Spot on floor, Smear 5
					BKGD	BKGD	NE		NA	NA	NA	NN	BKGD	BKGD	Rest of survey was BKGD
10	30	40	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
11	80	80	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
12	75	75	0.44	$4.6x10^4$				$1.4x10^3$				0.08	BKGD	BKGD	Spot on floor, Smear 7
					BKGD	BKGD	NE		NA	NA	NA	NN	BKGD	BKGD	Rest of survey was BKGD
13	50	50	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

(1) Beta Mode detects both electromagnetic and particulate radiation.

(2) NS-(Not Selected) Air sample locations were chosen on a selected basis throughout the areas surveyed.

(3) BKGD (Background) Instrument Background Readings

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 c/min-325 cm^2	0-50 c/min-325 cm^2
PAC-4G-3	150-200 c/min-61 cm^2	0-5- c/min-61 cm^2
PC-3A	50 c/min	0.4 c/min
10 Wire	500 c/min	10 c/min

G-M End Window Detector read <0.03 mR/h at 1 meter above floor.

(4) OSU (Overhead Structure Unavailable) Floor and wall survey indicate no necessity to demolish existing structures to reach original overhead surfaces.

(5) NE (Non-Existant) This location did not contain structural items classified as "other" such as the following: ducts louvers, pipes and vents.

(6) NA (Not Applicable) No activity detected above background in the beta mode; therefore, no alpha mode survey was necessary.

(7) NN (Not Necessary) No activity was detected; therefore, no contact G-M End Window Survey was necessary.

(8) NST(No Smear Taken)

(10) NRR (No Reading Recorded)

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TABLE 2

INSTRUMENTATION USED IN SURVEY

Type	Inventory Number	Probe Detection Area	Window Thickness
Eberline Floor Monitor utilizing a PAC-3G	181501	325 cm^2	0.85 mg/cm^2
Eberline Floor Monitor utilizing a PAC-3G	122313	325 cm^2	0.85 mg/cm^2
Eberline Floor Monitor utilizing a PAC-3G	169611	325 cm^2	0.85 mg/cm^2
Eberline PAC-3G	165253	61 cm^2	0.85 mg/cm^2
Eberline PAC-3G	165254	61 cm^2	0.85 mg/cm^2
Eberline PAC-3G	165256	61 cm^2	0.85 mg/cm^2
Eberline PAC-3G	169611	61 cm^2	0.85 mg/cm^2
Eberline PAC-4G-3	169613	61 cm^2	0.85 mg/cm^2
Eberline PAC-4G-3	170980	61 cm^2	0.85 mg/cm^2
Eberline E-500B Beta-Gamma End Window	159006	-	1.4 - 2 mg/cm^2
Nuclear Measurement Corp. PC-3A-2π Internal Gas Flow Counter	114969	-	0.85 mg/cm^2
Argonne National Laboratory Filter Queen Air Sampler using HV-70 filter media	-	-	-
Argonne National Laboratory 10-Wire Flat Plate Gas Proportional Detector	184343	400 cm^2	0.85 mg/cm^2

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TABLE 3

INSTRUMENT BACKGROUND READINGS

Instrument	Readings Alpha Mode(c/min)	Beta Mode(c/min)	1 meter above floor mR/h
Eberline Floor Monitor FM-4G using PAC-4G-3			
181501	0 - 50	1500 - 2000	
122313	0 - 50	1500 - 2000	
169611	0 - 50	1500 - 2000	
Eberline PAC-4G-3			
165253	0 - 50	150 - 200	
165254	0 - 50	150 - 200	
165256	0 - 50	150 - 200	
169611	0 - 50	150 - 200	
169613	0 - 50	150 - 200	
170980	0 - 50	150 - 200	
Eberline E-500B Beta-Gamma End Window			< 0.03
Nuclear Measurement Corporation PC-3A-2π Internal Gas Flow Counter	0.4	50	
Argonne National Laboratory 10-Wire Flat Plate Gas Proportional Detector with Eberline Mini Scaler MS-2	10	500	

*Background readings were initially taken in the mobile laboratory and rechecked throughout the various areas inside Eckhart Hall while surveying.

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TABLE 4

RADON CONCENTRATION DETERMINATIONS

Location	dis/min	dis/min-m^3	pCi/ℓ	% of MPC*
Room 3	434	852	0.38	13
Room 8	359	339	0.15	5
Room 12	510	998	0.45	15
Room 27	868	1518	0.68	23
Corridor 1st Floor	793	1349	0.61	20
Room 17	57	77	0.03	1
Main Corridor 2nd Floor	2265	4449	2.00	67
Corridor 3rd Floor	661	1277	0.58	19
Room 418	585	1149	0.52	17
Room 420	679	1334	0.60	20

*The 10 CFR 20 MPC for ^{222}Rn for an uncontrolled area is 3 x 10^{-9} μCi/ml which equals 3 pCi/ℓ.

Example Calculation - Room 12

$$998 \text{ dis/min-m}^3 \times \frac{1 \text{ pCi}}{2.22 \text{ dis/min}} \times \frac{\text{m}^3}{10^3 \ \ell} = 0.33 \text{ pCi/}\ell$$

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TABLE 5

SOIL SAMPLE WEIGHTS

Sample No.	Net Weight (grams)	Dry Weight (grams)	Sieved Weight (grams)	Rocks & Dross Weight (grams)
EH-1A	-	519.0	435.4	58.7
EH-1B	-	691.8	681.0	7.8
EH-1C	-	512.9	495.3	13.1
EH-1D	2461.9	2246.9	1070.2	1170.5
EH-2A	-	543.0	519.8	19.8
EH-2B	979.6	794.2	670.0	118.3
EH-2C	835.0	658.0	630.2	21.1
EH-2D	2339.1	1884.2	1704.3	132.6

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TABLE 6

Ge(Li) SPECTRUM AND URANIUM FLUOROMETRIC ANALYSES RESULTS

Sample No.	Ge(Li) Spectra pCi/g received wt ± σ(1)			Uranium	
	^{137}Cs	^{232}Th Decay Chain	^{226}Ra Decay Chain	μg/g ± σ(2)	pCi/g ± σ(3)
EH-1A	1.60 ± 0.8	0.7 ± 0.1	0.75 ± 0.7	3.2 ± 0.5	2.2 ± 0.3
EH-1B				3.2 ± 0.6	2.2 ± 0.4
EH-1C				3.2 ± 0.5	2.2 ± 0.3
EH-1D				1.3 ± 0.4	0.9 ± 0.3
EH-2A	0.64 ± 0.05	0 ± 0.2	0.70 ± 0.08	2.9 ± 0.4	1.3 ± 0.3
EH-2B				4.2 ± 0.5	2.9 ± 0.3
EH-2C				2.2 ± 0.4	1.5 ± 0.3
EH-2D				3.1 ± 0.4	2.2 ± 0.3
LFE Bland	0.00 ± 0.04	0.0 ± 0.1	0.00 ± 0.06	0.0 ± 0.2	0.0 ± 0.1

(1) One standard deviation due to counting statistics.

(2) Data results from LFE.

(3) ANL conversion from Appendix 4.

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TABLE 7

BACKGROUND SOIL SAMPLE DATA*

Cesium-137, Thorium, and Uranium in Soil 1976

Concentrations in pCi/g

Date Collected	Location	Cesium-137		Thorium-232		Uranium	
July 22	Argonne Area	0.3	0.1	0.21	0.04	1.3	0.1
July 22	Argonne Area	0.1	0.1	0.49	0.04	2.0	0.1
July 22	Argonne Area	0.3	0.1	0.48	0.04	1.5	0.1
October 18	Argonne Area	0.1	0.1	0.65	0.07	1.5	0.1
October 18	Argonne Area	0.1	0.1	0.43	0.04	1.4	0.1
October 18	Argonne Area	0.4	0.1	0.39	0.04	1.3	0.1
	Average	0.2	0.1	0.44	0.14	1.5	0.3
	Off-Site						
June 22	McKinley Woods State Park, IL	0.4	0.1	0.16	0.02	0.9	0.1
June 23	McCormick Woods Brookfield, IL	0.4	0.1	0.22	0.02	1.2	0.1
June 23	Bemis Woods Hinsdale, IL	0.4	0.1	0.18	0.02	1.6	0.1
October 12	St. Joseph, MI	0.4	0.1	0.20	0.02	0.3	0.1
October 13	Willow Springs, IL	0.5	0.2	-		1.0	0.1
October 14	Dresden Lock & Dam, IL	0.4	0.1	0.45	0.03	1.6	0.1
	Average	0.4	0.1	0.24	0.14	1.1	0.5

*These results are transcribed from "Environmental Monitoring at Argonne National Laboratory Annual Report for 1976" (ANL-77-13) by N. W. Golchert, T. L. Duffy and J. Sedlet. These measurments are presented in Table 13, on page 47 of the report.

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APPENDIX 1

CONVERSION FACTORS

INSTRUMENTATION

Below are the conversion factors used to obtain the readings in units of disintegrations per minute per 100 cm^2 (dis/min - 100 cm^2).

I Conversion Factors

	PAC-4G-3		Floor Monitor (FM-4G)	
	Alpha	Beta	Alpha	Beta
to 100 cm^2	1.64	1.64	0.31	0.31
c/min to dis/min for ^{90}Sr-^{90}Y	-	2	-	2
c/min to dis/min for ^{239}Pu	2	-	2	-
c/min to dis/min for ^{226}Ra + daughters	1.6	4.7	-	-

II Derivation of Conversion Factors

Floor Monitor (FM-4G)

Window Area: ~325 cm^2

Conversion to 100 cm^2 = .31 times floor monitoring reading

PAC-4G-3

Window Area: ~61 cm^2

Converison to 100 cm^2 = 1.64 times PAC reading

2π Internal Gas Flow Counter, PC-5

Geometry: Solid Stainless Steel Spun Top - 0.50

Geometry: Mylar Spun Top - 0.43

Mylar Spun Top Counting (window double aluminized mylar ~0.85 mg/cm) utilizes the well of the PC Counter and is a method developed and used by the Argonne National Laboratory Health Physics Section for negating the dielectric effect in counting samples on non-conducting media.

Utilizing a flat plate infinitely thin ^{226}Ra standard as a source of alpha emissions, the plate was counted in the well of a 2π internal gas flow counter, PC Counter, with the source leveled to an apparent 2π geometry.

The alpha count was found to be 20450 c/min or 20450/.5 = 40900 dis/min.

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APPENDIX 1
(contd)

Using the PAC-4G-3 and the radium source to convert counts per minute (c/min) to disintegrations per minute (dis/min), the count was found to be 12000 c/min at contact, therefore 40909/12000 = 3.4 dis/min per c/min.

The same source covered with 2 layers of conducting paper, each 6.65 mg/cm^2 to negate the alpha emissions, was counted for composite beta and gamma emissions in the PC counter. The course was leveled to an apparent 50% geometry; however, no provision was made for backscatter.

The composite beta-gamma count was found to be 6836 c/min or 6836/.5 = 13672 dis/min.

With the PAC-4G-3 in the beta mode and in contact with the covered source and on the probe, the count was 10000 c/min. This indicates a conversion factor 13672/10000 = 1.4 dis/min per c/min.

SMEAR COUNT

The conversion factors for c/min - 100 cm^2 to dis/min - 100 cm^2 are given below.

I CONVERSION EQUATION (ALPHA)

$$\frac{\text{c/min} - \text{Bkgd}}{\text{g x bf x sa x waf}} = \text{dis/min Alpha}$$

A geometry (g) of 0.43 is standard for all flat plate counting.

A backscatter factor (bf) of 1.0 is used when determining alpha activity on a filter media.

The self-absorption (sa) was assumed to be 1 unless otherwise determined.

If the energies of the isotope were known, the appropriate window air factor (waf) was used; if the energies of the isotopes were unknown the waf of Plutonium-239 which is .713, was used.

II CONVERSION EQUATION (BETA)

$$\frac{\text{c/min} - (\text{Beta Bkgd} + \text{Alpha c/min})}{\text{g x bf x sa x waf}} = \text{dis/min Beta}$$

A geometry (g) of 0.43 is standard for all flat plate counting.

A backscatter factor (bf) of 1.1 is used when determining beta activity on a filter media.

The self-absorption (sa) was assumed to be 1 unless otherwise determined.

If the energies of the isotopes were known, the appropriate window air factor (waf) was used; if the energies of the isotopes were unknown, the waf of Strontium-90-Yttrium-90, which is 0.85 was used.

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APPENDIX 2

RADON DETERMINATION CALCULATIONS

This attachment summarizes the basic assumptions and calculation methods used for samples collected using Argonne National Laboratory designed air sampler with HV-70 filter media.

I. Radon Concentrations Based on RaC' Counting Results

The following assumptions are made in deriving the Radon (^{222}Ra) concentrations based on the RaC' alpha count results.

1. RaA, RaB, RaC, RaC', are in equilibrium.

2. RaA is present only in the first count and not the 100-minute decay count.

3. That one-half of the Radon progeny is not adhered to airborne particulate, and therefore, not collected on the filter media.

4. The geometry factor (g) is 0.43 for both the alpha and beta activity.

5. The backscatter factor (bf) of 1.0 is used for the alpha activity which is determined from RaC'.

6. The sample absorption factor (sa) for RaC' is 0.77.

7. The window air factor (waf) for RaC' is 0.8.

8. RaB and RaC being beta emitters, are not counted in the alpha mode.

9. The half-life of the Radon progeny is approximately 36 minutes, based on the combined RaB and RaC half-lives.

10. No long-lived alpha emitters present as evidenced by the final recount.

11. For this method, RaC' decays at the rate of the composite of RaB and RaC which is approximately 36 minutes.

II. Equations Used to Derive Air Concentrations

$$A_o = \frac{A}{e^{-\lambda t}}$$

Where: A_o = Activity present at the end of the sampling period (dis/min)

A = Activity at some time, after end of sampling (dis/min)

t = Time interval from end of sampling period to midpoint of interval (min)

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APPENDIX 2
(contd)

$$\lambda = \frac{.693}{t_{1/2}}$$

$t_{1/2}$ = Half-life of isotope

$$C = \frac{A_o \lambda}{f} \frac{1}{1-e^{-\lambda t}}$$

Where: C = Concentration (dis/min - m^3)

A_o = Activity of filter media at end of sampling period (dis/min)

f = Sampling rate (m^3/minute) (= m^3/h · 1 h/60 min)

t_s = Length of sampling time (min)

$$\lambda = \frac{.693}{t_{1/2}}$$

$t_{1/2}$ = Half-life of isotope or controlling parent. (min)

III. <u>Example Calculation - Room 19</u>

$$A_o = \frac{510 \text{ dis/min}}{\exp\left[\frac{-.693 \times 112}{36}\right]} = 3419 \text{ dis/min}$$

$$C = \frac{4405 \times \frac{.693}{36}}{.33} \frac{1}{1-\exp\left[\frac{-.693 \times 37}{36}\right]} = 499 \text{ dis/min } m^3 \times 2 = 998 \frac{\text{dis/min}}{\text{dis/min } m^3}$$

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APPENDIX 3

SOIL ANALYSIS PROCEDURE FOR TOTAL URANIUM AND GAMMA-EMITTING NUCLIDES

Summary of Methods

A 60-millilitter volume of the received soil was counted in a petri dish for 500 minutes on a Ge(Li) detector over the energy range 0 - 1.5 MeV. This corresponded to between 60 to 100 g of soil, depending upon bulk soil density. Positive photopeaks above instrument background were converted to dis/min using a line efficiency curve based upon a National Bureau of Standards Multi-Gamma standard. The natural Thorium-232 and Radium-226 decay chains were calculated using the 0.910 MeV Actinium-228 and 0.609 MeV Bismuth-214 photopeaks respectively. Cesium-137 is reported for each sample as a representative gamma emitter. Potassium-40 was observed on all soil samples, as expected, but was not calculated or reported.

One gram of the soil sample was ashed and dissolved in $HF-HNO_3$ for the total uranium analysis. A 100-λ aliquot of the dissolved sample was fused with 98% NaF-2% LiF and the fluorescence determined using a Jarrell-Ash fluorometer. A quenching factor was determined for each sample by using an internal spike.

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APPENDIX 4

NATURAL URANIUM CALCULATIONS

Radioactive half-lives of ^{234}U, ^{235}U and ^{238}U as well as the percent abundance for each isotope was obtained as current best values from the "Table of Isotopes - 6th Edition" by C. M. Lederer, J. M Hollander and I. Perlman, 1967. The following values used are:

Isotope	Half-life	% Abundance
^{234}U	2.47×10^5 years	0.0057
^{235}U	7.1×10^8 years	0.7196
^{238}U	4.51×10^9 years	99.2760
		100.0013%

It should be noted that the abundance totals 100.0013%. Since it cannot be determined which isotope(s) are in error, the calculations are made with the .0013% error not accounted for.

Avogadro's Number Used = 6.025×10^{23}

$$SpA = \lambda A = \frac{\ln 2\ A}{t_{1/2}}$$

SpA = Specific activity

A = Number of radioactive atoms per unit mass = $\frac{\text{Avogadro's Number}}{\text{Gram atomic weight}}$

$t_{1/2}$ = Half-life

$$SpA = \frac{0.693 \times 6.025 \times 10^{23}}{t_{1/2}\ (\text{years}) \times 5.256 \times 10^5\ \frac{\text{minutes}}{\text{year}} \times \text{gram atomic weight}} = \text{dis/min - gram}$$

$$SpA\ ^{234}U = \frac{.693 \times 6.025 \times 10^{23}}{2.47 \times 10^5 \times 5.256 \times 10^5 \times 2.34 \times 10^2} = 1.374 \times 10^{10}\ \text{dis/min - gram}$$

$$= 1.374 \times 10^4\ \text{dis/min - }\mu\text{gram} \times 5.70 \times 10^{-5} = .783\ \text{dis/min - }\mu\text{gram of natural uranium}$$

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APPENDIX 4
(contd)

$$\text{SpA } ^{235}U = \frac{.693 \times 6.025 \times 10^{23}}{7.1 \times 10^{8} \times 5.256 \times 10^{5} \times 2.35 \times 10^{2}} = 4.76 \times 10^{6} \text{ dis/min - gram}$$

$$= 4.76 \text{ dis/min - } \mu\text{gram} \times 7.196 \times 10^{-3} = .034 \text{ dis/min - } \mu\text{gram of natural uranium}$$

$$\text{SpA } ^{238}U = \frac{.693 \times 6.025 \times 10^{23}}{4.51 \times 10^{9} \times 5.256 \times 10^{5} \times 2.38 \times 10^{2}} = 7.4 \times 10^{5} \text{ dis/min - gram}$$

$$= .74 \text{ dis/min - } \mu\text{gram} \times 9.9276 \times 10^{-1} = .735 \text{ dis/min - } \mu\text{gram of natural uranium}$$

Therefore, the activity of 1 μgram of natural uranium is

$$.783 \text{ dis/min } ^{234}U + .034 \text{ dis/min } ^{235}U + .735 \text{ dis/min } ^{238}U = 1.552 \text{ dis/min - } \mu\text{gram}$$

$$= \frac{1.552 \text{ dis/min - gram}}{2.22 \text{ dis/min - pCi}} = .6991 \text{ pCi/}\mu\text{gram natural uranium}$$

Conversion of μg/g to pCi/g

<u>Example Calculation - EH-1A as given in Table 6.</u>

$$\left[3.2 \pm 0.5\right] \frac{\mu\text{gram}}{\text{gram}} \times \frac{0.6991 \text{ pCi}}{\mu\text{gram}} = \left[2.2 \pm 0.3\right] \frac{\text{pCi}}{\text{gram}}$$

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APPENDIX 5

PERTINENT RADIOLOGICAL REGULATIONS, STANDARDS AND GUIDELINES

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Excerpts From

Proposed American National Standard

N13.12

Control of Radioactive Surface Contamination

on Materials, Equipment, and Facilities to be

Released for Uncontrolled Use

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

Property shall not be released for uncontrolled use unless measurements show the total and removable contamination levels to be no greater than the values in Table 1 or Table 2. (The values in Table 2 are easier to apply when the contaminants cannot be individually identified.)

Coatings used to cover the contamination shall not be considered a solution to the contamination problem. That is, the monitoring techniques shall be sufficient to determine, and such determination shall be made, that the total amount of contamination present on and under any coating does not exceed the Table 1 or Table 2 values before release.

TABLE 1

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SURFACE CONTAMINATION LIMITS*

Contaminants			Limit (Activity) (dpm/100 cm^2+)	
Group	Description	Nuclides (Note 1)	Removable	Total (Fixed plus Removable)
1	Nuclides for which the nonoccupational MPC_a (Note 2) is 2×10^{-13} Ci/m^3 or less or for which the nonoccupational MPC_w (Note 4) is 2×10^{-7} Ci/m^3 or less	227Ac 241, 242m, 243Am 249, 250, 251, 252Cf 243, 244, 245, 246, 247, 248Cm 125, 129I 237Np 231Pa 210Pb 238, 239, 240, 242, 244Pu 226, 228Ra 228, 230Th	20	Nondetectable (Note 3)
2	Those nuclides not in Group 1 for which the nonoccupational MPC_a (Note 2) is 1×10^{-12} Ci/m^3 or less or for which the nonoccupational MPC_w (Note 4) is 1×10^{-6} Ci/m^3 or less	254Es 256Fm 126, 131, 133I 210Po 223Ra 90Sr 232Th 232U	200	2000 α Nondetectable β, γ (Note 5)
3	Those nuclides not in Group 1 or Group 2		1000	5000

*The levels may be averaged over one square meter provided the maximum activity in any area of 100 cm^2 is less than three times the limit value. For purposes of averaging with regard to isolated spots of activity, any square meter of surface shall be considered to be contaminated above the limit L, applicable to 100 cm^2 if (1) from measurements of a representative number n of sections it is determined that $1/n \Sigma_i S_i \geq L$, where S_i is the dpm/100 cm^2 determined from measurement of section i; or (2) it is determined that the activity of all isolated spots or particles in any area less than 100 cm^2 exceeds $3L$.

+Disintegrations per minute per square decimeter.

NOTES:

(1) Values presented here are obtained from the *Code of Federal Regulations*, Title 10, Part 20, April 30, 1975. The most limiting of all given MPC values (for example, soluble versus insoluble) are to be used. In the event of the occurrence of mixtures of radionuclides, the fraction contributed by each constituent of its own limit shall be determined and the sum of the fractions shall be less than 1.

(2) Maximum permissible concentration in air applicable to continuous exposure of members of the public as published by or derived from an authoritative source such as the National Committee on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), or the Nuclear Regulatory Commission (NRC). From the *Code of Federal Regulations*, Title 10, Part 20, Appendix B, Table 2, Column 1.

(3) The instrument utilized for this measurement shall be calibrated to measure at least 100 pCi of any Group-1 contaminants uniformly spread over 100 cm^2.

(4) Maximum permissible concentration in water applicable to members of the public.

(5) The instrument utilized for this measurement shall be calibrated to measure at least 1 nCi of any Group-2 beta or gamma contaminants uniformly spread over an area equivalent to the sensitive area of the detector. Direct survey for unconditional release should be performed in areas where the background is $\leq$ 100 counts per minute. When the survey must be performed in a background exceeding 100 counts per minute, it may be necessary to use the indirect survey method to provide the additional sensitivity required.

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TABLE 2

ALTERNATE SURFACE CONTAMINATION LIMITS

(All Alpha Emitters, except U_{nat} and Th_{nat}, Considered as a Group)*

Contamination Contingencies	Limit (Activity) (dpm/100 cm^2)† Removable	Total (Fixed plus Removable)
If the contaminant cannot be identified; or if alpha emitters other than U_{nat} (Note 1) and Th_{nat} are present; or if the beta emitters comprise ^{227}Ac ^{228}Ra	20	Nondetectable (Note 2)
If it is known that all alpha emitters are generated from U_{nat} (Note 1) and Th_{nat}; and if beta emitters are present that, while not identified, do not include ^{227}Ac, ^{125}I, ^{226}Ra, and ^{228}Ra	200	2000 α Nondetectable β, γ (Note 3)
If it is known that alpha emitters are generated only from U_{nat} (Note 1) and Th_{nat} in equilibrium with its decay products; and if the beta emitters, while not identified, do not include ^{227}Ac, ^{125}I, ^{129}I, ^{90}Sr, ^{223}Ra, ^{228}Ra, ^{126}I, ^{131}I, and ^{133}I	1000	5000

*The levels may be averaged over one square meter provided the maximum activity in any area of 100 cm^2 is less than three times the limit value. For purposes of averaging with regard to isolated spots of activity, any square meter of surface shall be considered to be contaminated above the limit L, applicable to 100 cm^2, if (1) from measurements of a representative number n of sections it is determined that $1/n \sum_n S_i \geq L$, where S_i is the dpm/100 cm^2 determined from measurement of section i; or (2) it is determined that the activity of all isolated spots or particles in any area less than 100 cm^2 exceeds $3L$.

†Disintegrations per minute per square decimeter.

NOTES:

(1) U_{nat} and decay products.

(2) The instrument utilized for this measurement shall be calibrated to measure at least 100 pCi of any Group-1 contaminants uniformly spread over 100 cm^2.

(3) The instrument utilized for this measurement shall be calibrated to measure at least 1 nCi of any Group-2 beta or gamma contaminants uniformly spread over an area equivalent to the sensitive area of the detector. Direct survey for unconditional release should be performed in areas where the background is $\leq$ 100 counts per minute. When the survey must be performed in a background exceeding 100 counts per minute, it may be necessary to use the indirect survey method to provide the additional sensitivity required.

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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

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

November 1976

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

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

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

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

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

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

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

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

    a. Identify the premises.

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

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

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

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

TABLE I

ACCEPTABLE SURFACE CONTAMINATION LEVELS

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

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

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

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

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TABLE I (contd)

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

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

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

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RADIOLOGICAL SURVEY OF THE NEW CHEMISTRY LAB AND ANNEX, THE WEST STANDS, AND RICKETTS LAB, UNIVERSITY OF CHICAGO, CHICAGO, ILLINOIS

August 2, 1977

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PREFACE AND EXECUTIVE SUMMARY

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

Since the structures of West Stands, New Chemistry and Annex, and Ricketts Laboratory are no longer standing, it was necessary to obtain soil samples in the areas where the buildings once stood. Seventeen soil corings were taken at undisturbed locations at these three sites. Six samples were taken near West Stands, five near New Chemistry and Annex, and six near Ricketts Laboratory. The levels of natural uranium found in these samples ranged from <0.2 to 2.4 pCi/g.

Soil samples taken from the Chicago area to determine the background levels of natural uranium ranged from 0.5 to 3.4 pCi/g. These results indicate that no uranium concentrations above natural background levels are present in the soil from the areas of West Stands, New Chemistry and Annex, and Ricketts Laboratory.

Elevated levels of ^{60}Co were found in two of the soil samples taken from the top 5 cm of earth. Sample WS-4A contained 0.04 ± 0.02 pCi/g ^{60}Co and RI-6A contained 0.36 ± 0.04 pCi/g ^{60}Co. This activity could be a result of runoff from, or oxidation of stainless steel which contained induced activity

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that may been have stored in these areas. Although there are no limits set for ^{60}Co, these levels do not appear to present a radiological health hazard.

This report contains the results of surveys of the current radiological condition of the former sites of New Chemistry Lab and Annex, the West Stands and Ricketts Lab, University of Chicago, Chicago, Illinois.

This radiological assessment was performed by the following Health Physics personnel of the Occupational Health and Safety Division, Argonne National Laboratory, Argonne, Illinois: R. A. Wynveen, W. H. Smith, C. Boggs Mayes, P. C. Gray and D. W. Reilly.

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ABSTRACT

RADIOLOGICAL SURVEY OF
THE NEW CHEMISTRY LAB AND ANNEX,
THE WEST STANDS, AND RICKETTS LAB,
UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

Soil samples were collected from the areas where New Chemistry Laboratory and Annex, West Stands, and Ricketts Laboratory once stood. Soil corings were taken at undisturbed locations at these three locations. The levels of natural uranium found in these samples ranged from <0.2 to 2.4 pCi/g.

Soil samples taken from the Chicago area to determine the background levels of natural uranium ranged from 0.5 to 3.4 pCi/g. These results indicate that no uranium concentrations above natural background levels are present in the soil from the areas of West Stands, New Chemistry and Annex, and Ricketts Laboratory.

Elevated levels of ^{60}Co were found in two soil samples taken from the top 5 cm of earth. These samples contained 0.04 ± 0.02 pCi/g and 0.36 ± 0.04 pCi/g ^{60}Co. This radioactivity could be a result of runoff from, or oxidation of stainless steel which contained induced radioactivity that may have been stored in these areas. Although there are no limits set for ^{60}Co, these levels do not appear to present a radiological health hazard.

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RADIOLOGICAL SURVEY OF THE NEW CHEMISTRY LAB AND ANNEX, THE WEST STANDS, AND RICKETTS LAB, UNIVERSITY OF CHICAGO CHICAGO, ILLINOIS

INTRODUCTION

Much of the work involved in the Manhattan Engineer District/Atomic Energy Commission (MED/AEC) era was performed at the University of Chicago. The New Chemistry Lab and Annex, the West Stands and Ricketts Lab were buildings which were in use at the time. The buildings have since been torn down.

The work performed in these building, included the handling of radioactive materials. Both plutonium and uranium were in use in these buildings.

It was, therefore, felt that some type of soil analysis should be undertaken. The soil samples were taken from these areas on August 2, 1977. The purpose of this soil survey was to determine if any detectable contamination remains in the soil as a result of the MED/AEC operations.

SOIL SAMPLE METHODOLOGY AND ANALYTICAL PROCEDURE

Soil corings were taken at selected undisturbed locations on the site of the former buildings of New Chemistry Lab and Annex, the West Stands and Ricketts Lab to determine the deposition, if any, of nuclides that could have been spilled or released. Flurometric and gamma-spectral analyses were conducted on these soil samples.

The corings were effected using a 10.1-cm-diameter by 15.2-cm-long right-circular-cylinder cutting tool, used as a golf-green-hole cutter.

Each total core, 30 cm in length, was divided into four segments. Starting from the surface, three separate 5-cm segments are cut, bagged, and marked A, B, and C, respectively; the final segment of 15 cm was marked D.

The reason for the segmented coring is to determine what, if any, contamination migration has occurred, to reduce the dilution of lower-level soil with the upper-level segments in respect to the surface deposition of the contaminants or vice versa, and to reveal any overburden or backfill that may have occurred over the years.

Background data for the soil-sample analysis (Table 3) were obtained from a number of soil samples taken from the Chicago area. This information was obtained from the Environmental Monitoring Section of the Occupational Health and Safety (OHS) Division of Argonne National Laboratory (ANL).

All soil samples were prepared at ANL (Figure 1) and shipped to a commercial laboratory (LFE Environmental Analysis Laboratories) for radiochemical (fluorometric) and gamma-spectral analysis. Their procedure for soil analysis is described in Appendix 1.

Results submitted by LFE Environmental Analysis Laboratories, as listed in Table 2, are reported in picocuries per gram (pCi/g) for the Ge(Li)-spectral analysis and in micrograms per gram (μg/g) for the uranium-fluorometric analysis. The latter concentrations were converted to pCi/g by means of the calculation shown in Appendix 1.

Sample preparation consisted of weighing the samples in their entirety and then drying for approximately 24 hours at 80°C. All samples were then reweighed, put into mill jars (8.7 ℓ), and milled until a sufficient amount of the soil sample would pass a No. 30 standard sieve. At no point were the rocks and heavy material ground or pulverized since this material would act as a diluent and hence, lower the resultant concentration of deposited material.

After sufficient milling, the material was sieved using a No. 30, (600-micron) standard stainless steel sieve. The rocks and dross vs. sieved material were segregated, bagged, and weighed separately. Soil-sample weights are given in Table 1.

Aliquots of the sieved material were then loaded into screw-top plastic containers. The amount varied according to the type of analysis to be performed, 100 grams for gamma-spectral and radiochemical (fluorometric) analyses and 10 grams for radiochemical (fluorometric) only. All items of equipment were scrubbed and air dried before the introduction of the next sample.

Seventeen soil samples were taken on the grounds of the former buildings. These locations are shown in Figure 2. Samples WS-1 through WS-6 were taken in the vicinity of West Stands. Samples NC-1 through NC-5 were taken close to the New Chemistry Laboratory and Annex and samples RI-1 through RI-6 were taken in the vicinity of Ricketts Laboratory.

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RESULTS OF SOIL SAMPLE ANALYSIS

Soil samples taken from the Chicago area to determine the background levels of natural uranium ranged from 0.5 to 3.4 pCi/g. Results of soil samples taken near the West Stands site range from 0.3 to 1.7 pCi/g of natural uranium. Samples from New Chemistry range from <0.3 to 2.4 pCi/g of natural uranium and samples from Ricketts Laboratory range from <0.2 to 1.5 pCi/g of natural uranium. These results indicate that no uranium concentrations above natural background levels are present in the soil from the former West Stands, New Chemistry and Annex, and Ricketts Laboratory sites.

Elevated levels of ^{60}Co were found in two of the soil samples, WS-4A and RI-6A. Sample WS-4A contained 0.04 ± 0.02 pCi/g of ^{60}Co and RI-6A contained 0.32 ± 0.04 pCi/g of ^{60}Co. This activity could possibly be due to runoff from, or oxidation of stainless steel which contained induced activity that may have been stored in these areas.

FIGURE 1

SOIL-SAMPLING PROCEDURE AND PROCESSING DIAGRAM

ANL-HP-DWG. 78-2

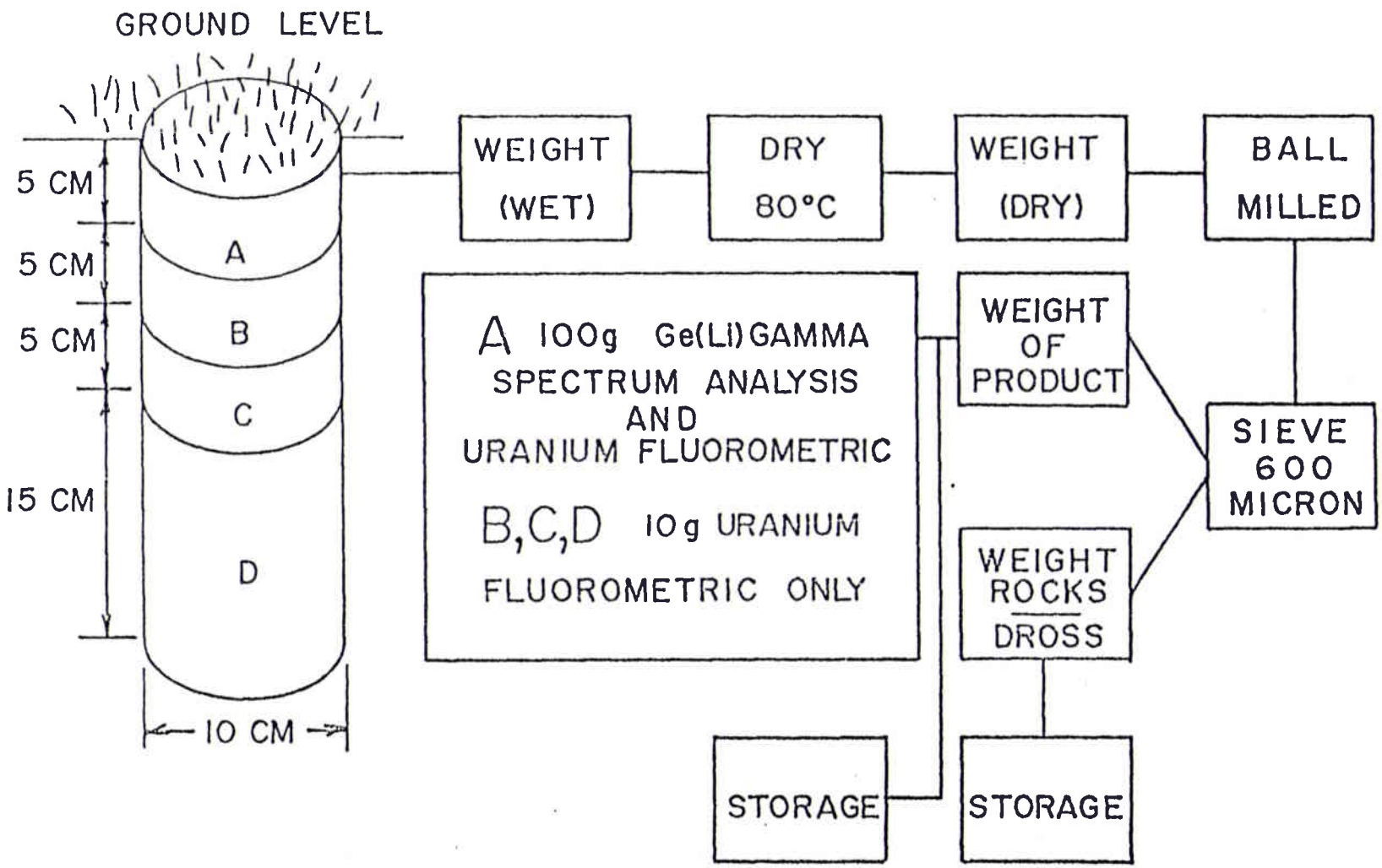

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FIGURE 2

NEW CHEMISTRY LAB AND ANNEX, WEST STANDS, AND RICKETTS LAB
SOIL SAMPLE LOCATIONS

ANL-HP DWG. NO. 78-38

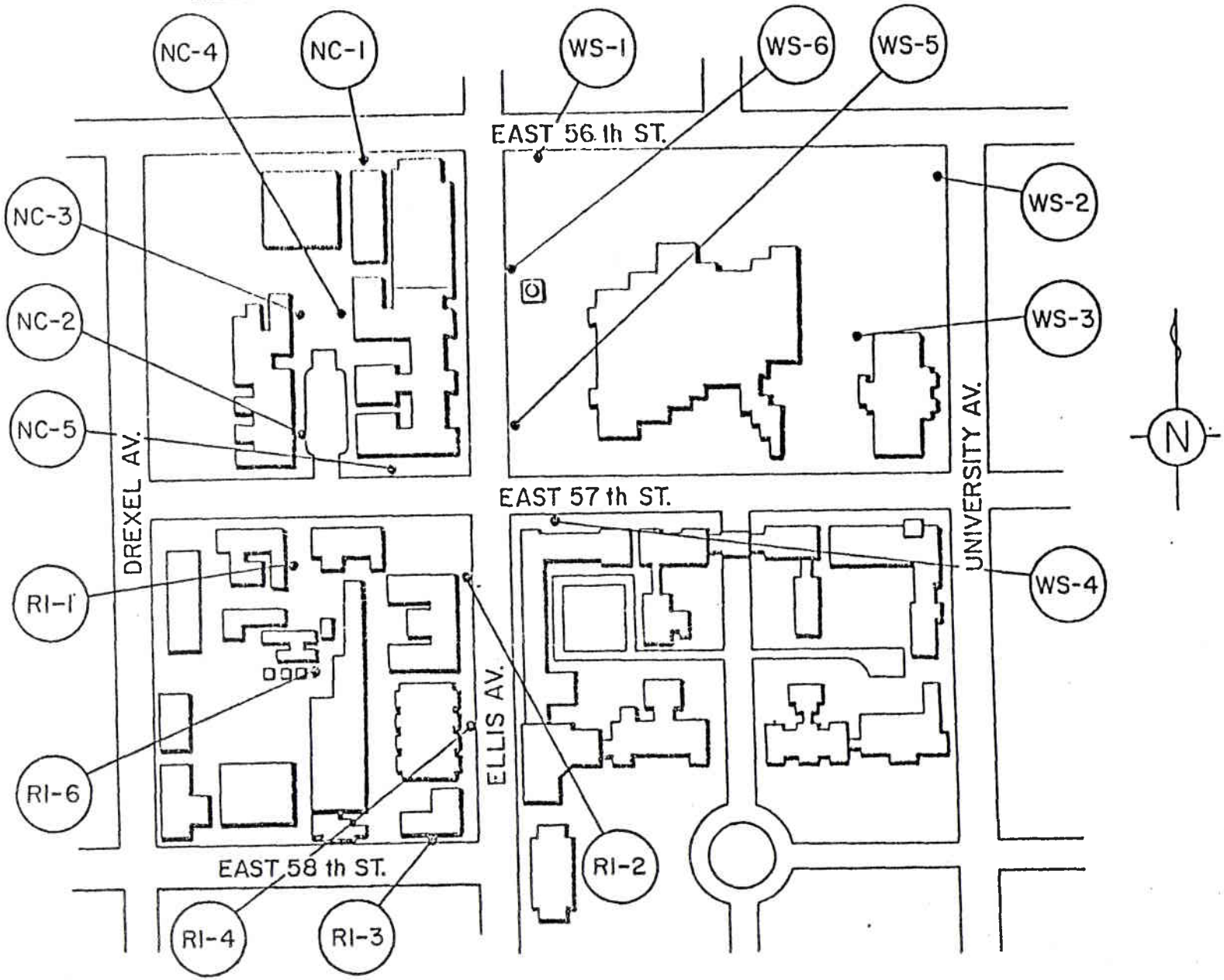

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TABLE 1

SOIL SAMPLE WEIGHTS

Sample No.	Wet Weight (grams)	Dry Weight (grams)	Sieved Weight (grams)	Rocks and Dross (grams)
WS-1A	629.0	499.7	370.8	121.8
WS-1B	587.1	512.7	367.7	136.0
WS-1C	903.4	794.8	300.7	194.0
WS-1D	2744.1	2190.8	1930.9	256.2
WS-2A	527.3	425.7	394.5	29.6
WS-2B	713.6	604.0	598.7	3.3
WS-2C	1008.0	882.2	793.3	85.0
WS-2D	2386.9	2129.0	1649.6	457.9
WS-3A	562.5	429.8	363.2	63.4
WS-3B	563.3	469.9	350.4	114.0
WS-3C	776.8	688.4	355.4	330.6
WS-3D	2223.0	1978.5	824.4	1128.3
WS-4A	627.3	477.6	400.0	22.1
WS-4B	668.7	522.5	504.2	5.4
WS-4C	929.4	726.3	697.5	25.4
WS-4D	2369.8	1892.7	1693.8	197.6
WS-5A	461.5	317.2	251.6	60.7
WS-5B	579.8	371.8	361.4	4.4
WS-5C	663.9	556.5	470.4	84.6
WS-5D	2254.9	2075.5	1741.6	329.5
WS-6A	471.1	338.3	266.9	61.2
WS-6B	651.2	497.8	400.4	45.2
WS-6C	734.0	549.4	445.6	102.4
WS-6D	2337.0	2126.4	1656.2	467.4
NC-1A	651.8	533.3	439.7	77.1
NC-1B	291.8	231.4	221.3	3.9
NC-1C	904.4	752.0	561.3	179.3
NC-1D	2231.0	2002.2	1576.6	414.8
NC-2A	537.7	420.6	361.1	58.1
NC-2B	715.9	561.6	527.2	29.3
NC-2C	1240.5	1023.6	956.6	53.0
NC-2D	1869.3	1729.7	1390.0	337.5

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TABLE 1
(cont'd)

SOIL SAMPLE WEIGHTS

Sample No.	Wet Weight (grams)	Dry Weight (grams)	Sieved Weight (grams)	Rocks and Dross (grams)
NC-3A	452.7	331.4	319.9	9.8
NC-3B	955.5	803.6	754.0	49.3
NC-3C	1012.2	858.0	824.8	32.7
NC-3D	2066.0	1790.3	1575.9	213.6
NC-4A	526.9	391.5	373.7	11.7
NC-4B	723.7	588.7	560.7	14.9
NC-4C	1052.5	876.3	830.8	35.0
NC-4D	2295.9	2004.0	1898.3	102.5
NC-5A	645.6	508.0	463.0	40.6
NC-5B	563.5	429.1	412.4	16.5
NC-5C	1050.0	949.6	879.2	68.7
NC-5D	2116.0	1979.5	1850.1	78.2
RI-1A	746.9	588.9	555.0	33.0
RI-1B	292.9	254.5	246.2	6.9
RI-1C	585.6	519.3	493.9	14.5
RI-1D	2662.3	2261.1	1889.3	268.9
RI-2A	735.2	556.2	466.7	90.8
RI-2B	1050.3	852.3	805.3	43.0
RI-2C	534.7	492.2	419.2	10.9
RI-2D	2691.9	2336.6	2024.7	309.4
RI-3A	962.8	654.4	500.3	153.0
RI-3B	718.8	546.6	504.2	38.4
RI-3C	878.5	738.9	688.2	49.8
RI-3D	1090.1	904.8	790.2	114.0
RI-4A	681.8	551.4	516.7	26.3
RI-4B	458.8	370.9	328.6	38.6
RI-4C	1208.3	1033.6	910.7	121.9
RI-4D	1643.5	1401.4	1279.6	115.2
RI-5A	681.2	491.4	479.6	10.0
RI-5B	525.1	413.1	383.0	20.0
RI-5C	806.2	642.2	604.5	32.6
RI-5D	1353.0	1225.9	476.2	748.2

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TABLE 2

Ge(Li)-SPECTRAL AND URANIUM-FLUOROMETRIC ANALYSES RESULTS

Sample No.	Ge(Li) Spectra pCi/g received wt ± σ(1)			Uranium	
	^{137}Cs	^{232}Th Decay Chain	^{226}Ra Decay Chain	μg/g ± σ(2)	pCi/g ± σ(3)
WS-1A	0.92 ± 0.06	0.44 ± 0.22	0.47 ± 0.08	1.2 ± 0.5	0.8 ± 0.3
WS-1B				1.0 ± 0.3	0.7 ± 0.2
WS-1C				0.9 ± 0.4	0.6 ± 0.3
WS-1D				1.0 ± 0.4	0.7 ± 0.3
WS-2A	1.14 ± 0.06	0.29 ± 0.08	0.46 ± 0.05	0.7 ± 0.3	0.5 ± 0.2
WS-2B				0.4 ± 0.2	0.3 ± 0.1
WS-2C				1.0 ± 0.5	0.7 ± 0.3
WS-2D				0.4 ± 0.3	0.3 ± 0.2
WS-3A	1.83 ± 0.09	0.50 ± 0.05	0.74 ± 0.04	1.3 ± 0.4	0.9 ± 0.3
WS-3B				1.6 ± 0.4	1.1 ± 0.3
WS-3C				1.1 ± 0.3	0.8 ± 0.2
WS-3D				1.5 ± 0.5	1.0 ± 0.3
WS-4A(4)	0.69 ± 0.03	0.74 ± 0.05	1.00 ± 0.04	1.3 ± 0.4	0.9 ± 0.3
WS-4B				2.4 ± 0.6	1.7 ± 0.4
WS-4C				1.8 ± 0.4	1.3 ± 0.3
WS-4D				1.8 ± 0.4	1.3 ± 0.3
WS-5A	1.99 ± 0.10	0.43 ± 0.13	0.70 ± 0.10	2.0 ± 0.4	1.4 ± 0.3
WS-5B				1.1 ± 0.4	0.8 ± 0.3
WS-5C				1.0 ± 0.4	0.7 ± 0.3
WS-5D				1.5 ± 0.4	1.0 ± 0.3
WS-6A	2.54 ± 0.13	0.44 ± 0.10	0.54 ± 0.08	1.3 ± 0.5	0.9 ± 0.3
WS-6B				1.1 ± 0.3	0.8 ± 0.2
WS-6C				1.7 ± 0.8	1.2 ± 0.6
WS-6D				<0.7	<0.5
NC-1A	1.06 ± 0.05	0.38 ± 0.09	0.48 ± 0.06	0.6 ± 0.4	0.4 ± 0.3
NC-1B				0.9 ± 0.4	0.6 ± 0.3
NC-1C				1.0 ± 0.7	0.7 ± 0.5
NC-1D				0.9 ± 0.4	0.6 ± 0.3
NC-2A	0.76 ± 0.04	0.71 ± 0.09	0.85 ± 0.06	1.4 ± 0.5	1.0 ± 0.3
NC-2B				0.8 ± 0.4	0.6 ± 0.3
NC-2C				1.8 ± 0.9	1.3 ± 0.6
NC-2D				<0.7	<0.5

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TABLE 2
(cont'd)

Ge(Li)-SPECTRAL AND URANIUM-FLUOROMETRIC ANALYSES RESULTS

Sample No.	Ge(Li) Spectra pCi/g received wt ± σ(1)			Uranium	
	^{137}Cs	^{232}Th Decay Chain	^{226}Ra Decay Chain	μg/g ± σ(2)	pCi/g ± σ(3)
NC-3A	0.81 ± 0.06	0.54 ± 0.12	0.73 ± 0.08	3.5 ± 0.5	2.4 ± 0.3
NC-3B				0.8 ± 0.4	0.6 ± 0.3
NC-3C				0.9 ± 0.6	0.6 ± 0.4
NC-3D				0.8 ± 0.4	0.6 ± 0.3
NC-4A	0.73 ± 0.07	0.94 ± 0.16	1.04 ± 0.10	2.6 ± 0.5	1.8 ± 0.3
NC-4B				1.3 ± 0.4	0.9 ± 0.3
NC-4C				0.9 ± 0.5	0.6 ± 0.3
NC-4D				<0.6	<0.4
NC-5A	0.82 ± 0.06	0.73 ± 0.12	0.76 ± 0.08	<0.8	<0.6
NC-5B				1.3 ± 0.4	0.9 ± 0.3
NC-5C				<0.4	<0.3
NC-5D				<0.4	<0.3
RI-1A	2.00 ± 0.10	0.45 ± 0.10	0.63 ± 0.08	<0.4	<0.3
RI-1B				0.8 ± 0.5	0.6 ± 0.3
RI-1C				0.4 ± 1.0	0.3 ± 0.7
RI-1D				0.9 ± 0.4	0.6 ± 0.3
RI-2A	2.52 ± 0.13	0.56 ± 0.10	0.67 ± 0.07	0.8 ± 0.5	0.6 ± 0.3
RI-2B				1.1 ± 0.8	0.8 ± 0.6
RI-2C				1.2 ± 0.4	0.8 ± 0.3
RI-2D				<0.6	<0.4
RI-3A	0.50 ± 0.04	0.82 ± 0.10	0.80 ± 0.06	1.8 ± 0.5	1.3 ± 0.3
RI-3B				2.2 ± 0.6	1.5 ± 0.4
RI-3C				0.8 ± 0.2	0.6 ± 0.1
RI-3D				0.8 ± 0.5	0.6 ± 0.3
RI-4A	0.22 ± 0.02	0.27 ± 0.05	0.40 ± 0.04	0.7 ± 0.4	0.5 ± 0.3
RI-4B				<0.6	<0.4
RI-4C				<0.4	<0.3
RI-4D				<0.3	<0.2
RI-5A	1.64 ± 0.08	0.76 ± 0.14	0.98 ± 0.10	1.5 ± 0.7	1.0 ± 0.5
RI-5B				1.6 ± 0.2	1.1 ± 0.1
RI-5C				0.9 ± 1.0	0.6 ± 0.7
RI-5D				1.3 ± 0.6	0.9 ± 0.4

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TABLE 2
(cont'd)

Ge(Li)-SPECTRAL AND URANIUM-FLUOROMETRIC ANALYSES RESULTS

Sample No.	Ge(Li) Spectra pCi/g received wt ± σ(1)			Uranium	
	^{137}Cs	^{232}Th Decay Chain	^{226}Ra Decay Chain	μg/g ± σ(2)	pCi/g ± σ(3)
RI-6A(5)	1.91 ± 0.10	0.32 ± 0.03	0.31 ± 0.05	0.6 ± 0.4	0.4 ± 0.3
RI-6B				0.6 ± 0.4	0.4 ± 0.3
RI-6C				1.0 ± 0.4	0.7 ± 0.3
RI-6D				0.5 ± 0.3	0.3 ± 0.2

(1) One standard deviation due to counting statistics.
(2) DATA results for LFE.
(3) ANL conversion from Appendix 2.
(4) Sample WS-4A contained 0.04 ± 0.02 pCi/g ^{60}Co.
(5) Sample RI-6A contained 0.36 ± 0.04 pCi/g ^{60}Co.

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TABLE 3

BACKGROUND SOIL SAMPLE DATA
Cesium-137, Thorium-232,
Natural Uranium in Soil, 1977

(Concentrations in 10^{-6} μCi/g)

Date Collected	Location	Cesium-137	Thorium-232	Uranium (natural)
June 16	Argonne Area	1.0 ± 0.3	0.34 ± 0.01	1.6 ± 0.1
June 16	Argonne Area	0.9 ± 0.3	0.23 ± 0.01	1.8 ± 0.1
June 16	Argonne Area	1.1 ± 0.3	0.15 ± 0.01	1.2 ± 0.1
June 16	Argonne Area	0.5 ± 0.2	0.36 ± 0.03	1.6 ± 0.1
June 16	Argonne Area	1.0 ± 0.3	0.33 ± 0.04	1.1 ± 0.1
Nov. 15	Argonne Area	0.4 ± 0.1	0.25 ± 0.01	1.1 ± 0.1
Nov. 15	Argonne Area	1.1 ± 0.3	0.07 ± 0.01	0.9 ± 0.1
Nov. 15	Argonne Area	1.1 ± 0.3	0.07 ± 0.01	1.4 ± 0.1
Nov. 15	Argonne Area	0.9 ± 0.3	0.07 ± 0.01	1.2 ± 0.1
	Average	0.9 ± 0.2	0.21 ± 0.08	1.3 ± 0.2
	Off-Site			
June 14	Channahon, IL	0.9 ± 0.3	-	1.3 ± 0.1
June 14	Morris, IL	1.2 ± 0.4	0.32 ± 0.03	3.0 ± 0.2
June 14	Starved Rock State Pk., IL	0.6 ± 0.2	0.26 ± 0.01	0.5 ± 0.1
June 16	Lemont, IL	0.7 ± 0.2	0.38 ± 0.01	1.2 ± 0.1
June 16	Romeoville, IL	0.5 ± 0.2	0.17 ± 0.02	3.4 ± 0.2
October 6	McKinley Wds. State Pk., IL	1.0 ± 0.3	0.13 ± 0.01	1.0 ± 0.1
October 6	Dresden Lock and Dam, IL	1.2 ± 0.4	-	2.0 ± 0.1
October 27	Saganashkee Slough, IL	0.8 ± 0.3	0.23 ± 0.01	1.6 ± 0.1
October 27	McGinnis Slough, IL	0.9 ± 0.3	0.19 ± 0.01	1.5 ± 0.1
	Average	0.9 ± 0.2	0.24 ± 0.07	1.7 ± 0.6

*These results are transcribed from "Environmental Monitoring at Argonne National Laboratory Annual Report for 1977" (ANL-78-26) by N. W. Golchert, T. L. Duffy, and J. Sedlet.

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APPENDIX 1

SOIL-ANALYSIS PROCEDURE FOR TOTAL URANIUM AND GAMMA-EMITTING NUCLIDES

A 60-milliliter volume of the received soil was counted in a petri dish for 500 minutes on a Ge(Li) detector over the energy range 0-1.5 MeV. This corresponded to 60-100 g of soil, depending upon bulk soil density. Positive photopeaks above instrument background were converted to dis/min using a line efficiency curve based upon a National Bureau of Standards Multi Gamma standard. The natural-thorium-232 and radium-226 decay chains were calculated using the 0.910-MeV actinium-228 and 0.609-MeV bismuth-214 photopeaks, respectively. Cesium-137 is reported for each sample as a representative gamma emitter. Potassium-40 was observed on all soil samples, as expected, but was not calculated or reported.

One gram of the soil sample was ashed and dissolved in HF-HNO_3 for the total uranium analysis. A 100-λ aliquot of the dissolved sample was fused with 98% NaF-2% LiF and the fluorescence determined using a Jarrel-Ash fluorometer. A quenching factor was determined for each sample by using an internal spike.

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APPENDIX 2

NATURAL-URANIUM CALCULATIONS

Radioactive half-lives of ^{234}U, ^{235}U, and ^{238}U, as well as the present abundance for each isotope, were obtained as current best values from the "Table of Isotopes" - 6th Edition by C. M. Lederer, J. M. Hollander, and I. Perlman, 1967. The values used are:

Isotope	Half-life (years)	% Abundance
^{234}U	2.47×10^5	0.0057
^{235}U	7.1×10^8	0.7196
^{238}U	4.51×10^9	99.2760
		100.0013

Note that the abundance totals 100.0013%. Since it cannot be determined which isotope(s) are in error, the calculations are made with the 0.0013% error not accounted for.

$$SpA = \lambda N = \frac{(\ln 2)N}{t_{1/2}}$$

SpA = Specific Activity

A = Number of radioactive atoms per unit mass $= \frac{\text{Avogadro's Number}}{\text{Gram atomic weight}}$

Avogadro's Number = 6.025×10^{23}

N = Number of radioactive atoms per unit mass

$= \frac{\text{Avogadro's Number}}{\text{gram atomic weight}}$

$t_{1/2}$ = Half-life in years (a)

$$SpA = \frac{0.693 \cdot 6.025 \times 10^{23}}{t_{1/2}(a) \cdot 5.256 \times 10^5 \ \frac{min}{a} \cdot \text{gram atomic weight}} = \text{dis/min-gram}$$

$$SpA\ ^{234}U = \frac{0.693 \cdot 6.025 \times 10^{23}}{2.47 \times 10^5 \cdot 5.256 \times 10^5 \cdot 2.34 \times 10^2}$$

$= 1.374 \times 10^{10}$ dis/min-gram

$= 1.374 \times 10^4$ dis/min-μg $\cdot\ 5.70 \times 10^{-5}$

= 0.783 dis/min-μg of natural uranium

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APPENDIX 2
(cont'd)

NATURAL-URANIUM CALCULATIONS

$$\text{SpA } ^{235}U = \frac{0.693 \cdot 6.025 \times 10^{23}}{7.1 \times 10^{8} \cdot 5.256 \times 10^{5} \cdot 2.35 \times 10^{2}}$$

$$= 4.76 \times 10^{6} \text{ dis/min-gram}$$

$$= 4.76 \text{ dis/min-}\mu g \cdot 7.196 \times 10^{-3}$$

$$= 0.034 \text{ dis/min-}\mu g \text{ of natural uranium}$$

$$\text{SpA } ^{238}U = \frac{0.693 \cdot 6.025 \times 10^{23}}{4.51 \times 10^{9} \cdot 5.256 \times 10^{5} \cdot 2.38 \times 10^{2}}$$

$$= 7.4 \times 10^{5} \text{ dis/min-gram}$$

$$= 0.74 \text{ dis/min-}\mu g \cdot 9.9276 \times 10^{-1}$$

$$= 0.735 \text{ dis/min-}\mu g \text{ of natural uranium}$$

Therefore, the activity of 1 μg of natural uranium is

$$0.783 \text{ dis/min } ^{234}U + 0.034 \text{ dis/min } ^{235}U + 0.735 \text{ dis/min } ^{238}U$$

$$= 1.552 \text{ dis/min-}\mu g.$$

Conversion of μg/g to pCi/g

$$= \frac{1.552 \text{ dis/min-}\mu g}{2.22 \text{ dis/min-pCi}}$$

$$= 0.6991 \text{ pCi}$$

Example Calculation: WS-1A

$$[1.2 \pm 0.5] \frac{\mu g}{gram} \cdot \frac{0.6991 \text{ pCi}}{\mu g} = [0.8 \pm 0.3] \frac{pCi}{gram}$$

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SURVEY TECHNIQUES

General

All accessible original walls were surveyed to a height of 2 meters and all accessible floor areas were surveyed (Table 1). In many areas, the floors and walls had been carpeted or painted. Even though these were not the original surfaces, these areas were surveyed since the capability of detection was adequate to detect activity on the original structures underneath. A representative selective survey of overheads such as ducts and beams was performed in areas where the original structures were available. See Table 1 and Figures 1A through 1F for locations of accessible areas surveyed. (All measurements were originally taken using the English system. The SI units are to the nearest approximation. For example, 2 inches are equal to 5 cm.)

Instrumentation

Three types of survey instruments were used (Table 2). An Eberline FM-4G having a detection area of 325 cm , utilizing the Eberline PAC-4G-3 electonics, was used to survey the floors. A PAC-4G-3 with a hand-held detector, 51 cm in sensitive area, was used to survey the walls and other accessible areas. Double aluminized mylar (0.85 mg/cm) windows were used in both detectors. This allows low energy detection and, therefore, provides for increased instrument sensitivity. Both of these instruments were initially used in the beta mode. In the beta mode, the detector responds to alpha and beta particles and X and gamma rays. When areas were found which indicated a higher count rate than the instrument background, the instrument was then switched to the alpha mode and a reading of the alpha activity was obtained. In the alpha mode, the instrument only responds to particles with high specific ionization such as alpha particles.