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FORMERLY UTILIZED MED/AEC SITES REMEDIAL ACTION PROGRAM

RADIOLOGICAL SURVEY OF THE GEORGE HERBERT JONES CHEMICAL LABORATORY THE UNIVERSITY OF CHICAGO CHICAGO, ILLINOIS

June 13-17, 1977

OCCUPATIONAL HEALTH AND SAFETY DIVISION
Health Physics Section
ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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June 13-17, 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) to determine the condition of sites formerly used by the Manhattan Engineer District (MED) and the AEC for work involving the handling of radioactive materials.* Since the early 1940s, 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 the decontamination work done at the time nuclear activities ceased is adequate by current guidelines. The George Herbert Jones Chemical Laboratory at the University of Chicago in Chicago, Illinois, was one such site. Radiochemistry for the MED/AEC project was performed in this building. It is presently used as offices, laboratories and classrooms.

To determine if any radioactive contamination remains as a result of the MED/AEC activities, a comprehensive radiological assessment of the laboratory was conducted during June 1977. Direct instrument surveys and smear surveys indicated that some contamination and radioactive materials are still present. Contamination or radioactive material was found at 53 locations in 20 rooms or areas throughout Jones Laboratory. However, some of this radioactivity is a result of later use rather than of MED/AEC operations. Contamination possibly resulting from MED/AEC activities was found at 46 locations in 17 rooms or areas throughout Jones Laboratory. In most instances, small spots of contamination were found, mainly on the floors and walls. The attic was the only room where extensive contamination was found. This is an 18 m by 27 m (60 ft x 90 ft)** concrete-floored room now used for materiel storage.

The beta-gamma readings obtained with a gas-flow proportional survey meter at the contaminated areas in the attic ranged from 1.7×10^3 to 3.0×10^5 dis/min-100 cm^2. The alpha readings in the attic ranged from background to 1.5×10^4 dis/min-100 cm^2. The highest Geiger-Mueller (GM) End-Window exposure

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*The various types and sources of radiation mentioned in this report are discussed in more detail in Appendix 8.

**When metric units are followed (in parentheses) by English units, the measurements were originally made in English units and then converted into metric. In cases where only metric units are given, the values were either originally given in metric, or resulted from calculations involving numbers previously converted from English into metric.

reading from contamination in the attic was 0.5 mR/h at contact, and no GM End-Window exposure readings taken at 1 m (3 ft) were distinguishable from the instrument background of 0.03 to 0.05 mR/h.

The beta-gamma contamination levels detected in the rest of the building with the gas-flow proportional survey meter ranged from 3×10^2 to 3.9×10^5 dis/min-100 cm^2. The alpha readings at these locations ranged from background to 9.6×10^3 dis/min-100 cm^2. The highest GM End-Window contact exposure reading in the rest of the building was 9 mR/h, and no GM exposure readings taken at 1 m (3-ft) were distinguishable from the instrument background.

Contamination was detected on four smears but three of those were found in Room 104 and were a result of use subsequent to MED/AEC occupancy. The other contaminated smear, obtained in Room 404E, measured background for beta-gamma and 3.3×10^1 dis/min-100 cm^2 for alpha.

The radiation readings obtained in the contaminated areas were compared with standards and guidelines in the American National Standard N13.12, "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use," and the Nuclear Regulatory Commission's "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."

The attic was the only room where the radionuclides of contamination were identified. The results of gamma-spectral analysis identified the contaminant as normal uranium. Therefore, the ANSI Standard limits for natural uranium were used as the basis of comparison for the readings in this room. The specific radionuclides present in contaminated areas throughout the rest of the building were not identified. Since it was known that plutonium and radium had been used in the building, the acceptable surface contamination levels for plutonium and radium-226 (^{226}Ra) were used for comparative purposes for the rest of the building. Thirty-five areas of contamination possibly due to MED/AEC occupancy in 16 rooms exceeded the ANSI Standard for plutonium and ^{226}Ra. Eight areas in the attic exceeded the ANSI Standard for natural uranium. Four contaminated areas (in Room 10 and the attic) also exceeded the NRC Guideline of a "maximum radiation level of 1.0 mrad/h at 1 cm or the average radiation level of 0.2 mrad/h at 1 cm" for surface contamination resulting from beta-gamma emitters.

Under current use conditions, the potential for radiation exposures to occupants of this building from these sources of contamination is remote.

Additionally, except in one instance, the contamination is "fixed to" or under existing surfaces and thus is not readily available for transfer to other locations.

Radon-daughter concentrations measured in indoor air samples ranged from 0.0001 to 0.010 Working Levels (WL), including background. Grab-Sampling techniques were used to collect air samples at selected locations, including the areas where contamination was found. Under the Surgeon General's Guidelines, no need for remedial action is indicated when concentrations of radon daughters are less than 0.01 WL above background. The concentrations detected in the laboratory indicated normally expected background concentrations, and no long-lived radionuclides were detected in any air sample.

Soil samples were taken about the grounds of Jones Laboratory to determine the presence of any radionuclides that could have been spilled or released outside during the MED/AEC activities. Because of many modifications in the landscaping since the MED/AEC era, only two soil samples were obtained in what appeared to be undisturbed areas in the immediate vicinity of Jones Laboratory.

The background samples taken from the Chicago area indicated concentrations of natural uranium ranging from 0.5 to 3.4 pCi/g. Analyses of the soil samples taken about Jones Laboratory indicated uranium concentrations ranging from 0.0 to 5.8 pCi/g. Even though some of these samples exceeded 3.4 pCi/g, they are most probably not a result of contamination from the MED/AEC era. Since fertilization of the soil with inorganic compounds can increase the levels of uranium and thorium, these elevated readings could be a result of fertilization, rather than residual contamination.

Potential 50-year dose commitments resulting from exposure to the radioactivity remaining from MED/AEC use of Jones Laboratory were calculated for a pathway that could result in the presumed maximum internal radiation doses from inhalation/ingestion of radioactive material. These internal 50-year dose commitments were calculated to be 4.3 mrem to the lung, 0.88 mrem to the bone, 0.21 mrem to the kidney, and 0.053 mrem whole-body. Each of these is less than 1% of the appropriate annual standards for an individual in an uncontrolled area. Since no GM end-window exposure readings at 1 m were greater than the instrument background, no external radiological hazard is envisioned.

In order to reduce the potential for radiation exposure, remedial measures such as stabilization of the contamination in place would be applicable as a

short-term measure. In order to reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution would involve decontamination by removal of the radioactive residues from the 17 rooms or areas where contamination possibly resulting from MED/AEC activities were detected.

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, and D. W. Reilly

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RADIOLOGICAL SURVEY OF THE GEORGE HERBERT JONES CHEMICAL LABORATORY UNIVERSITY OF CHICAGO CHICAGO, ILLINOIS

ABSTRACT

A comprehensive radiological survey was conducted at George Herbert Jones Chemical Laboratory at the University of Chicago, Chicago, Illinois. Radiochemistry for the MED/AEC project was performed in this building in the 1940s. The building is now used as laboratories, offices, and classrooms.

The survey was undertaken to determine the location and quantities of any radioactive materials remaining from the MED/AEC operations. Survey measurements included alpha and beta-gamma contamination determinations, both fixed and removable; beta-gamma exposure readings at contact and at 1 m; estimates of radon-daughter concentrations; and determinations of concentrations of ^{137}Cs, the ^{232}Th decay chain, the ^{226}Ra decay chain, and uranium in the soil on the site.

Forty-three spots of contamination possibly resulting from MED/AEC occupancy in 17 rooms exceeded the allowable limits as given in the ANSI Standard N13.12. Except in a few instances, the contamination was found to be "fixed to," or under existing surfaces and not readily available for transfer to other locations. Under current use conditions, the potential for radiation exposure to occupants of this building from these sources of contamination is remote.

Concentrations of radon daughters in the air of the building, as measured with grab-sampling techniques, were below the limit of 0.01 WL above background as given in the Surgeon General's Guidelines. No long-lived radionuclides were detected in any air sample. Concentrations of radionuclides in soil samples from near the laboratory generally indicated background levels. The presumed maximum potential internal radiation 50-year dose commitments from inhalation/ingestion of contamination remaining from MED/AEC activities were calculated to be 4.3 mrem to the lung, 0.88 mrem to the bone, 0.21 mrem to the kidney, and 0.053 mrem whole-body. Each of these is less than 1% of the appropriate annual standards for an individual in an uncontrolled area.

In order to reduce the potential for radiation exposure, remedial measures such as stabilization of the contamination in place would be applicable as a short-term measure. In order to reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution would involve decontamination by removal of the radioactive residues from the 17 rooms or areas where contamination possibly resulting from MED/AEC activities were detected.

INTRODUCTION

Much of the work of the Manhattan Engineer District/Atomic Energy Commission (MED/AEC) in the late 1940s was performed at the University of Chicago, and the George Herbert Jones Chemical Laboratory near Ellis Avenue and East 58th Street was one of the buildings used. Radiochemistry for the MED/AEC project was performed in this building. The laboratory is presently in use as offices, laboratories, and classrooms.

No reports could be found of radiation* surveys or decontamination efforts being conducted at Jones Laboratory after the termination of MED/AEC activities. It was, therefore, specified that a radiation survey should be undertaken to determine if any detectable radioactive contamination remains as a result of the MED/AEC operations. The survey of Jones Laboratory was conducted from June 13 to June 17, 1977.

SURVEY AND ANALYTICAL TECHNIQUES

General

A radiological survey of the laboratory was performed on all accessible floors and original walls to a height of 2 m (7 ft). A representative selection of accessible overhead structures such as pipes, vents, and light fixtures was also surveyed. In many areas, the floors and walls had been retiled or painted

*See Appendix 8 for a detailed discussion and definitions of the various terms and concepts mentioned in this report relative to types of radiation, exposures doses, and similar topics.

after MED/AEC activities ended. Even though these were not the original surfaces, such areas were surveyed with instruments that have some capability to detect potential beta-gamma activity on the original, underlying surfacess. The locations of accessible areas surveyed are indicated in Table 1 and Figures 1-8.

Instrumentation Used for Direct Surveys

Three types of survey instruments were used in direct surveys. An Eberline gas-flow proportional probe (FM-4G) with a detection area of 325 cm^2 and using the Eberline PAC-4G-3 electronics was used to survey the floors. A PAC-4G-3 with a hand-held gas-flow proportional probe with a detection area of 51 cm^2 was used to survey the walls and other areas not accessible with the FM-4G. An Eberline Model 530 Geiger-Mueller (GM) detector with an Eberline HP-190 end-window probe was used to measure the contact exposure rate (mR/h) of the contaminated areas. This instrument also was held at 1 m (3 ft) above the floor to determine general ambient background radiation levels throughout the surveyed area. The instruments are described in more detail in Appendix 1.

Although ^{239}Pu and ^{90}Sr-^{90}Y standards were used to calibrate the instruments, it should be noted that the numerous isotopes which could be encountered exhibit emission energies differing from those of the standards. For cases when known isotopes that emit alpha and beta energies differing from those of the standards were being detected, a conversion factor for those particular radionuclides was developed to determine the appropriate yield. (The methods used to determine the conversion factors are described in Appendix 2.) In this report all readings of disintegrations per minute per 100 square centimeters (dis/min-100 cm^2) are equated to ^{239}Pu and ^{90}Sr-^{90}Y, unless otherwise stated. It should also be noted that since calibrations are to infinitely-thin flat-plate standards, all reported readings should be interpreted as minimal values. No corrections were made for absorption by surface media.

When possible, the isotopes of contamination were identified by performing a gamma-spectral analysis, using a multichannel analyzer described in Appendix 1, on the contaminated item or on a sample of material taken from the contaminated area.

Smear Surveys

Dry smears were taken at selected locations throughout the entire Jones Laboratory. Smears were taken on original structures and components, such as walls, floors, pipes, and vents. All smears were taken with Whatman No. 1 filter paper, 4.25 cm in diameter. A standard smear is performed by applying moderate pressure by the tips of the first two fingers to the back of the filter paper and rubbing the paper over the surface. Smears of about 930 cm^2 (1 ft^2) were normally taken. If an instrument reading higher than background was obtained for an area or object, a smear of 100 cm^2 was taken. A smear of 100 cm^2 also was taken if there was excessive dirt or dust on an area.

Two different instruments were used to measure (count) the contamination on the smears. They were first counted in groups of ten using a 10-wire flat-plate gas-flow proportional detector developed at ANL. The instrument detects alpha and beta particles and x- and gamma-rays. Additionally, at least one smear of each group was removed and counted in the more sensitive 2π Internal Gas-Flow Proportional Counter, (PC counter) using an aluminized Mylar window (Mylar spun top) over the smear. All smears from areas or objects with elevated direct readings were counted in the PC counter and all smears in groups indicating results above the instrument background levels in the 10-wire assembly were individually counted in the PC counter. Smears were counted in each detector for both alpha and beta-gamma activity. The instruments are described in detail in Appendix 1 and the derivation of the smear-count conversion factors used are given in Appendix 2. The activity detected on the smears is equated to ^{239}Pu and ^{90}Sr-^{90}Y as described in Appendix 1.

The locations of elevated instrument readings and all smear locations are shown in Figures 1-8 and the results of the instrument and smear surveys are given in Table 1.

Air Samples

Air samples were collected with a commercial vacuum cleaner modified at ANL for use as a particulate air-sampling device. A flow rate of 20 or 40 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-gamma activity in the PC counter, using a Mylar spun top. The counting results were

used to determine radon and radon-daughter concentrations and the presence of any long-lived radionuclides. Procedures used in these determinations are detailed in Appendix 3, and results are shown in Table 2.

Soil Samples

Two soil corings were taken at selected, apparently undisturbed, locations outside Jones Laboratory (see Fig. 9) to detect any deposition of radionuclides that could have been spilled or released during MED/AEC activities. Two soil samples were taken from the grounds adjacent to the Jones Laboratory. The samples were subjected to uranium-fluorometric and gamma-spectral analyses.

The corings were obtained with a 10-cm (4-in) diameter, 15-cm (6-in) long right-circular-cylinder cutting tool commonly used to cut golf-green holes. Each core was 30 cm long and each 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 (see Fig. 10).

The segmented coring technique was used to determine if any contaminant migration had occurred, to reduce the dilution of upper-level soil with the lower-level segments with respect to the surface deposition of the contaminants (or vice versa), and to reveal if any overburden or backfill material had been added over the years.

Results of the soil-sample analyses (Table 4) were compared with background data obtained from a number of soil samples collected at several Chicago-area locations (Table 5). This information was obtained from the Environmental Monitoring Section of the Occupational Health and Safety Division of Argonne National Laboratory.

All soil samples were processed at ANL and shipped to a commercial laboratory (LFE Environmental Analysis Laboratories) for radiochemical (fluorometric) and gamma-spectral analyses. Their procedures are described in Appendix 4.

As shown in Figure 10, sample preparation consisted of weighing the samples and then drying them for about 24 hours at 80°C. All samples were then reweighed, placed into mill jars (8.7 ℓ), and milled until a sufficient amount of the soil sample could pass through a No. 30 standard stainless-steel sieve (600 micron mesh). At no point were the rocks and solid material ground or pulverized, since this material would act as a diluent and, hence, lower the reported concentration of deposited radioactive material. The rocks and dross and the

sieved material were segregated, bagged, and weighed separately (weights are given in Table 3).

Aliquots of the sieved material were loaded into screwtop plastic containers. The amount placed in the containers vaired according to the type of analysis to be performed--100 g for gamma-spectral and radiochemical (fluorometric) analysis and 10 g for radiochemical (fluorometric) only. Every effort was made throughout the sample preparation to eliminate cross-contamination. Soil samples suspected of containing elevated amounts of radioactivity were processed in separate equipment from that used to process the soil samples considered to contain background levels of radiation. In addition, all items of equipment were thoroughly scrubbed and air dried before introduction of the next sample.

SURVEY RESULTS

General

Results of the survey are discussed in this section. The PAC-4G-3 instrument readings and smear results have been normalized to units of disintegrations per minute per 100 square centimeters (dis/min-100 cm^2) using the factors derived in Appendix 2. The contamination in the attic is equated to normal uranium; the rest of the contamination is equated to ^{90}Sr-^{90}Y or ^{239}Pu. The PAC-4G-3 readings and smear data are reported in net count rates; i.e., the background count rates have been subtracted from the gross count rates prior to conversion to dis/min-100 cm^2. Any alpha contributions have been subtracted from readings taken in the beta mode so that the corrected values reflect only the beta-gamma readings. The GM exposure rates given in Table 1 include the instrument background of 0.03-0.05 mR/h.

The room background levels varied somewhat, due in part to differences in the construction materials used. The average background readings for all modes of operation of the instruments used are summarized in Appendix 1.

The fraction of surface areas accessible for survey varied from room to room. Table 1 includes the percent of the areas accessible for survey. The average percent of the total area that was accessible was 45% for the floors and 50% for the walls.

Instrument and Smear Surveys

Radioactivity was found at 53 locations in 20 rooms or areas throughout Jones Laboratory. The maximum instrument readings are shown in Table 1, and the locations are shown in Figures 1-8. Some of this radioactivity was determined to have resulted from later use, not MED/AEC operations. Radioactive sources, samples, and contamination were found in Rooms 104, 213, 404B, and in the attic that were not a result of MED/AEC occupancy.

Contamination possibly present as a result of the MED/AEC occupancy was found at 46 locations in 17 rooms or areas throughout Jones Laboratory. In most instances, this contamination consisted of small localized spots found mainly on the walls and floors of the rooms. The PAC beta-gamma contamination levels ranged from 3×10^2 to 3.9×10^5 dis/min-100 cm^2. The maximum beta-gamma reading, 3.9×10^5 dis/min-100 cm^2, was on a junction box in Room 10. The highest GM contact exposure rate reading of 9 mR/h was also found on this junction box. The PAC alpha contamination levels ranged from background to 1.5×10^4 dis/min-100 cm^2. The highest level of alpha contamination, 1.5×10^4 dis/min-100 cm^2, was on the concrete floor in the attic. No GM exposure rate readings taken at 1 m were distinguishable from the instrument background.

The attic was the only area where extensive contamination was found. The attic is a concrete-floored room, 18 m by 27 m (60 ft x 90 ft), now used for materiel storage. Since contamination was widespread in the attic, the room was divided into sections to facilitate documentation of the survey results.

A sample of the contamination chipped from the spot in the attic where the radiation was the highest was determined by gamma-spectral analysis to be normal uranium. (See Fig. 11 for the gamma spectrum of a sample of the attic floor.) Therefore, all contamination detected in the attic area (except for radium sources) is reported in terms of disintegrations per minute of normal uranium.

The extent of the attic contamination and maximum readings in each section were as follows: (see Fig. 7 for locations)

I-A — Contamination was found over most of the floor area. The maximum readings were 3.0×10^5 dis/min-100 cm^3 beta-gamma and 3.3×10^3 dis/min-100 cm^2 alpha; the end window GM detector readings were 0.5 mR/h at contact and background at 1 m.

I-B Contamination was found over most of the floor area. The maximum readings were 1.9×10^5 dis/min-100 cm^2 beta-gamma and 1.5×10^4 dis/min-100 cm^2 alpha; the end window GM detector readings were 0.5 mR/h at contact and background at 1 m.

I-C No contamination was found in this area.

I-D No contamination was found in this area.

I-E Contamination was confined to a few small spots. The maximum readings were 6.5×10^4 dis/min-100 cm^2 beta-gamma and 2.9×10^3 dis/min-100 cm^2 alpha; the end window GM detector readings at contact and at 1 m were background.

II-A Contamination was found over most of the floor area. The maximum readings were 7.0×10^3 dis/min-100 cm^2 beta-gamma and background alpha; the end window GM detector readings at contact and at 1 m were background.

II-B Contamination was found over most of the floor area. The maximum readings were 5.5×10^3 dis/min-100 cm^2 beta-gamma and background alpha; the end window GM detector readings at contact and 1 m were background.

II-C Contamination was found over most of the floor area. The maximum readings were 7.5×10^4 dis/min-100 cm^2 beta-gamma and 2.6×10^3 dis/min-100 cm^2 alpha; the end window GM detector readings were 0.3 mR/h at contact and background at 1 m.

II-D Contamination was found over most of the floor area. The maximum readings were 1.7×10^3 dis/min-100 cm^2 beta-gamma and background alpha; the end window GM detector readings at contact and 1 m were background.

II-E Contamination was confined to a few small spots. The maximum readings were 2.2×10^3 dis/min-100 cm^2 beta-gamma and background alpha; the end window GM detector readings at contact and 1 m were background.

III-A Contamination was confined to a few small spots. The maximum readings were 1.3×10^5 dis/min-100 cm^2 beta-gamma and 7.3×10^3 dis/min-100 cm^2 alpha; the end window GM detector readings were 0.2 mR/h at contact and background at 1 m.

III-B Contamination was confined to a few small spots. The maximum readings were 5.5×10^4 dis/min-100 cm^2 beta-gamma and 7.3×10^3 dis/min-100 cm^2 alpha; the end window GM detector readings were 0.2 mR/h at contact and background at 1 m.

III-C A speck of material was found on the shelf which gave a reading of 2.9×10^3 dis/min-100 cm^2 beta-gamma and 7.3×10^2 dis/min-100 cm^2 alpha. The end window reading at contact and 1 m were background. No contamination was found on the floor area, but several ^{226}Ra sources were found on a shelf.

III-D No contamination was found in this area.

III-E No contamination was found in this area.

Radioactive contamination was found on four of the smears collected during the survey. The contaminated smears (indicating presence of loose contamination) were taken at the following locations:

Room 104 Location 81 (see Fig. 2) on the floor was 1.4×10^3 dis/min-100 cm^2 beta-gamma and 290 dis/min-100 cm^2 alpha.

Location 82 on the floor was background beta-gamma and 52 dis/min-100 cm^2 alpha.

Location 84 on the floor was 130 dis/min-100 cm^2 beta-gamma and 560 dis/min-100 cm^2 alpha.

(NOTE: Room 104 is presently used as a chemistry laboratory and has been repainted and retiled. Therefore, this activity in Room 104 is probably a result of recent use, rather than MED/AEC operations.)

Room 404E Location 221 (see Fig. 5) on the wall was background beta-gamma and 33 dis/min-100 cm^2 alpha.

No contamination greater than the instrument background of the gas-flow proportional counters was detected on any other smears. The locations at which all smears were taken are shown in Figures 1-8.

Radiation levels determined during the instrument and smear surveys were compared with both the ANSI Standard N13.12 "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use," and the NRC's 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" (see Appendix 6). Since normal uranium was identified in the attic, the surface contamination limits for natural uranium were used for comparison with all readings from that room.

Since none of the other spots of contamination could be easily chipped or otherwise removed, the radionuclides involved could not be identified. However, based on the recollections of persons who were involved with the MED/AEC activities, it is known that plutonium and ^{226}Ra were used in this particular building. In the ANSI Standard, plutonium and radium are Group 1 radionuclides and uranium is in Group 3. Since it is possible that plutonium and radium could be the contaminating radionuclides in the Jones Laboratory, the more restrictive

limits for Group 1 have been used in this report for comparative purposes for all rooms except the attic.

The allowable limit in the ANSI Standard for plutonium and radium is 20 dis/min-100 cm^2 removable, and the limits are such that the total (fixed plus removable) activity must be nondetectable using instruments calibrated to measure at least 1000 pCi of the contaminant uniformly spread over 100 cm^2. The NRC Guidelines for plutonium and radium are stated 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 used for the average may not be averaged over more than 1-m^2, 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 allowable limit in the ANSI Standard for natural uranium activity is 5000 dis/min-100 cm^2 total, of which only 1000 dis/min-100 cm^2 can be removable. The NRC Guidelines for natural uranium are as follows: the average is 5000 dis/min-100 cm^2 alpha, and the removable is 1000 dis/min-100 cm^2 alpha. Thus, the ANSI Standard is identical to the NRC Guidelines for uranium, except the ANSI limits do not exclude the determination of uranium by beta-gamma activity. The NRC Guidelines are stated in terms of alpha activity only.

The 35 locations of the building (exclusive of the attic) where contamination possibly due to MED/AEC activity was found to exceed the acceptable levels are listed in Table 6. The ANSI Standard for Group 1 radionuclides was used as the limit for surface contamination levels, and the NRC Guidelines were used for the average and maximum radiation levels at 1 cm.

The eight locations in the attic where contamination possibly due to MED/AEC activity was found to exceed the acceptable surface contamination levels for uranium as given in the ANSI Standard or the average and maximum radiation levels of 0.2 and 1.0 mrad/h, respectively, at 1 cm as given in the NRC Guidelines are listed in Table 7.

Air Samples

The analyses of air samples collected at 20 selected locations inside the laboratory are reported in Table 2. Techniques detailed in Appendix 3 were used to determine the radon-222 concentration and daughter Working Levels (WL). The results ranged from 0.0001 to 0.0100 WL and were within the values expected for background levels. As specified in the Surgeon General's Guidelines (Appendix 6), concentrations of radon daughters of less than 0.01 WL above background do not indicate a need for remedial action. No long-lived radionuclides were detected on any air sample.

Soil Samples

As previously indicated, much of the ground around the Jones Laboratory had been distrubed and subject to changes in landscaping subsequent to the termination of MED/AEC activities. Dirt had been removed in some areas, and fill added in others. Therefore, soil samples could be obtained from only two locations around Jones Laboratory that appeared to be undisturbed. Results of the gamma-ray spectral and uranium-fluorometric analyses performed on these samples are shown in Table 4. The analyses indicated concentrations of natural uranium ranging from 0.0 to 5.8 pCi/g. As indicated in Table 5, levels of natural uranium in background samples collected in the Chicago area ranged from 0.5 to 3.4 pCi/g. Thus, the maximum reading from the Jones Laboratory samples exceeded the highest background reading reported. However, since fertilizing the soil with inorganic compounds can result in increased levels of uranium and throium, these elevated levels around the laboratory are presumed to be a result of fertilization, rather than residual contamination.

ESTIMATED EXTENT OF CONTAMINATION

Any estimate of the total mass and volume of radioactively contaminated material that would be generated by remedial action at Jones Laboratory is subject to many uncertainties. For example, one can only surmise as to the actual depth of contamination within the concrete floors or stairs. For the purposes of this report, it will be assumed that contamination on concrete will require removal to a depth of 5 cm (2 in); contamination on wooden floors will

require removal to 2 cm (3/4 in), the standard thickness of such floors. These assumptions are believed to be conservative.

Estimates of the total activity of contaminated material are likewise subject to some uncertainties because of survey limitations. Unless otherwise known, as in the fourth-floor attic, all readings of dis/min-100 cm^2 (as reported in Table 1) are equated to ^{239}Pu or ^{90}Sr-^{90}Y infinitely-thin flat-plate standards. (In the case of the fourth floor attic, readings of dis/min-100 cm^2 are equated to a 3-mm thick plate of normal uranium.) No corrections can be accurately made for absorption by surface media, and hence, estimates of activity in surface media could be underestimated.

Despite these uncertainties and limitations, estimates of volume, mass, and activity for each type of material have been made and are presented in Table 8. The total would consist of an estimated 1.7 m^3 of material with a mass of 4.0×10^3 kg and an activity of 2.4×10^2 μCi.

DOSE AND POTENTIAL HAZARD EVALUATION

The survey data on surface contamination, external penetrating radiation, radioactivity on airborne particulates, and radioactivity in soil samples at the Jones Laboratory may be evaluated in terms of the doses that potentially exposed persons could receive. The doses can then be compared to the appropriate standards and/or natural background radiation doses or used to estimate risks of health effects.

The appropriate radiation protection standards for external and internal exposure of individuals and population groups in uncontrolled areas are given in the Department of Energy publication "Requirements for Radiation Protection" (see Appendix 6) and are expressed as the permissible dose or dose commitment annually (in mrem) beyond that received from background radiation and medical exposures.

Natural background radiation doses consist of an external penetrating dose from cosmic and terrestrial sources and an internal dose from the inhalation/ingestion of radioactivity from cosmogenic and terrestrial sources. The average annual natural background doses for the U. S. population are 54 mrem external and 28 mrem internal to the whole-body (soft tissue), 54 mrem external and 125 mrem internal to the lung, and 54 mrem external and 117 mrem internal to the bone (osteocytes) (Ref. 1). The total whole-body, lung, and bone doses are thus

82 mrem, 179 mrem, and 171 mrem per year, respectively. Background radiation is discussed in more detail in Appendix 8.

Estimates of radiological risks resulting from specific doses are usually based on risk factors as provided in reports by the International Commission on Radiological Protection (ICRP) (Ref. 2), National Research Council Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) (Refs. 3, 4), or United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (Ref. 5). By multiplying the estimated dose by the appropriate risk factor, one can obtain an estimate of the risk or probability of the occurrence of heatlh effects such as cancers and hereditary effects to an individual or his descendants as a result of that exposure. The evaluation of risk factors is presently subject to large uncertainties and continual revision, and is the subject of considerable controversy. For these reasons, it will not be considered further.

Potential doses resulting from exposure to the radioactivity remaining from MED/AEC use of Jones Laboratory, were calculated for a pathway or scenario that could result in the presumed maximum internal radiation dose from inhalation/ingestion of radioactive material. Since no GM end-window exposure readings at 1 m were greater than the instrument background, no external radiological hazard is envisioned from the contaminated items and areas. Additionally, since the radioactivity on airborne particulates and the radioactivity in soil samples indicated natural background only, no pathways are considered here for these two terms. Therefore, only surface contamination is considered. Details of the dose calculations are discussed in Appendix 7; results are given below.

The internal radiation dose commitments from potential inhalation/ingestion of contamination possibly resulting from MED/AEC occupancy were calculated to be 4.3 mrem to the lung, 0.88 mrem to the bone, 0.21 mrem to the kidney, and 0.053 mrem to the whole body. These are 50-year dose commitments and represent the total dose that would be accumulated in the body or specific critical organs over a 50-year period from inhalation/ingestion in the first year. Fifty-year dose commitments are always as large or larger than first year annual doses; hence all comparisons to annual dose standards are of a conservative nature. The dose commitments to the lung, bone, and kidney represent increases of approximately 2.4%, 0.5%, and 0.25% above the 179 mrem, 171 mrem, and 82 mrem annual natural background lung, bone, and kidney doses, respectively, and 0.3%, 0.06% and 0.014% of the 1500 mrem standard for an individual in an uncontrolled area.

For the whole-body, this represents approximately 0.065% of the 82-mrem annual natural background whole-body dose and 0.011% of the 500-mrem standard for an individual in an uncontrolled area.

In order to reduce the potential for radiation exposure, remedial measures such as stabilization of the contamination in place would be applicable as a short-term measure. In order to reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution to the problem would involve decontamination by removal of the radioactive residues from the 17 rooms or areas in the facility where conamination possibly resulting from MED/AEC activities was detected.

REFERENCES

1. National Council on Radiation Protection and Measurements. 1975. "Natural Background Radiation in the United States." NCRP Report No. 45.

2. International Commission on Radiological Protection. 1977. "Reccommendations of the International Commission on Radiological Protection." Annals of the ICRP, Vol. 1. No. 3, ICRP Publication 26, Pergamon Press, New York.

3. National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). 1972. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation." National Academy of Sciences.

4. National Research Council, Committee on the Biological Effects of Ionizing Radiation (BEIR). 1980. "The Effects on Populations of Exposure to Low-Levels of Ionizing Radiation: 1980." National Academy of Sciences.

5. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 1977. "Sources and Effects of Ionizing Radiation, 1977 Report to the General Assembly." United Nations Publication E.77.IX.1.

FIGURE 1

AIR SAMPLE AND SURVEY LOCATIONS IN JONES LABORATORY BASEMENT

ANL-HP DWG. NO. 78-10

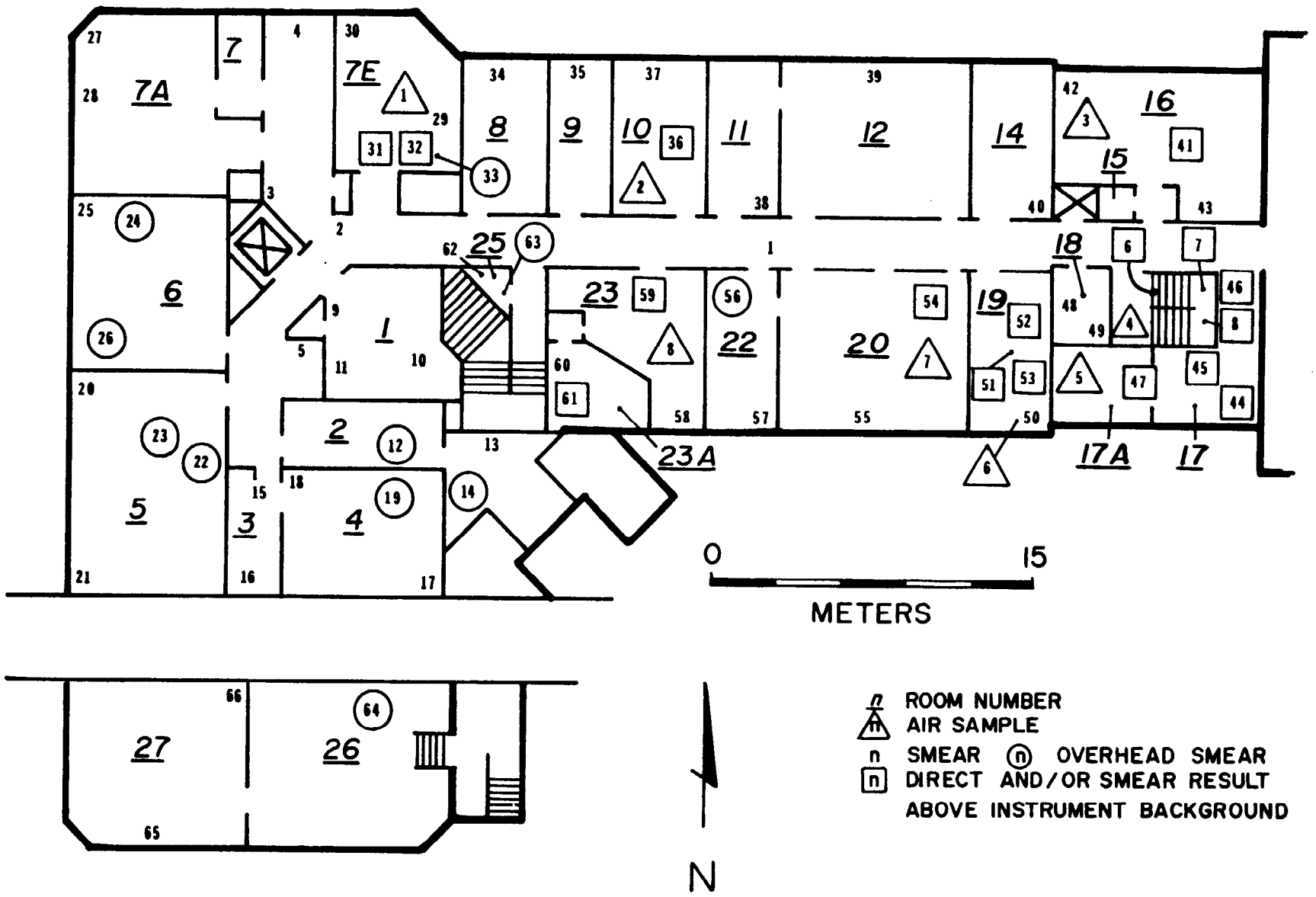

FIGURE 2

AIR SAMPLE AND SURVEY LOCATIONS IN JONES LABORATORY FIRST FLOOR

ANL-HP DWG. NO. 78-11

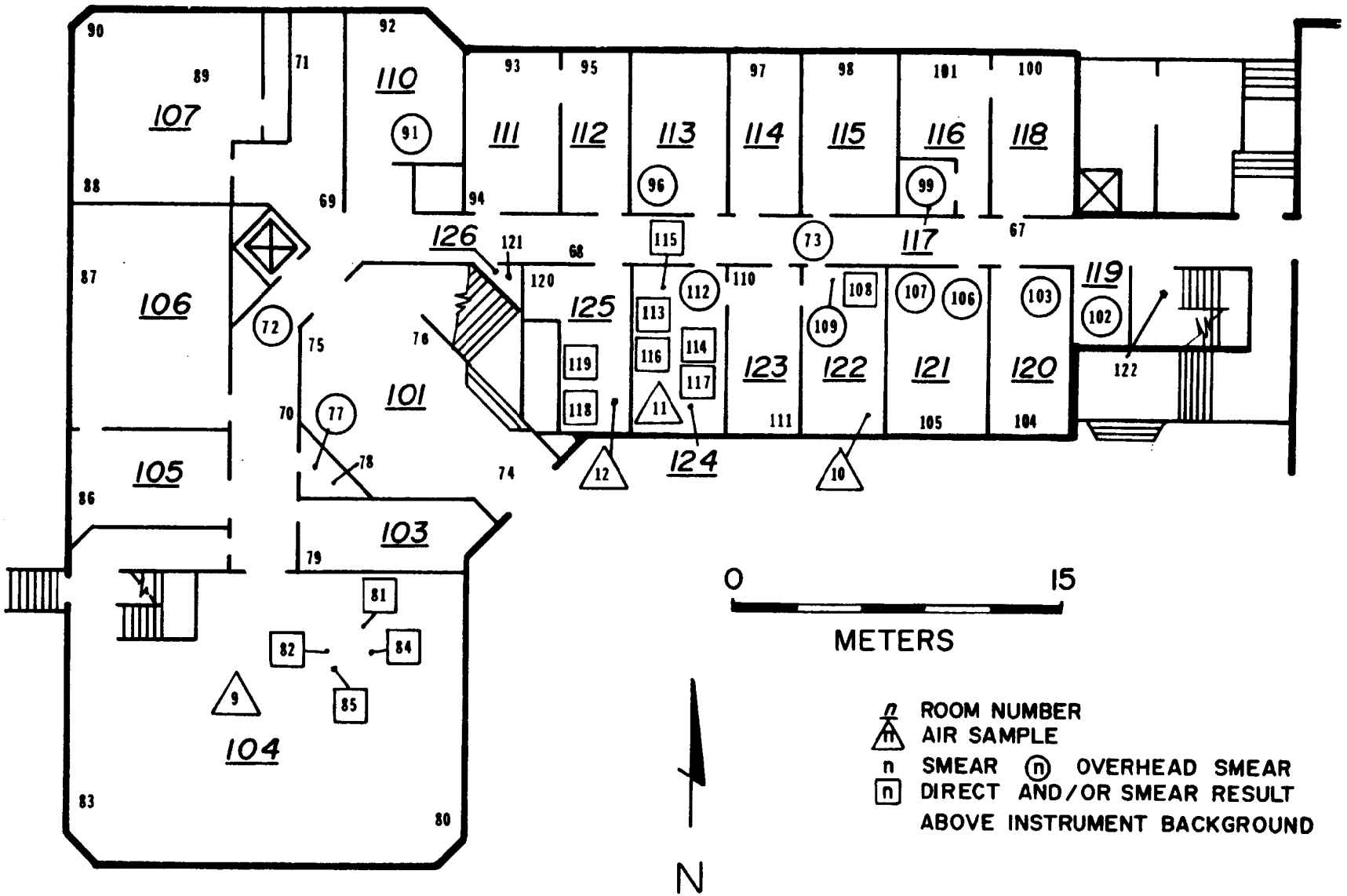

FIGURE 3

AIR SAMPLE AND SURVEY LOCATIONS IN JONES LABORATORY SECOND FLOOR

ANL-HP DWG. NO. 78-12

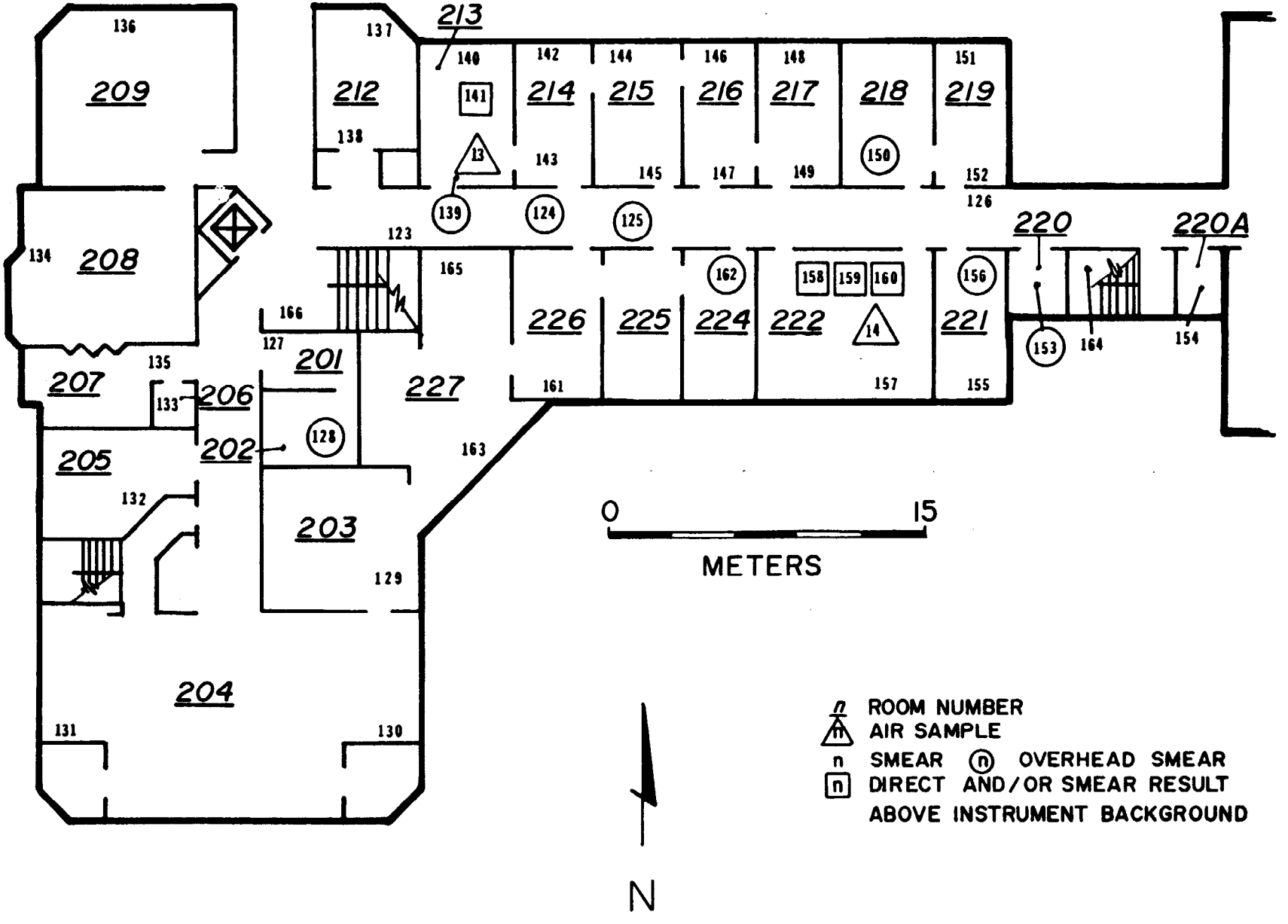

FIGURE 4

AIR SAMPLE AND SURVEY LOCATIONS IN JONES LABORATORY THIRD FLOOR

ANL-HP DWG. NO. 78-13

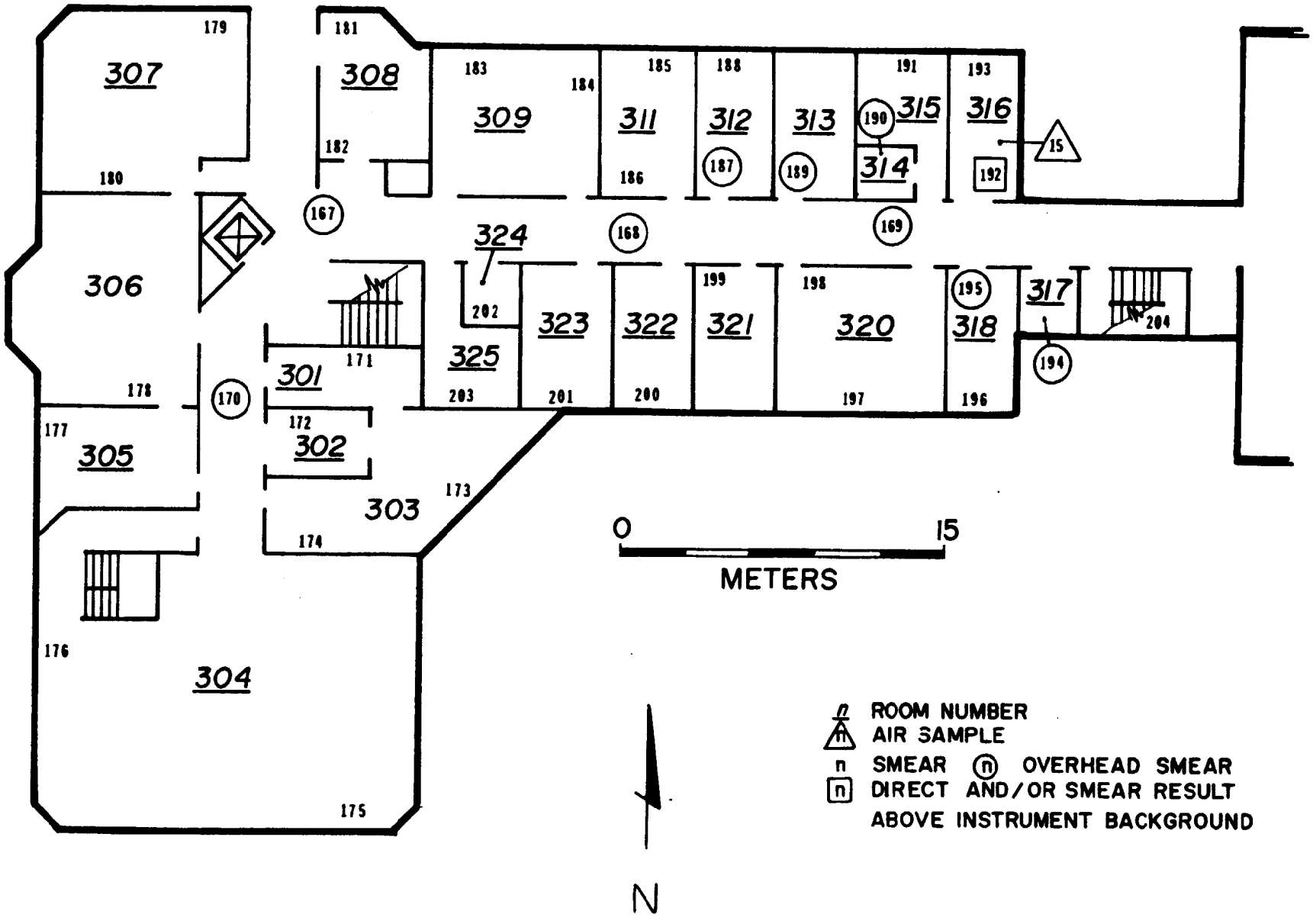

FIGURE 5

AIR SAMPLE AND SURVEY LOCATIONS IN JONES LABORATORY FOURTH FLOOR

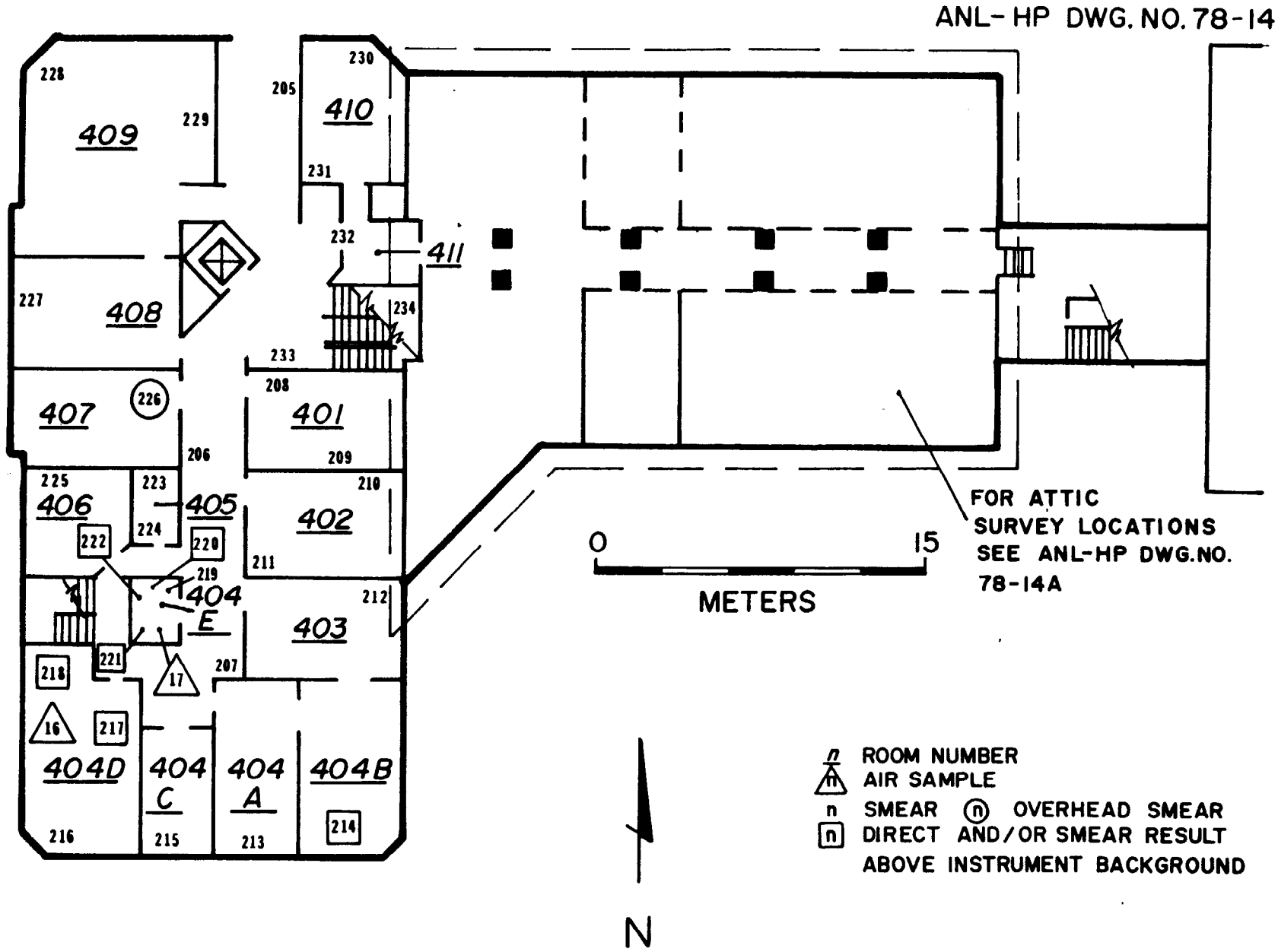

FIGURE 6

JONES LABORATORY FOURTH FLOOR ATTIC SECTIONS

ANL-HP DWG. NO. 79-1

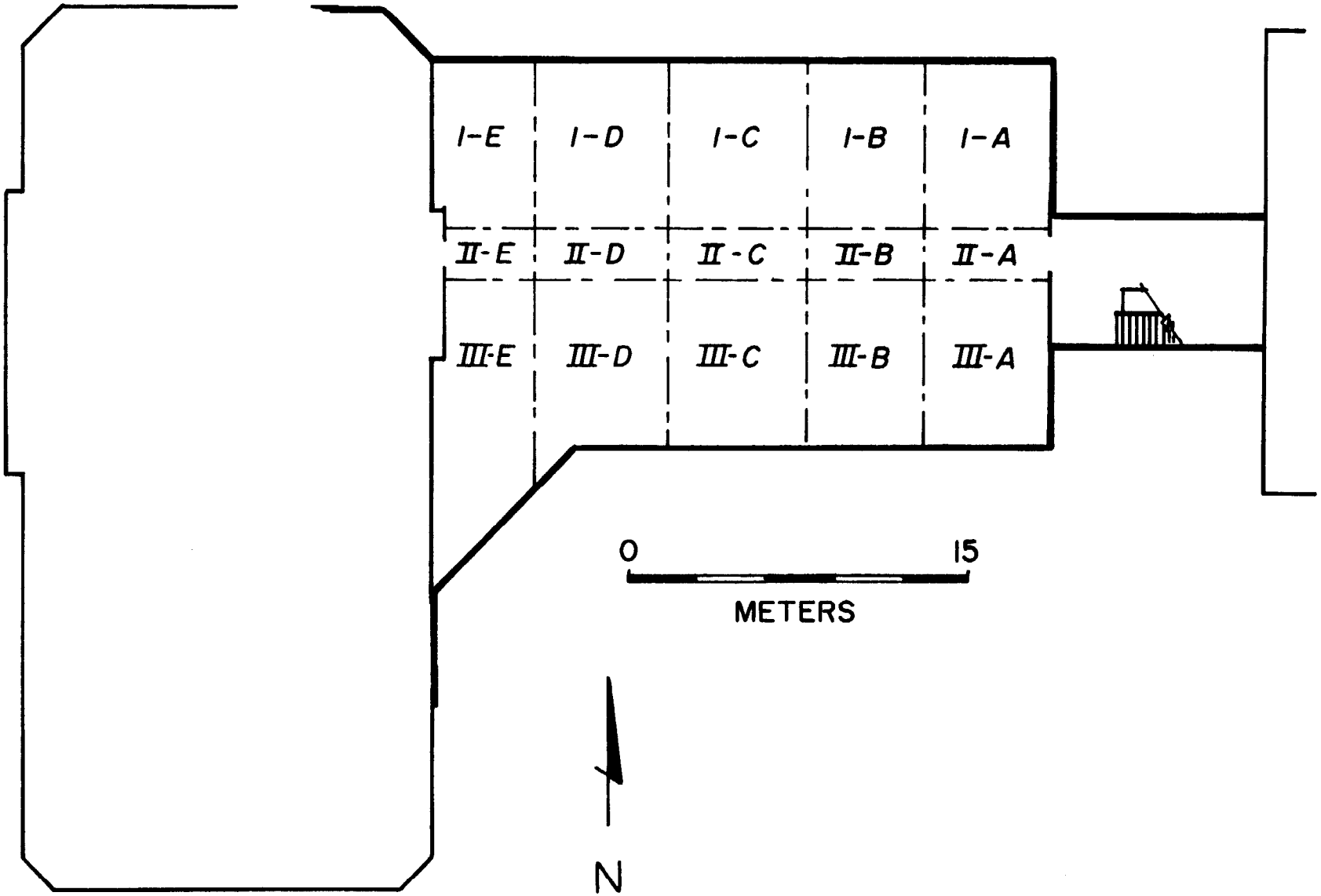

FIGURE 7

AIR SAMPLE AND SURVEY LOCATIONS IN JONES LABORATORY FOURTH FLOOR ATTIC

ANL-HP DWG. NO. 78-14A

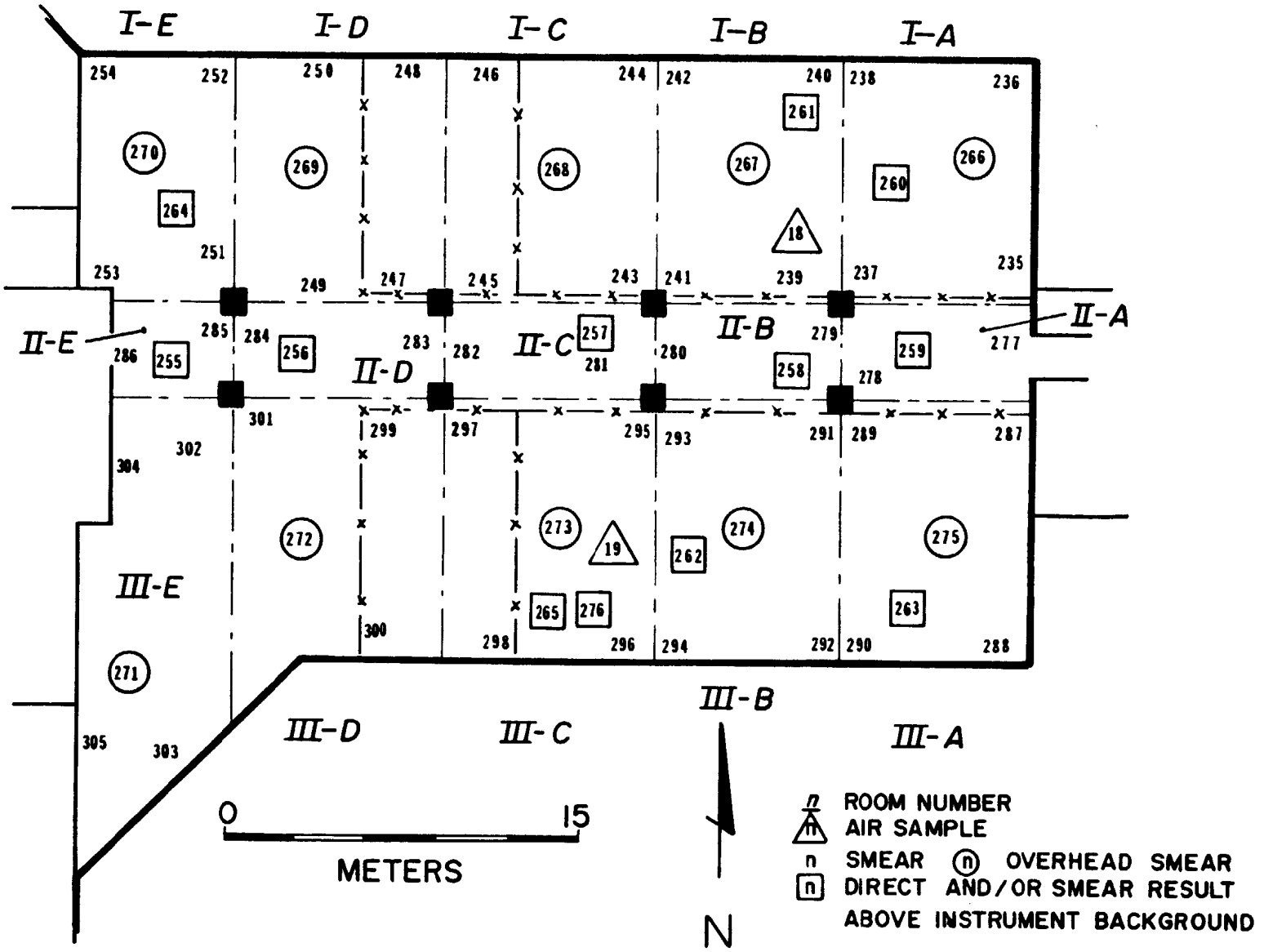

FIGURE 8

AIR SAMPLE AND SURVEY LOCATIONS IN JONES LABORATORY FIFTH FLOOR FAN LOFT

ANL-HP DWG. NO. 78-15

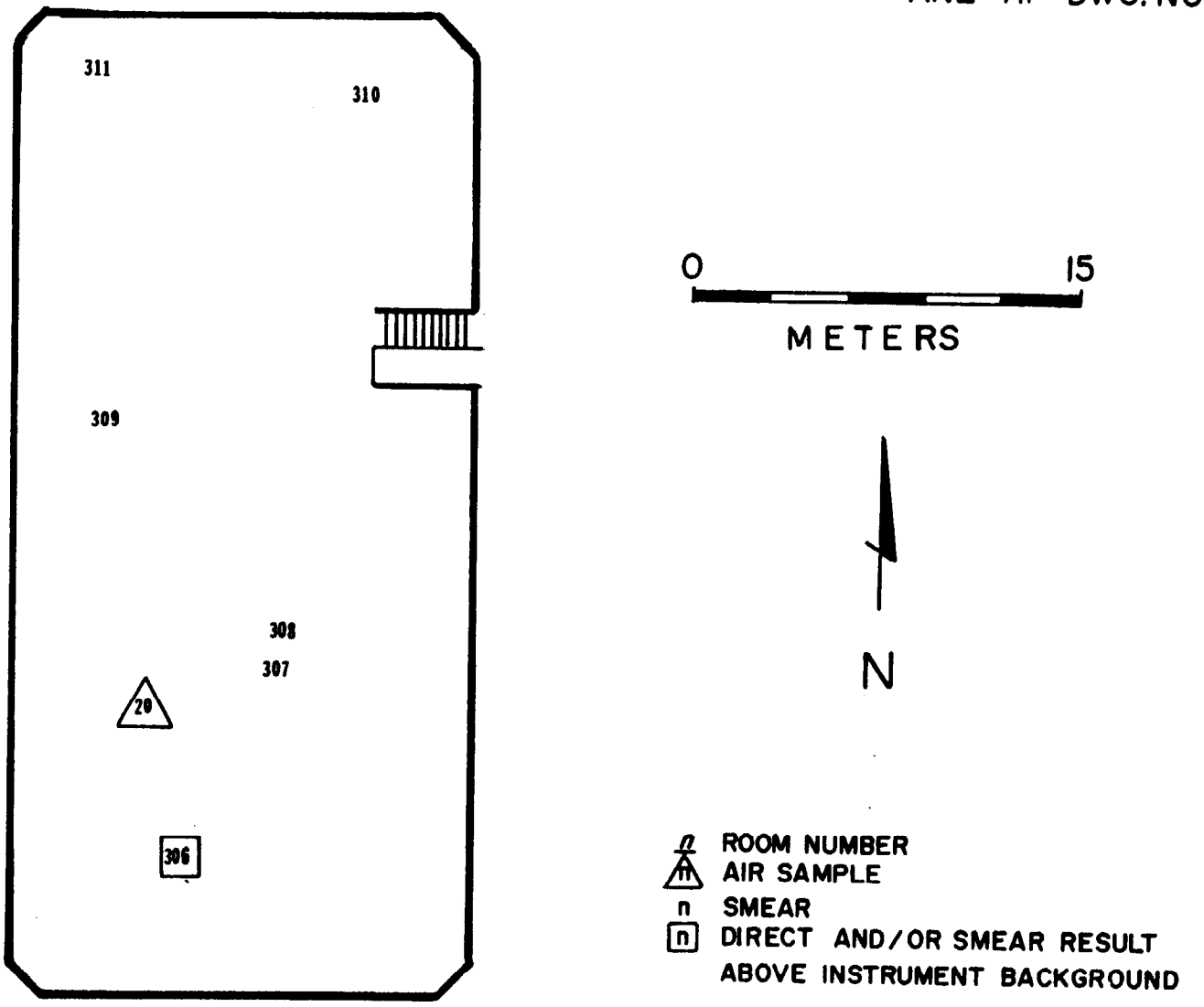

FIGURE 9

SOIL SAMPLE LOCATIONS AT JONES LABORATORY

ANL-HP DWG. NO. 78-24

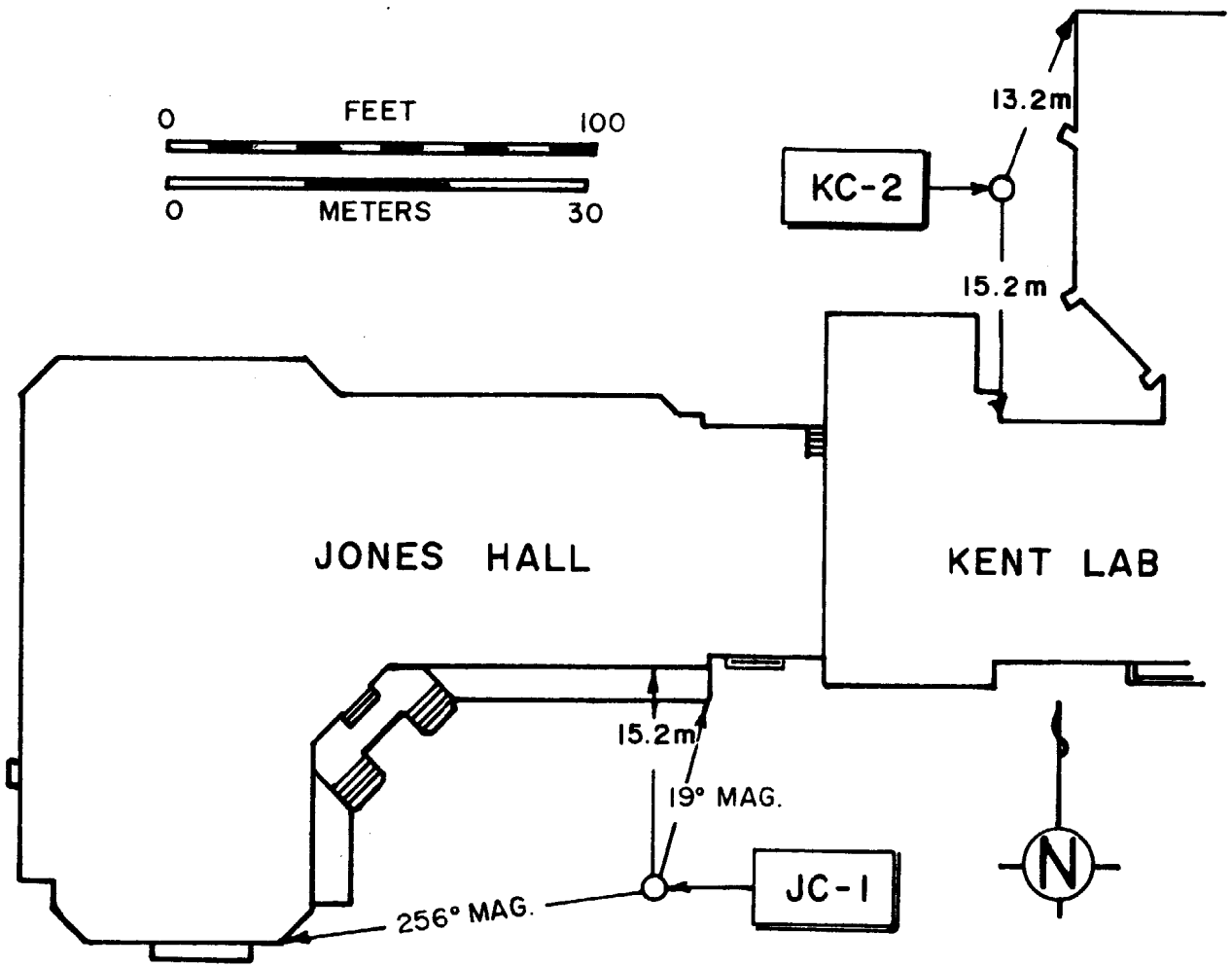

FIGURE 10

SOIL SAMPLING PROCEDURE AND PROCESSING

ANL-HP-DWG. 78-2

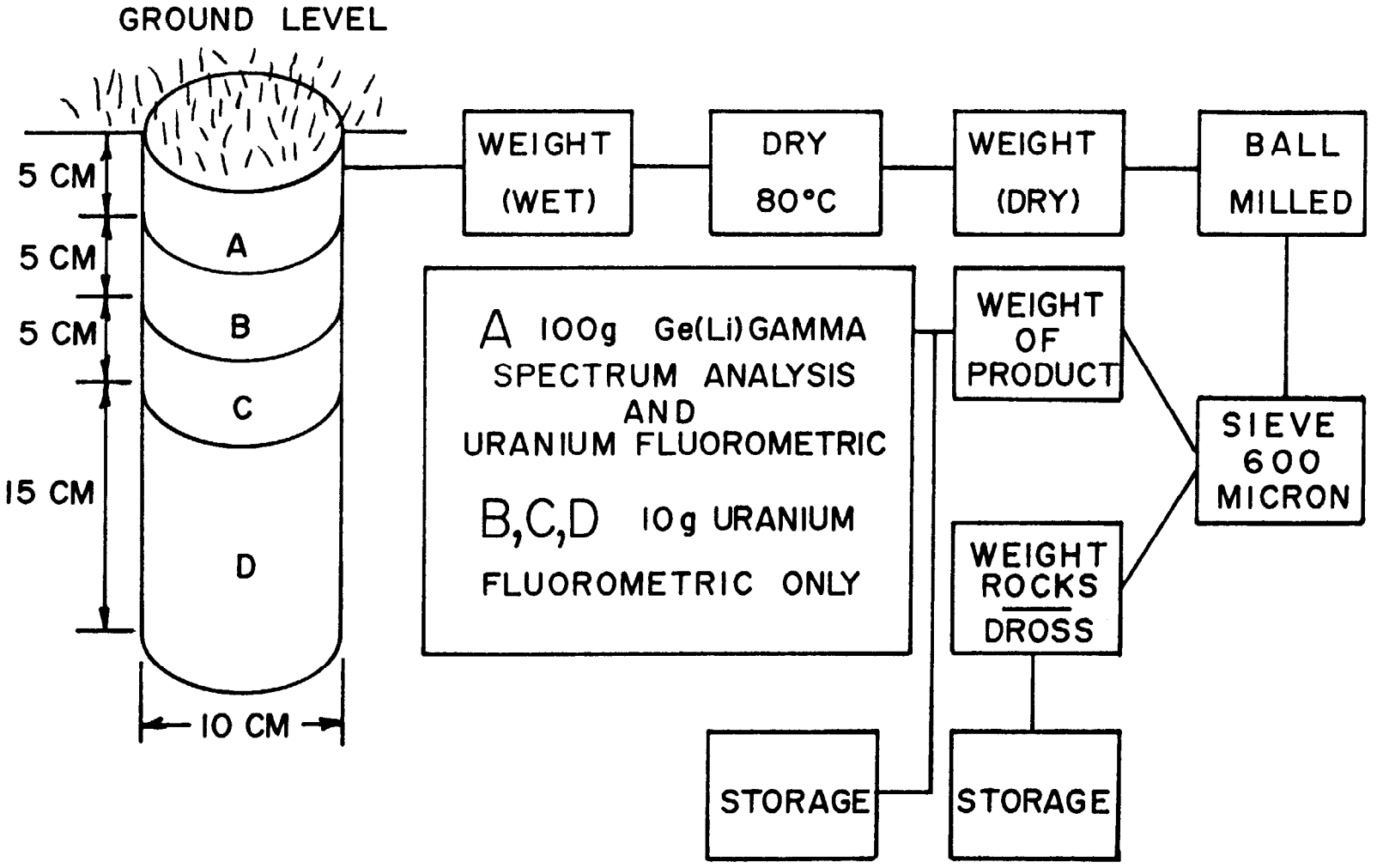

FIGURE 11

GAMMA SPECTRUM OF CONTAMINATED SAMPLE FROM ATTIC FLOOR IN JONES LABORATORY

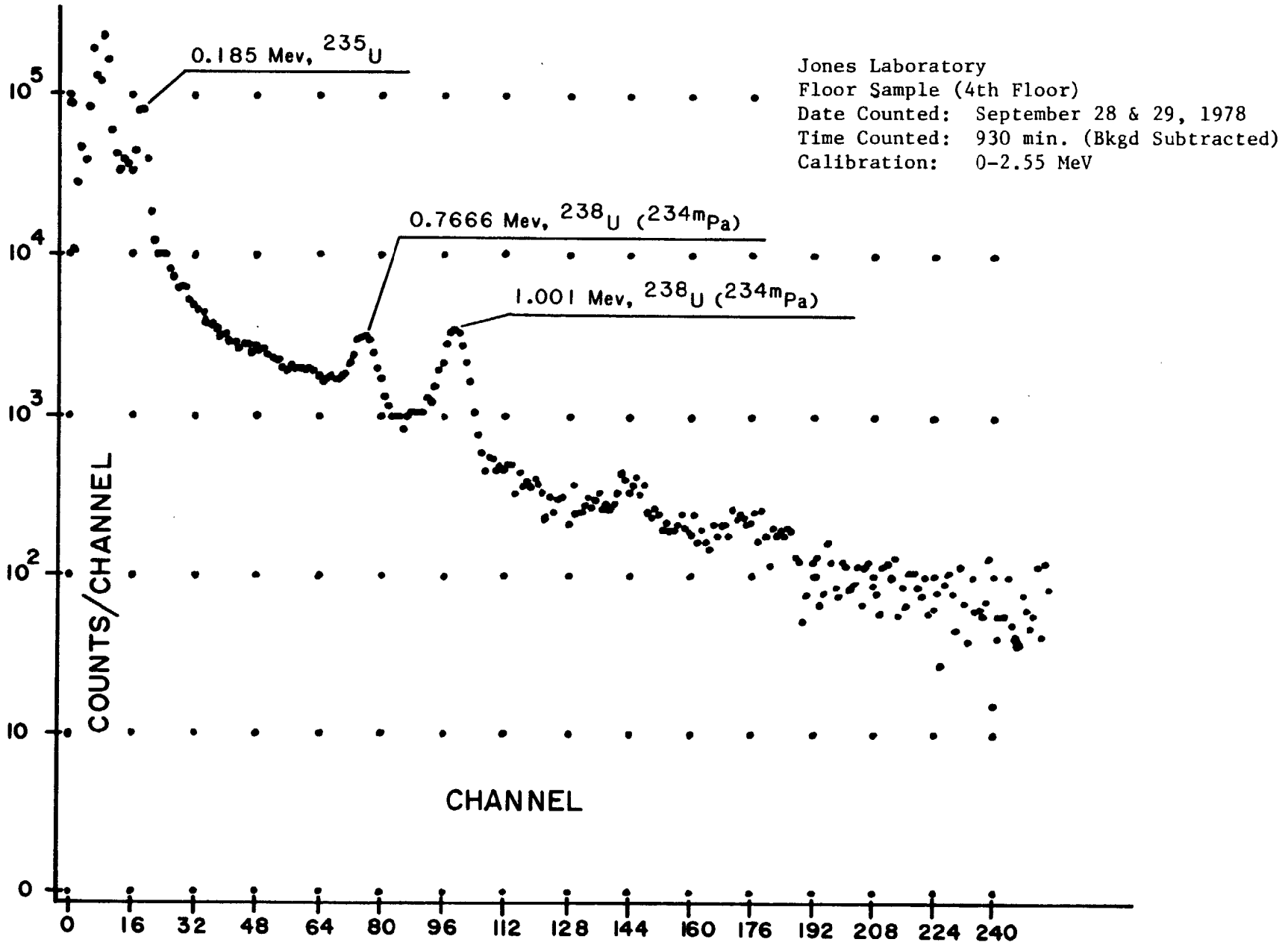

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
Basement Corridor	100	100	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
Basement Stairway	100	100	0.0031						Air Sample 4
				1.2×10^3	BKGD	BKGD	BKGD	BKGD	Location 6, Spot on concrete stair
				6.2×10^2	BKGD	BKGD	BKGD	BKGD	Location 7, Spot on concrete stair
				9.2×10^2	BKGD	BKGD	BKGD	BKGD	Location 8, Spot on concrete stair
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
									Original floor
1	80	70	NS	BKGD	NA	NA	BKGD	BKGD	
2	100	50	NS	BKGD	NA	NA	BKGD	BKGD	
3	60	50	NS	BKGD	NA	NA	BKGD	BKGD	
4	50	40	NS	BKGD	NA	NA	BKGD	BKGD	
5	40	20	NS	BKGD	NA	NA	BKGD	BKGD	
6	30	30	NS	BKGD	NA	NA	BKGD	BKGD	
7A	50	60	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm²)	Comments
7	50	20	NS	BKGD	NA	NA	BKGD	BKGD	
7E	20	15	0.0016						Air Sample 1
				2.0×10^3	BKGD	BKGD	BKGD	BKGD	Location 31, Spot on concrete floor
				2.3×10^3	BKGD	BKGD	BKGD	BKGD	Location 32, Area on concrete floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
8	60	70	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
9	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
10	50	50	0.0006						Air Sample 2
				3.9×10^5	BKGD	9	BKGD	BKGD	Location 36, Steel junction box on wall
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
11,12,14	40	20	NS	BKGD	NA	NA	BKGD	BKGD	
15 & 16	70	90	0.0100						Air Sample 3
				6.2×10^2	BKGD	BKGD	BKGD	BKGD	Location 41, Spot on concrete floor by lead pig
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
17 and	30	40	0.0074						Air Sample 5
17A				$1.5x10^3$	BKGD	BKGD	BKGD	BKGD	Location 44, Spot on concrete floor
				$2.0x10^3$	BKGD	BKGD	BKGD	BKGD	Location 45, Spot on concrete floor
				$2.0x10^3$	BKGD	BKGD	BKGD	BKGD	Location 46, Spot on concree floor
				$3.0x10^3$	BKGD	BKGD	BKGD	BKGD	Location 47, Spot on concrete floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
									Original floor
18	60	70	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
19	60	40	0.0033						Air Sample 6
				$3.0x10^2$	BKGD	BKGD	BKGD	BKGD	Location 51, Spot on asphalt tiled floor
				$6.0x10^2$	BKGD	BKGD	BKGD	BKGD	Location 52, Spot on asphalt tiled floor
				$1.2x10^4$	$9.6x10^2$	BKGD	BKGD	BKGD	Location 53, Spot on asphalt tiled floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
20	10	15	0.0013						Air Sample 7
				9.0×10^2	BKGD	BKGD	BKGD	BKGD	Location 54, Spot on asphalt tiled floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD Original floor
22	45	50		NS	BKGD	NA	NA	BKGD	BKGD
23 and 23A	20	40	0.0017						Air Sample 8
				3.0×10^2	BKGD	BKGD	BKGD	BKGD	Location 59, Spot on asphalt tiled floor
				1.2×10^3	BKGD	BKGD	BKGD	BKGD	Location 61, Spot on asphalt tiled floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD Original floor
25	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
26	20	10	NS	BKGD	NA	NA	BKGD	BKGD	
27	40	10	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
1st floor corridor	100	100	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
1st floor Stairways	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
101	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
102	80	80	NS	BKGD	NA	NA	BKGD	BKGD	
103	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
104	40	30	0.0013						Air Sample 9
				$3.0x10^4$	$3.2x10^4$	0.3	BKGD	α =290[e] $\beta\gamma$=1400	Location 81 Spot, on floor[g]
				$2.4x10^3$	$3.1x10^1$	0.1	BKGD	α =52 $\beta\gamma$=BKGD	Location 82, Spot on floor[g]
				$2.3x10^4$	$1.6x10^4$	0.3	BKGD	α =560[e] $\beta\gamma$=130	Location 84, Spot on floor[g]
				BKGD[c]	$1.6x10^5$	BKGD	BKGD	BKGD	Location 85, Spot on floor[g]
				BKGD	NA[d]	NA	BKGD	BKGD	Rest of Survey was BKGD
									Original floor

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
105	90	90	NS[b]	BKGD	NA	NA	BKGD	BKGD	
106	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
107	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
110	30	30	NS	BKGD	NA	NA	BKGD	BKGD	
111	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
112	50	80	NS	BKGD	NA	NA	BKGD	BKGD	
113	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
114	40	50	NS	BKGD	NA	NA	BKGD	BKGD	
115 and 116	60	65	NS	BKGD	NA	NA	BKGD	BKGD	
117	40	20	NS	BKGD	NA	NA	BKGD	BKGD	
118	15	10	NS	BKGD	NA	NA	BKGD	BKGD	
119	50	40	NS	BKGD	NA	NA	BKGD	BKGD	
120	40	40	NS	BKGD	NA	NA	BKGD	BKGD	
121	30	30	NS	BKGD	NA	NA	BKGD	BKGD	
122	10	5	0.0018						Air Sample 10
				6.0×10^2	BKGD[c]	BKGD	BKGD	BKGD	Location 108, Spot on linoleum floor
				BKGD	NA[d]	NA	BKGD	BKGD	
123	50	30	NS[b]	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
124	50	30	0.0008						Air Sample 11
				5.9×10^3	BKGD	BKGD	BKGD	BKGD	Location 113, Spot on linoleum floor
				1.6×10^3	BKGD	BKGD	BKGD	BKGD	Location 114, Spot on linoleum floor
				2.5×10^3	BKGD	BKGD	BKGD	BKGD	Location 115, Spot on linoleum floor
				5.9×10^3	BKGD	BKGD	BKGD	BKGD	Location 116, Spot on linoleum floor
				7.5×10^3	BKGD	BKGD	BKGD	BKGD	Location 117, Spot on linoleum floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
125	30	15	0.0017						Air Sample 12
				5.4×10^3	5.0×10^2	BKGD	BKGD	BKGD	Location 118, Spot on linoleum floor
				1.4×10^4	9.6×10^3	BKGD	BKGD	BKGD	Location 119, Spot on linoleum floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
126	15	50	NS	BKGD	NA	NA	BKGD	BKGD	
2nd floor corridor	100	95	NS	BKGD	NA	NA	BKGD	BKGD	
2nd floor Stairways	100	100	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
201 and 202	80	60	NS	BKGD	NA	NA	BKGD	BKGD	
203	30	10	NS	BKGD	NA	NA	BKGD	BKGD	
204	50	30	NS	BKGD	NA	NA	BKGD	BKGD	
205	15	5	NS	BKGD	NA	NA	BKGD	BKGD	
206	30	5	NS	BKGD	NA	NA	BKGD	BKGD	
207,208, and 209	50	30	NS	BKGD	NA	NA	BKGD	BKGD	
212	60	30	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
213	30	5	0.0013						Air Sample 13
				1.4×10^4	BKGD	BKGD	BKGD	NST[f]	Location 141 Thorium nitrate bottle.[g] Chemical Storeroom
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
214	30	30	NS	BKGD	NA	NA	BKGD	BKGD	
215	40	30	NS	BKGD	NA	NA	BKGD	BKGD	
216	30	30	NS	BKGD	NA	NA	BKGD	BKGD	
217	40	20	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
218, 219	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
220	30	30	NS	BKGD	NA	NA	BKGD	BKGD	
220A	50	40	NS	BKGD	NA	NA	BKGD	BKGD	
221	70	90	NS	BKGD	NA	NA	BKGD	BKGD	
222	50	20	0.0012						Air Sample 14
				9.5×10^4	BKGD	BKGD	BKGD	BKGD	Location 158, Spot on hood
				1.4×10^3	BKGD	BKGD	BKGD	BKGD	Location 159, Spot on hood
				1.0×10^5	BKGD	BKGD	BKGD	BKGD	Location 160, Spot on hood
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
224, 225 226, 227	25	10	NS	BKGD	NA	NA	BKGD	BKGD	
3rd floor corridors	100	90	NS	BKGD	NA	NA	BKGD	BKGD	
3rd floor stairways	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
301	20	30	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
302	50	60	NS	BKGD	NA	NA	BKGD	BKGD	
303	50	20	NS	BKGD	NA	NA	BKGD	BKGD	
304	35	50	NS	BKGD	NA	NA	BKGD	BKGD	
305	50	60	NS	BKGD	NA	NA	BKGD	BKGD	
306	10	5	NS	BKGD	NA	NA	BKGD	BKGD	
307	15	15	NS	BKGD	NA	NA	BKGD	BKGD	
308	50	40	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
309	40	25	NS	BKGD	NA	NA	BKGD	BKGD	
311	30	10	NS	BKGD	NA	NA	BKGD	BKGD	
312	50	30	NS	BKGD	NA	NA	BKGD	BKGD	
313	50	10	NS	BKGD	NA	NA	BKGD	BKGD	
314	40	10	NS	BKGD	NA	NA	BKGD	BKGD	
315	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
316	40	30	0.0001						Air Sample 15
				5.6×10^3	BKGD	BKGD	BKGD	BKGD	Location 192, Spot on linoleum floor
				BKGD	BKGD	BKGD	BKGD	BKGD	Rest of Survey was BKGD
									Original floor
317	40	40	NS	BKGD	NA	NA	BKGD	BKGD	
318	5	5	NS	BKGD	NA	NA	BKGD	BKGD	
320	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
321	5	25	NS	BKGD	NA	NA	BKGD	BKGD	
322	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
323	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
324	40	40	NS	BKGD	NA	NA	BKGD	BKGD	
325	100	70	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
4th floor Corridor	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
4th floor Stair-ways	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
401	50	20	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
402	35	20	NS	BKGD	NA	NA	BKGD	BKGD	
403	30	15	NS	BKGD	NA	NA	BKGD	BKGD	
404A	15	5	NS	BKGD	NA	NA	BKGD	BKGD	
404B	15	5	NS	1.1×10^3	BKGD	BKGD	BKGD	BKGD	Location 214, Spot on floor[g]
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
404C	30	30	NS	BKGD	NA	NA	BKGD	BKGD	Isotope Laboratory

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min·100 cm²) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min·100 cm²)	Comments
404D	50	10	0.0036						Air Sample 16
				2.1×10^4	BKGD	BKGD	BKGD	BKGD	Location 217, Spot on asphalt tiled floor
				1.1×10^4	BKGD	BKGD	BKGD	BKGD	Location 218, Spot on steel pipe
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
404E	5	30	0.0039						Air Sample 17
				2.8×10^3	BKGD	BKGD	BKGD	BKGD	Loction 220, Spot on asphalt tiled floor
				6.1×10^3	BKGD	BKGD	BKGD	α =33[e] $\beta\gamma$=BKGD	Location 221, Spot on brick wall
				4.8×10^4	BKGD	BKGD	BKGD	BKGD	Location 222, Spot on brick wall
				BKGD[c]	NA[d]	NA	BKGD	BKGD	Rest of survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
405	40	20	NS[b]	BKGD	NA	NA	BKGD	BKGD	
406	95	100	NS	BKGD	NA	NA	BKGD	BKGD	
407	15	5	NS	BKGD	NA	NA	BKGD	BKGD	
408	100	90	NS	BKGD	NA	NA	BKGD	BKGD	
409	40	30	NS	BKGD	NA	NA	BKGD	BKGD	
410	20	10	NS	BKGD	NA	NA	BKGD	BKGD	
411	60	100	NS	BKGD	NA	NA	BKGD	BKGD	
Attic									
IA	20	20	NS	3.0×10^5	3.3×10^3	0.5	BKGD	BKGD	Location 260, Area of concrete floor, dis/min equated to uranium
				BKGD	BKGD	NA	BKGD	BKGD	Rest of Survey was BKGD
IB	50	40	0.0045						Air Sample 18
				1.9×10^5	1.5×10^4	0.5	BKGD[c]	BKGD	Location 261, Area of concrete floor, dis/min equated to uranium
				BKGD	NA[d]	NA	BKGD	BKGD	Rest of Survey was BKGD
IC	50	30	NS[b]	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
ID	10	50	NS	BKGD	NA	NA	BKGD	BKGD	
IE	5	5	NS	6.5×10^4	2.9×10^3	BKGD	BKGD	BKGD	Location 264, Spot on concrete floor, dis/min equated to uranium
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
IIA	50	20	NS	7.0×10^3	BKGD	BKGD	BKGD	BKGD	Location 259, Area of concrete floor, dis/min equated to uranium
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
IIB	50	30	NS	5.5×10^3	BKGD	BKGD	BKGD	BKGD	Location 258, Area of concrete floor, dis/min equated to uranium
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
IIC	60	30	NS[b]	7.5×10^4	2.6×10^3	0.3	BKGD	BKGD	Location 257, Area on concrete floor by grate, dis/min equated to uranium
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
IID	90	10	NS	1.7×10^3	BKGD	BKGD	BKGD	BKGD	Location 256, Area of concrete floor, dis/min equated to uranium
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
IIE	95	10	NS	2.2×10^3	BKGD	BKGD	BKGD	BKGD	Location 255, Spot on concrete floor, dis/min equated to uranium
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
IIIA	20	40	NS[b]	1.3×10^5	7.3×10^3	0.2	BKGD[c]	BKGD	Location 263, Spot on concrete floor, dis/min equated to uranium
				BKGD	NA[d]	NA	BKGD	BKGD	Rest of Survey was BKGD
IIIB	15	5	NS	5.5×10^4	7.3×10^3	0.2	BKGD	BKGD	Location 262, Spot on concrete floor, dis/min equated to uranium
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
IIIC	10	15	0.0078						Air Sample 19
				2.9×10^3	7.3×10^2	BKGD	BKGD	NST[f]	Location 276, Speck of material equated to uranium
				6.4×10^3	1.6×10^3	50	BKGD	NST	Location 265, Radium sources[g]
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD
IIID	5	5	NS	BKGD	NA	NA	BKGD	BKGD	
IIIE	10	5	NS	BKGD	NA	NA	BKGD	BKGD	
5th Floor Fan Loft	25	10	0.0014						Air Sample 20
				3.0×10^4	5.0×10^2	0.1	BKGD[c]	BKGD	Location 306, Area on wooden floor
				BKGD	NA[d]	NA	BKGD	BKGD	Rest of Survey was BKGD

FOOTNOTES FOR TABLE 1

[a]The Beta Mode Direct Readings and Alpha Mode Direct Readings are taken with PAC-4G-3 instruments (see Appendix 1). The beta mode detects both electromagnetic and particulate radiation. If an area indicated an instrument reading higher than background, a beta mode reading was obtained. The instrument was then switched to the alpha mode, and a reading of the alpha contamination was obtained. In the alpha mode, the instrument only responds to particles with high-specific ionization, such as alpha particles. The beta mode readings were compensated for any alpha contribution by subtracting the alpha-mode reading from the beta-mode reading.

[b]NS=Not Selected. Locations of air samples were chosen on a selected basis throughout the areas surveyed. "NS" indicates that the room or area was not selected for an air sample.

[c]BKGD=Background. The following are the instrument background readings:

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 cts/min-325 cm^2	0-50 cts/min-325 cm^2
PAC-4G-3	150-200 cts/min-51 cm^2	0-50 cts/min-51 cm^2
PC-5 Counter	40.0±1.4 cts/min*	0.2±0.1 cts/min*
PC-3A	40.0±1.7 cts/min*	0.3±0.1 cts/min*
10-Wire	443.0±4.7 cts/min*	5.2±0.5 cts/min*

GM End Window Detector read 0.03 to 0.05 mR/h at 1 m above floor.

[d]NA=Nonapplicable. No contamination was detected above background in the beta mode; therefore, no alpha mode or contact GM End Window survey was necessary.

[e]α =Alpha
$\beta\gamma$=Beta-gamma (The beta-gamma readings are compensated for any alpha contamination by subtracting the alpha reading from the beta-gamma reading.)

[f]NST=No Smear Taken.

[g]Presumably not a result of MED/AEC occupancy.

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*One standard deviation due to counting statistics.

TABLE 2

RADON DETERMINATIONS

Air Sample Number	Location[a]	Figure	dis/min-m^3	pCi/ℓ	WL[b]
1	Room 7E	1	358	0.16	0.0016
2	Room 10	1	139	0.06	0.0006
3	Room 15/16	1	2210	1.00	0.0100
4	Stairwell by 17	1	698	0.31	0.0031
5	Room 17-17A	1	1643	0.74	0.0074
6	Room 19	1	736	0.33	0.0033
7	Room 20	1	292	0.13	0.0013
8	Room 23	1	382	0.17	0.0017
9	Room 104	2	297	0.13	0.0013
10	Room 122	2	394	0.18	0.0018
11	Room 124	2	170	0.08	0.0008
12	Room 125	2	377	0.17	0.0017
13	Room 213	3	294	0.13	0.0013
14	Room 222	3	270	0.12	0.0012
15	Room 316	4	18	0.01	0.0001
16	Room 404D	5	804	0.36	0.0036
17	Room 404E	5	870	0.39	0.0039
18	Attic Section IB	7	1002	0.45	0.0045
19	Attic Section III C	7	1724	0.78	0.0078
20	Fan Loft	8	321	0.14	0.0014

Example Calculation: Room 19

$$736 \text{ dis/min-m}^3 \times \frac{1 \text{ pCi}}{2.22 \text{ dis/min}} \times \frac{1 \text{ m}^3}{10^3 \ell} = 0.33 \text{ pCi/}\ell = 0.0033 \text{ WL}$$

[a] Locations are shown in Figures 1-8.

[b] A Working Level (WL) is defined as any combination of short- lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. The numerical value of the WL is derived from the alpha energy released by the total decay through RaC' of the short-lived radon daughter products, RaA, RaB, and RaC at radioactive equilibrium with 100 pCi of ^{222}Rn per liter of air.

TABLE 3

SOIL SAMPLE WEIGHTS
(grams)

Sample Number	Wet Weight	Dry Weight	Sieved Weight	Rocks and Dross
JC-1A	799.9	554.7	446.8	100.1
JC-1B	808.5	591.6	581.0	2.5
JC-1C	835.7	633.8	623.0	5.5
JC-1D	2151.6	1831.9	1500.8	324.6
KC-2A	584.2	458.1	436.8	7.6
KC-2B	601.0	454.8	439.9	8.7
KC-2C	982.5	768.8	722.9	39.5
KC-2D	2242.6	1844.1	1704.9	123.8

TABLE 4

GAMMA-RAY SPECTRAL AND URANIUM-FLUOROMETRIC ANALYSES OF SOIL SAMPLES

Sample Number	Ge(Li) Spectra pCi/g received wt±σ[a] ^{137}Cs	^{232}Th Decay Chain	^{226}Ra Decay Chain	Uranium μg±σ[b]	Uranium pCi/g±σ[c]
JC-1A	1.00±0.05	0.8±0.1	0.84±0.08	4.0±0.6	2.8±0.4
JC-1B				3.1±0.4	2.2±0.3
JC-1C				8.3±0.8	5.8±0.6
JC-1D				0.0±0.4[d]	0.0±0.3[d]
KC-2A	0.82±0.06	0.7±0.2	1.00±0.09	5.0±0.6	3.5±0.4
KC-2B				2.6±0.3	1.8±0.2
KC-2C				3.8±0.5	2.7±0.3
KC-2D				2.6±0.4	1.8±0.3
LFE Blank	0.00±0.04[d]	0.0±0.1[d]	0.00±0.06[d]	0.0±0.2[d]	0.0±0.1[d]

[a] One standard deviation due to counting statisics

[b] Data results from LFE.

[c] ANL conversion from Appendix 5.

[d] Less than detectable limits.

TABLE 5

BACKGROUND SOIL SAMPLE DATA[a]
Cesium-137, Thorium-232, and
Natural Uranium in Soil, 1977

(Concentrations in 10^{-6} Ci/g)

Date Collected	Location	Cesium-137	Thorium-232	Uranium (natural)
June 16	Argonne Area[b]	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
November 15	Argonne Area	0.4±0.1	0.25±0.01	1.1±0.1
November 15	Argonne Area	1.1±0.3	0.07±0.01	0.9±0.1
November 15	Argonne Area	1.1±0.3	0.07±0.01	1.4±0.1
November 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
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	McKinely 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

[a]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

[b]All sites marked "Argonne Area" were collected at Argonne National Laboratory near Lemont, Illinois, southwest of Chicago.

TABLE 6

LOCATIONS (EXCLUSIVE OF ATTIC) WHERE
MED/AEC RESIDUAL CONTAMINATION EXCEEDED ACCEPTABLE LIMITS[a]

Room Number	Location Number	Figure	Estimated Area of Contamination (cm^2)	Maximum PAC Readings (dis/min-100 cm^2) Beta-Gamma	Alpha	GM Contact Reading (mR/h)	Smear Results (dis/min-100 cm^2) Beta-Gamma	Alpha
Stairs by	6	1	200	1.2×10^3	BKGD[b]	BKGD	BKGD	BKGD
17	7		200	6.2×10^2	BKGD	BKGD	BKGD	BKGD
	8		200	9.2×10^2	BKGD	BKGD	BKGD	BKGD
7E	31	1	200	2.0×10^3	BKGD	BKGD	BKGD	BKGD
	32		20,000	2.3×10^3	BKGD	BKGD	BKGD	BKGD
10	36	1	100	3.9×10^5	BKGD	9	BKGD	BKGD
16	41	1	200	6.2×10^2	BKGD	BKGD	BKGD	BKGD
17 and	44	1	300	1.5×10^3	BKGD	BKGD	BKGD	BKGD
17A	45		300	2.0×10^3	BKGD	BKGD	BKGD	BKGD
	46		300	2.0×10^3	BKGD	BKGD	BKGD	BKGD
	47		300	3.0×10^3	BKGD	BKGD	BKGD	BKGD
19	51	1	300	3.0×10^2	BKGD	BKGD	BKGD	BKGD
	52		300	6.0×10^2	BKGD	BKGD	BKGD	BKGD
	53		300	1.2×10^4	9.6×10^2	BKGD	BKGD	BKGD
20	54	1	300	9.0×10^2	BKGD	BKGD	BKGD	BKGD
23 and	59	1	300	3.0×10^2	BKGD	BKGD	BKGD	BKGD
23A	61		300	1.2×10^3	BKGD	BKGD	BKGD	BKGD
122	108	2	300	6.0×10^2	BKGD	BKGD	BKGD	BKGD
124	113	2	200	5.9×10^3	BKGD	BKGD	BKGD	BKGD
	114		300	1.6×10^3	BKGD	BKGD	BKGD	BKGD

TABLE 6
(Cont'd.)

LOCATIONS (EXCLUSIVE OF ATTIC) WHERE
MED/AEC RESIDUAL CONTAMINATION EXCEEDED ACCEPTABLE LIMITS[a]

Room Number	Location Number	Figure	Estimated Area of Contamination (cm^2)	Maximum PAC Readings (dis/min-100 cm^2) Beta-Gamma	Maximum PAC Readings (dis/min-100 cm^2) Alpha	GM Contact Reading (mR/h)	Smear Results (dis/min-100 cm^2) Beta-Gamma	Smear Results (dis/min-100 cm^2) Alpha
124 (cont'd.)	115	2	200	2.5×10^3	BKGD	BKGD	BKGD	BKGD
	116		200	5.9×10^3	BKGD	BKGD	BKGD	BKGD
	117		200	7.5×10^3	BKGD	BKGD	BKGD	BKGD
125	118	2	300	5.4×10^3	5.0×10^2	BKGD	BKGD	BKGD
	119		200	1.4×10^4	9.6×10^3	BKGD	BKGD	BKGD
222	158	3	100	9.5×10^4	BKGD	BKGD	BKGD	BKGD
	159		100	1.4×10^3	BKGD	BKGD	BKGD	BKGD
	160		100	1.0×10^5	BKGD	BKGD	BKGD	BKGD
316	192	4	300	5.6×10^3	BKGD	BKGD	BKGD	BKGD
404D	217	5	300	2.1×10^4	BKGD	BKGD	BKGD	BKGD
	218		200	1.1×10^4	BKGD	BKGD	BKGD	BKGD
404E	220	5	300	2.8×10^3	BKGD	BKGD	BKGD	BKGD
	221		500	6.1×10^3	BKGD	BKGD	BKGD	33
	222		500	4.8×10^4	BKGD	BKGD	BKGD	BKGD
5th Floor	306	8	10,000	3.0×10^4	5.0×10^2	0.1	BKGD	BKGD

[a] "Acceptable Limits" are as specified for Group 1 radionuclides in ANSI Standard N13.12 or the average and maximum radiation levels of 0.2 and 1.0 mrad/h at 1 cm as given in NRC Guidelines.

[b] BKGD = Background.

TABLE 7

ATTIC LOCATIONS WHERE RESIDUAL CONTAMINATION EXCEEDED ACCEPTABLE LIMITS[a,b]

Section Number	Location Number	Estimated Area of Contamination (cm^2)	Maximum PAC Readings (dis/min-100 cm^2) Beta-Gamma	Alpha	GM Contact Reading (mR/h)	Smear Results (dis/min-100 cm^2)
IA	260	100,000	3.0×10^5	8.5×10^4	0.5	BKGD[c]
IB	261	100,000	1.9×10^5	1.5×10^4	0.5	BKGD
IE	264	1,000	6.5×10^4	2.9×10^3	BKGD	BKGD
IIA	259	50,000	7.0×10^3	3.6×10^4	BKGD	BKGD
IIB	258	50,000	5.5×10^3	BKGD	BKGD	BKGD
IIC	257	50,000	7.5×10^4	2.6×10^3	0.3	BKGD
IIIA	263	1,000	1.3×10^5	7.3×10^3	0.2	BKGD
IIIB	262	1,000	5.5×10^4	7.3×10^3	0.2	BKGD

[a] Locations are shown in Figure 7.

[b] "Acceptable Limits" are those for uranium as given in ANSI Standard N13.12 or the average and maximum radiation levels of 0.2 and 1.0 mrad/h at 1 cm as given in the NRC Guidelines.

[c] BKGD = Background

TABLE 8

ESTIMATED VOLUME, MASS, AND ACTIVITY OF MATERIAL
THAT COULD BE GENERATED BY REMEDIAL ACTION

Type of Material	Estimated Volume (m^3)	Estimated Mass (kg)	Estimated Activity (μCi)
Concrete (ρ = 2.35)	1.6	3.9×10^{3}	2.4×10^{2}
Brick (ρ = 2.2)	1.7×10^{-2}	3.7×10^{1}	1.2×10^{-1}
Linoleum and Asphalt Tile (ρ = 1.2)	5.3×10^{-3}	6.4	1.0×10^{-1}
Steel (ρ = 7.8)	1.9×10^{-4}	1.4	1.9×10^{-1}
Wood (including asbestos mill-board) (ρ = 0.9)	6.1×10^{-2}	5.5×10^{1}	1.4
Total	1.7 m^3	4.0×10^{3} kg	2.4×10^{2} μCi

APPENDIX 1

INSTRUMENTATION

I. PORTABLE RADIATION SURVEY METERS

A. Gas-Flow Proportional Survey Meters

The Eberline PAC-4G-3 was the primary instrument used for surveying. This instrument is a gas-flow proportional alpha counter which utilizes a gas-proportional probe, 51 cm^2 (PAC-4G-3) or 325 cm^2 (FM-4G) in area, with a thin double-aluminized Mylar window (~ 0.85 mg/cm^2).

Since this instrument has three high-voltage positions, it can be used to distinguish between alpha and beta-gamma contamination. This instrument was 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 indicated a higher count rate than the average instrument background, the beta mode reading was recorded, and the instrument was then switched to the alpha mode to determine any alpha contribution. In the alpha mode, the instrument responds only to particles with high specific ionization. This instrument is calibrated in the alpha mode, with a flat-plate infinitely-thin NBS traceable ^{239}Pu standard, and in the beta mode, with a flat-plate infinitely-thin NBS traceable ^{90}Sr-^{90}Y standard. The PAC-4G-3 instruments are calibrated to an apparent 50% detection efficiency.

B. Beta-gamma End Window Survey Meter

When an area of contamination is found with a PAC instrument, a reading is taken with an Eberline Beta-gamma Geiger-Mueller Counter, Model E-530 with a HP-190 probe. This probe has a thin mica end window, and is, therefore, sensitive to alpha and beta particles and x- and gamma-rays. A thin piece of aluminum is added to the mica, making the window density ~ 7 mg/cm^2. At this density, the instrument is not sensitive to alpha paricles. A maximum reading is obtained with the probe placed in contact with the area of contamination. Another reading is obtained with the probe held 1 m from the contaminated area. This instrument is calibrated with an NBS traceable ^{137}Cs source.

II. SMEAR-COUNTING INSTRUMENTATION

The 10-wire instrument consists of a gas-flow proportional probe (ANL design) which uses an Eberline Mini Scaler Model MS-2. The double-aluminized Mylar probe (400 cm^2) uses P-10 (90% argon and 10% methane) as the counting gas. This system consists of two Mini Scalers and two probes. One is used for counting in the alpha mode; the other is used in the beta mode. The metal smear holder has been machined so that it can hold ten smears. The probe is placed over the smears and a count is taken.

APPENDIX 1
(Cont'd.)

All smears of contaminated areas are counted in a Nuclear Measurements Corporation PC-3A or PC-5 Gas-Flow Proportional Counter (PC counter) with a double-aluminized Mylar spun top. The top is placed over nonconducting media such as paper to negate the dielectric effect. This counter also uses P-10 counting gas. Smears are counted in both the alpha and beta modes of the detector. These instruments are calibrated using ^{239}Pu and ^{90}Sr-^{90}Y NBS traceable sources.

III. AIR-SAMPLING DEVICE

The air samples were collected with a commercial vacuum cleaner modified at ANL. The air was drawn at a flow rate of 20 or 40 m^3/h. The particulates in the air were collected on a 200-cm^2 sheet of Hollingsworth-Vose (HV-70 0.23 mm) filter paper. The collection efficiency at these flow rates for 0.3-micron particles is about 99.9%.

IV. GAMMA-SPECTRAL INSTRUMENTATION

A Nuclear Data Multichannel Analyzer Model ND-100, with a 7.6 cm diameter by 7.6-cm-length NaI(Tℓ) crystal was used to determine the gamma spectrum. This instrument was calibrated with ^{60}Co and ^{137}Cs NBS traceable sources. Samples of contaminated areas were counted with the analyzer, and the radionuclides of contamination were determined.

V. INSTRUMENTATION USED IN SURVEY

	Inventory Number	Probe Area (cm^2)	Window Thickness (mg/cm^2)
Eberline Floor Monitor FM-4G using a PAC-4G-3	181501	325	~ 0.85
Eberline Floor Monitor FM-4G using a PAC-4G-3	183413	325	~ 0.85
PAC-4G-3	183414	51	~ 0.85
PAC-4G-3	183415	51	~ 0.85
PAC-4G-3	183416	51	~ 0.85
PAC-4G-3	184339	51	~ 0.85
PAC-4G-3	184340	51	~ 0.85
PAC-4G-3	184341	51	~ 0.85
Eberline HP-190 Beta-Gamma End Window	184576	-	7

APPENDIX 1
(Cont'd.)

	Inventory Number	Probe Area (cm^2)	Window Thickness (mg/cm^2)
Nuclear Measurements Corp. PC-5 2π Internal Gas-Flow Counter	184065	-	~ 0.85
Nuclear Measurements Corp. PC-3A 2π Internal Gas-Flow Counter	18442	-	~ 0.85
Argonne National Laboratory 10-Wire Flat-Plate Gas-Flow Proportional Detector with Eberline Mini Scaler MS-2	184342	400	~ 0.85
Argonne National Laboratory Filter Queen Air Sampler using HV-70 filter media	-	-	-
Nuclear Data Multichannel Analyzer Model ND-100 with 7.6 dis x 7.6 cm NaI(Tℓ) crystal.	184764		

VI. AVERAGE INSTRUMENT BACKGROUND READINGS[a]

Instrument	Alpha Mode (cts/min)	Beta Mode (cts/min)	1 m above floor
Eberline Floor Monitor FM-4G using PAC-4G-3			
181501	0-50	1500-2000	
183413	0-50	1500-2000	
Eberline PAC-4G-3			
183414	0-50	150-200	
183415	0-50	150-200	
183416	0-50	150-200	
184339	0-50	150-200	
184340	0-50	150-200	
184341	0-50	150-200	

APPENDIX 1
(Cont'd.)

Instrument	Alpha Mode (cts/min)	Beta Mode (cts/min)	1-m above floor
Eberline 530 with HP-190 Beta-Gamma End Window	-	-	0.03-0.05 mR/h
Nuclear Measurements Corp. PC-5 2π Internal Gas-Flow Counter	0.2±0.1[b]	40.0±1.4[b]	
Nuclear Measurements Corp. PC-3A 2π Internal Gas-Flow Counter	0.3±0.1[b]	40.0±1.7[b]	
Argonne National Laboratory 10-Wire Flat-Plate Gas-Flow Proportional Detector with Eberline Mini Scaler MS-2	5.2±0.5[b]	443.±4.7[b]	

[a]Background readings were initially taken in the mobile laboratory and rechecked throughout the various areas while surveying.

[b]One standard deviation due to counting statistics.

APPENDIX 2

CONVERSION FACTORS

I. INSTRUMENTATION

The factors used to convert the instrument readings into units of disintegrations per minute per 100 cm^2 (dis/min-100 cm^2) alpha and the derivation of those factors are listed below.

A. Conversion Factors

	PAC-4G-3		Floor Monitor (FM-4G)	
	Alpha	Beta	Alpha	Beta
To 100 cm^2	1.96	1.96	0.31	0.31
cts/min to dis/min ^{239}Pu	2	-	2	-
cts/min to dis/min ^{90}Sr-^{90}Y	-	2	-	2
cts/min to dis/min for normal uranium	5.9	3.5	-	-
cts/min to dis/min ^{226}Ra plus daughters	1.6	4.7	-	-

B. Derivation of Conversion Factors

. Floor Monitor (FM-4G)

Window Area: ~ 325 cm^2
Conversion to 100 cm^2 = 0.31 times Floor Monitor Readings

. PAC-4G-3

Window Area: ~ 51 cm^2
Conversion to 100 cm^2 = 1.96 times PAC reading

. 2π Internal Gas-Flow Counter, PC Counter

Geometry: Solid Steel Spun Top - 0.50

Geometry: Mylar Spun Top - 0.43
Mylar Spun Top counting {double-aluminized Mylar window (~ 0.85 mg/cm^2)} 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 nonconducting media.

APPENDIX 2
(Cont'd.)

A 3.2 x 3.2 x 0.3-cm normal-uranium plate (used as a source of uranium alpha emissions) was counted in the well of a 2π Internal Gas-Flow Counter with the source leveled to an apparent 2π geometry. As previously stated, this instrument was calibrated using ^{239}Pu NBS traceable sources. The alpha reading was 4.7×10^4 cts/min, or $4.7 \times 10^4 \div 0.50 = 9.4 \times 10^4$ dis/min alpha with the PC counter.

The same uranium source, when counted in the alpha mode with the PAC instrument, was found to be 1.6×10^4 cts/ min at contact. The conversion factor for cts/min to dis/min for the PAC instrument is $9.4 \times 10^4 \div 1.6 \times 10^4 = 5.9$ dis/min alpha to cts/min alpha.

The same normal uranium source, but covered with two layers of conducting paper, each 6.65 mg/cm^2 to absorb the alpha emissions, was counted for composite beta and gamma emissions in the PC counter; however, no provision was made for backscatter. The composite beta-gamma count was 5.2×10^5 cts/min, or $5.2 \times 10^5 \div 0.50 = 1.04 \times 10^6$ dis/min beta-gamma.

When the covered normal uranium source was counted in the beta mode of the PAC-4G-3, the count was 3.0×10^5 cts/min. This indicates a conversion factor of $1.04 \times 10^6 \div 3.0 \times 10^5 = 3.5$ dis/min beta-gamma to cts/min beta-gamma.

A similar method was used to determine the ^{226}Ra plus daughters conversion factors.

II. SMEAR COUNT

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

A. Conversion Equation (Alpha)

$$\frac{\text{cts/min - (Bkgd)}}{\text{g x bf x sa x waf}} = \text{dis/min alpha}$$

A geometry (g) of 0.43 is standard for all flat-plate counting using a Mylar spun top.

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

The self-absorption factor (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 ^{239}Pu (0.713) was used.

The (waf) for normal uranium alphas is 0.54.

The (waf) for alphas from ^{226}Ra plus daughters is 0.55.

APPENDIX 2
(Cont'd.)

B. Conversion Equation (Beta)

$$\frac{\text{cts/min} - \{\beta \text{ Bkgd (cts/min)} + \alpha \text{ cts/min}\}}{g \times bf \times sa \times waf} = \text{dis/min beta}$$

A geometry (g) of 0.43 is standard for all flat-plate counting using the Mylar spun top.

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

A self-absorption factor (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 ^{90}Sr-^{90}Y (0.85) was used.

The (waf) for normal uranium betas is 0.85.

The (waf) for betas from ^{226}Ra plus daughters is 0.85.

APPENDIX 3

RADON-DETERMINATION CALCULATIONS

The calculations for air samples collected with an Argonne National Laboratory-designed air sampler with HV-70 filter media are summarized in this appendix. The appendix includes the basic assumptions and calculations used to derive the air concentrations.

I. RADON CONCENTRATIONS BASED ON RaC' RESULTS

The following postulates are assumed in deriving the radon-222 (^{222}Rn) concentrations as based on the RaC' alpha count results.

A. RaA, RaB, RaC, and RaC' are in equilibrium.

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

C. One-half of the radon progeny is not adhered to airborne particulates and, therefore, is not collected on the filter media.

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

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

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

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

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

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

J. No long-lived alpha emitters are present, as evidenced by the final count.

K. For all practical purposes, RaC' decays at the rate of the composite of RaB and RaC, which is about 36 minutes.

APPENDIX 3
(Cont'd.)

II. EQUATIONS USED TO DERIVE AIR CONCENTRATIONS

The activity present at the end of the sampling period is determined by the equation:

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

Where: A_o = Activity (dis/min) present at the end of the sampling period (usually 40 min)

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

t = Time interval (min.) from end of sampling period to counting interval (usually $\simeq$ 100 min)

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

$t_{\frac{1}{2}}$ = Half-life of isotope (min)

Concentration is determined by the equation:

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

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

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

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

t_s = Length of sampling time (min)

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

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

APPENDIX 3
(Cont'd.)

III. EXAMPLE CALCULATION:

Data obtained in the air sampling of Room 19 have been used below to illustrate the application of the equations for determining activities and concentrations.

$$A_o = \frac{453}{\exp \frac{-0.693 \times 105}{36}} = 3419 \text{ dis/min}$$

$$C = \frac{3419 \times \frac{0.693}{36 \text{ min}}}{20/60} \times \frac{1}{1 - \exp \frac{-0.693 \times 40}{36}} = 368 \text{ dis/min-m}^3$$

Since we assume that half of the radon progeny is not adhered to the airborne particulates, the above concentration is then multiplied by a factor of two to determine the actual concentration:

C actual = C measured x progeny correction factor

$$= 368 \text{ dis/min-m}^3 \times 2 = 736 \text{ dis/min-m}^3$$

The resultant concentration is 736 dis/min-m^3.

APPENDIX 4

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 (^{232}Th) and radium-226 (^{226}Ra) decay chains were calculated using the 0.910 MeV actinium-228 (^{228}Ac) and 0.609 MeV bismuth-214 (^{214}Bi) photopeaks, respectively. Cesium-137 is reported for each sample as a representative gamma emitter. Potassium-40 (^{40}K) 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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*The procedure used by LFE Environmental Analysis Laboratories to analyze the soil samples collected near Jones Laboratory by the ANL survey team are summarized in this appendix.

APPENDIX 5

CALCULATION OF NORMAL-URANIUM SPECIFIC ACTIVITY

Radioactive half-lives of ^{234}U, ^{235}U, and ^{238}U, as well as the percent 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%. The calculations are made with the 0.0013% not accounted for since it cannot be determined which isotope(s) are in error.

$$SpA = \lambda N$$

Where:

SpA = Specific Activity = activity per unit mass

$\lambda = \ell n2/t_{\frac{1}{2}}$

N = Number of radioactive atoms per unit mass

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

Avogadro's Number = 6.025×10^{23}

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

Therefore:

$$SPA = (\ell n2)N/t_{\frac{1}{2}}$$

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

For ^{234}U, the specific activity would be:

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

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

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

$= 0.783$ dis/min-µg of normal uranium

For ^{235}U, the specific activity would be:

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

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

$= 4.76$ dis/min-µg $\times 7.196 \times 10^{-3}$

$= 0.034$ dis/min-µg of normal uranium

For ^{238}U, the specific activity would be:

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

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

$= 0.74$ dis/min-µg $\times 9.9276 \times 10^{-1}$

$= 0.735$ dis/min-µg of normal uranium.

Therefore, the activity of 1 µg of normal uranium is

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

$= 1.552$ dis/min-µg.

Conversion of µg/g to pCi/g

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

$= 0.6991$ pCi/µg normal uranium.

Example Calculation: JL-1A

4.0 ± 0.6 µg/gram x 0.6991 pCi/µg = 2.8 ± 0.4 pCi/gram

APPENDIX 6

PERTINENT RADIOLOGICAL REGULATIONS STANDARDS, AND GUIDELINES

I. Excerpts From

DRAFT AMERICAN NATIONAL STANDARD

N13.12

Control of Radioactive Surface Contamination

On Materials, Equipment, and Facilities to be

Released for Uncontrolled Use

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.

APPENDIX 6
(Cont'd.)

TABLE 1

SURFACE CONTAMINATION LIMITS*

Contaminants			Limit (Activity) (dis/min-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	^{227}Ac $^{241,242m,243}Am$ $^{249,250,251,252}Cf$ $^{243,244,245,246,247,248}Cm$ $^{125,129}I$ ^{237}Np ^{231}Pa ^{210}Pb $^{238,239,240,242,244}Pu$ $^{226,228}Ra$ $^{228,230}Th$	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	^{254}Es ^{256}Fm $^{126,131,133}I$ ^{210}Po ^{223}Ra ^{90}Sr ^{232}Th ^{232}U	200	2000 α Nondetectable β,γ (Note 5)
3	Those nuclides not in Group 1 or Group 2		1000	5000

APPENDIX 6
(Cont'd.)

SURFACE CONTAMINATION LIMITS*

*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 $1/n \Sigma_n S_i \geq L$, where S_i is the dis/min-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 3 L.

+Disintegrations per minute per square decimeter.

NOTES:

(1) Values presented here are obtained from the Code of FederalRegulations, 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 fraction 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 ≦ 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.

APPENDIX 6
(Cont'd.)

ALTERNATE SURFACE CONTAMINATION LIMITS

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

Contamination Contingencies	Limit (Activity) (dis/min-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 or ^{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

APPENDIX 6
(Cont'd.)

ALTERNATE SURFACE CONTAMINATION LIMITS

*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 $1/n \Sigma_n S_i \geq L$, where S_i is the dis/min-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 3 L.

+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 of unconditional release should be performed in areas where the background is ≦ 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.

APPENDIX 6
(Cont'd.)

II. GUIDELINES FOR DECONTAMINATION OF FACILITIES AND AND EQUIPMENT PRIOR TO RELEASE FOR UNRESTRICTED USE OR TERMINATION OF LICENSES FOR BY-PRODUCT SOURCE, OR SPECIAL NUCLEAR MATEIAL

(These have been retyped for purposes of this report.)

The instructions in this guide, in conjunction with Table 1, specify the radioactivity and radiation exposure rate limits which should be used in accomplishing the decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table 1 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 1 prior to applying the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.

3. The radioactivity on the interior surfaces of pipes, drain lines, or duct 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.

APPENDIX 6
(Cont'd.)

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

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table 1. 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.

APPENDIX 6
(Cont'd.)

TABLE 1

ACCEPTABLE SURFACE CONTAMINATION LEVELS

NUCLIDES[a]	AVERAGE[bcf]	MAXIMUM[bdf]	REMOVABLE[bef]
U-nat, ^{235}U, ^{238}U and associated decay products	5000 dis/min-100 cm^2 α	15,000 dis/min-100 cm^2 α	1000 dis/min-100 cm^2 α
Transuranics, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{228}Th, ^{231}Pa, ^{227}Ac, ^{125}I, ^{129}I	100 dis/min-100 cm^2	300 dis/min-100 cm^2	20 dis/min-100 cm^2
Th-nat, ^{232}Th, ^{90}Sr, ^{223}Ra, ^{224}Ra, ^{232}U, ^{126}I, ^{131}I, ^{133}I	1000 dis/min-100 cm^2	3,000 dis/min-100 cm^2	200 dis/min-100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above.	5000 dis/min-100 cm^2 $\beta\gamma$	15,000 dis/min-100 cm^2 $\beta\gamma$	1000 dis/min-100 cm^2 $\beta\gamma$

APPENDIX 6
(Cont'd.)

TABLE 1
(Footnotes)

ACCEPTABLE SURFACE CONTAMINATION LEVELS

[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, dis/min (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

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

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

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

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

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III. SURGEON GENERAL'S GUIDELINES
as included in 10 CFR Part 712
Grand Junction Remedial Action Criteria

712.1 Purpose

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

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

712.2 Scope

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

712.3 Definitions

As used in this part:

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

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

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

(d) "DOE" means the U. S. Department of Energy or any duly authorized representative thereof.

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

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

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

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

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

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

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

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

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

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

712.4 Interpretations

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

712.5 Communications

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

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712.6 General radiation exposure level criteria for remedial action.

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

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

712.7 Criteria for determination of possible need for remedial action

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

(a) Where DOE approved data on indoor radon daughter concentration levels are available.

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

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

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

(1) For dwellings and schoolrooms:

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

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

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

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

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

(2) For other structures:

(i) An external gamma radiation level of 0.15 mR/h above background averaged on a room-by-room basis.

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

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

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

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

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

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

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

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

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

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

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

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

712.10 Selection of appropriate remedial action.

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

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

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IV. EXCERPTS FROM DOE 5480.1 Chg. 6, CHAPTER XI

"Requirements for Radiation Protection"

Exposure of Individuals and Population Groups in Uncontrolled Areas. Exposures to members of the public shall be as low as reasonably achievable levels within the standards prescribed below.

Radiation Protection Standards
for External and Internal Exposure
of Members of the Public

	Annual Dose Equivalent or Dose Commitment	
Type of Exposure	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on Average Dose to a Suitable Sample of the Exposed Population
Whole body, gonads, or bone marrow	0.5 rem (or 500 mrem)	0.17 rem (or 170 mrem)
Other organs	1.5 rem (or 1500 mrem)	0.5 rem (or 500 mrem)

APPENDIX 7

DOSE-DETERMINATION CALCULATIONS

To assess the internal radiological hazard from inhalation/ingestion of contamination possibly due to MED/AEC occupancy, a hypothetical, yet conceivable, worst-case situation involving the fourth floor attic was developed. Based on the results of gamma-spectral analysis of a sample of contamination from the attic, normal uranium has been used as the nuclide of contamination in the following scenario

The highest level of contamination was found on the attic floor and was spread over an area of about 100,000 cm^2 at Location 260. The maximum reading detected at this location was 3.0×10^5 dis/min-100 cm^2 beta-gamma equated to normal uranium. Assuming that the short-lived daughters of ^{238}U and ^{235}U are in equilibrium with ^{238}U and ^{235}U, respectively, the above beta-gamma disintegration rate will be presumed to yield an equal alpha disintegration rate. Thus the activity (A) is:

$$A = 3.0 \times 10^5 \text{ dis/min-100 cm}^2 \times \frac{1 \text{ Ci of Normal U*}}{4.54 \times 10^{12} \text{ dis/min}} \times \frac{10^6 \mu\text{Ci}}{1 \text{ Ci}}$$

$$= 6.61 \times 10^{-2} \mu\text{Ci}/100 \text{ cm}^2$$

The worst likely situation which could arise would probably involve the use of a concrete saw in a dry mode of operation. It will be assumed that a person is using a portable saw of this type to cut a rectangular hole in the concrete floor to install a new duct. A typical saw balde used in cutting concrete would have a diameter of 36 cm (14 in), a thickness of 0.32 cm (1/8 in), and a cutting depth of 13 cm (5-1/8 in). The wobble of the blade would probably increase the width of the kerf to 0.40 cm. If the cross contamination of the duct was 30 cm (12 in) by 61 cm (24 in), the perimeter would then be 182 cm (72 in). The overlap of the cuts upon the concrete floor will add 104 cm (41 in). The area of concrete floor (B) that the blade would consume is then:

$$B = (182 \text{ cm} + 104 \text{ cm}) \times 0.40 \text{ cm} = 1.15 \times 10^2 \text{ cm}.$$

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*A Curie of normal uranium normalized to ^{238}U, i.e., the sum of 3.7×10^{10} dis/s from ^{238}U, plus 3.7×10^{10} dis/s from ^{234}U, plus 1.7×10^9 dis/s from ^{235}U. This equals 7.57×10^{10} dis/s or 4.54×10^{12} dis/min. A standard curie is 3.7×10^{10} dis/s or 2.22×10^{12} dis/min.

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With a level of activity (A) of 6.61×10^{-2} μCi/100 cm^2 and if it is assumed that only 50% of the concrete that is displaced becomes airborne and respirable, then the total amount of activity that becomes airborne and respirable (C) due to the cutting is:

$$C = 6.61 \times 10^{-2} \text{ μCi/100 cm}^2 \times 1.15 \times 10^2 \text{ cm}^2 \times 0.50 = 3.8 \times 10^{-2} \text{ μCi.}$$

The total volume of the attic is approximately 2.1×10^3 m^3. If the dust created would become dispersed throughout the entire attic, the concentration of normal uranium in the air (D) would be:

$$D = 3.8 \times 10^{-2} \text{ μCi}/2.1 \times 10^3 \text{ m}^3 = 1.8 \times 10^{-5} \text{ μCi/m}^3.$$

More than two people would probably not be involved in this operation, and the job should require no more than a few hours. Assuming a person would inhale 1.2 m^3 of air per hour (Ref. 1) and would be involved in this job for a two hour period, the amount of activity (E) that would be inhaled is:

$$\begin{aligned} E &= 1.8 \times 10^{-5} \text{ μCi/m}^3 \times 1.2 \text{ m}^3\text{/h} \times 2 \text{ h} \\ &= 4.3 \times 10^{-5} \text{ μCi} \\ &= 4.3 \times 10^{1} \text{ pCi.} \end{aligned}$$

The adult inhalation dose commitment factors for the bone, kidney, lung, and total body from ^{238}U, ^{234}U, ^{235}U, and short-lived daughters (Ref. 2) are presented in Table 7.1. The sum of the factors for ^{238}U and ^{234}U and short-lived daughters is also presented. Utilizing the results of the calculations given in Appendix 5, i.e., that 2.2% of normal-uranium disintegrations per minute are due to ^{235}U and 97.8% due to $^{238,234}U$ (or 48.9% each), the dose commitment factors for normal uranium are obtained and are presented in terms of pCi of ^{238}U.

The fifty year dose commitment (F) from the inhalation of 4.3×10^1 pCi of normal-uranium is:

$$F = 4.3 \times 10^{1} \text{ pCi} \times$$

(1) 1.0×10^{-1} mrem/pCi inhaled = 4.3 mrem, lung
(2) 2.04×10^{-2} mrem/pCi inhaled = 8.8×10^{-1} mrem, bone
(3) 4.78×10^{-3} mrem/pCi inhaled = 2.1×10^{-1} mrem, kidney
(4) 1.24×10^{-3} mrem/pCi inhaled = 5.3×10^{-2} mrem, total body.

Thus, the person would receive a 4.3 mrem dose commitment to the lung, a 0.88 mrem dose commitment to the bone, a 0.21-mrem dose commitment to the kidneys, and a 0.053-mrem dose commitment to the total body from this scenario.

Even though these calculations are based on reasonable hypothesized values, the actual total activity inhaled and subsequent dose commitments could differ from that hypothesized. This is due to uncertainties in the estimation of activity in the concrete floor, in the estimation of the fraction that becomes airborne and respirable, in the estimation of the breathing rate and duration of inhalation and in the application of the dose commitment factors to the person

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involved. The hypothesized case is, however, based on reasonably conservative assumptions and, therefore, most probably overestimates the true potential situation.

REFERENCES

1. Bureau of Radiological Health 1970. "Radiological Health Handbook." Rev. e, pg. 216.

2. G. R. Holmes and J. K. Soldat. 1977. "Age Specific Radiation Dose Commitment Factors for a One Year Chronic Intake." NUREG-0172 U. S. Nuclear Regulatory Commission. pg. 39

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TABLE 7.1

ADULT DOSE-COMMITMENT FACTORS
(mrem/50 yr per pCi inhaled in the 1st year)

Nuclide	Bone	Kidney	Lung	Total Body
^{238}U	9.58×10^{-3}	2.18×10^{-3}	4.58×10^{-2}	5.67×10^{-4}
^{234}Th	1.63×10^{-6}	5.41×10^{-7}	1.89×10^{-4}	4.7×10^{-8}
^{234}U	1.04×10^{-2}	2.49×10^{-3}	5.22×10^{-2}	6.46×10^{-4}
^{235}U	1.0×10^{-2}	2.34×10^{-3}	4.90×10^{-2}	6.07×10^{-4}
^{234}U & ^{238}U & short-lived daughters (per pCi of ^{238}U)	2.0×10^{-2}	4.67×10^{-3}	9.82×10^{-2}	1.21×10^{-3}
normal U* (per pCi of ^{238}U)	2.04×10^{-2}	4.78×10^{-3}	1.0×10^{-1}	1.24×10^{-3}

*Normal U is 2.2% ^{235}U, 97.8% ^{234}U and ^{238}U, by pCi (see Appendix 5).

APPENDIX 8

EVALUATION OF RADIATION EXPOSURES AT THE JONES CHEMICAL LABORATORY

I. PREFACE

The U. S. Department of Energy has initiated a program to determine the present radiological condition of sites formerly used for work with radioactive material by the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC). Much of the work involved in the MED/AEC era was performed at the University of Chicago in Chicago, Illinois. The George Herbert Jones Chemical Laboratory was one of the university buildings in use at that time. Some radiochemistry and/or physics research was performed in this building. Jones Laboratory is presently used for offices, laboratories, and classrooms. Since existing documentation was insufficient to determine the adequacy of any decontamination work performed at the time nuclear activities ceased at the Jones Laboratory, a comprehensive radiological assessment of the facility was conducted from June 13, 1977 to June 17, 1977.

II. INTRODUCTION

A. Types of Radiation

Radiation is the emission or transmission of energy in the form of waves or particles. Examples are acoustic waves (i.e., sound), electromagnetic waves (such as radio, light, x- and gamma-rays), and particulate radiations (such as alpha particles, beta particles, neutrons, protons, and the elementary particles).

The class of radiation of importance to this report is known as ionizing radiation. Ionizing radiations are those, either electromagnetic or particulate, with sufficient energy to ionize matter, i.e., to remove or displace electrons from atoms and molecules. The most common types of ionizing radiation are x- and gamma-rays, alpha particles, beta particles, and neutrons.

X- and gamma-rays are electromagnetic waves of pure energy, having no charge and no mass or existance at rest. Gamma-rays and x-rays are identical except that x-rays originate in the atom and gamma-rays originate in the nucleus of an atom. X- and gamma-rays are highly penetrating and can pass through relatively thick materials before interacting. Upon interaction, some or all of the energy is transferred to electrons, which, in turn, produce additional ionizations while coming to rest.

Alpha particles are positively charged particulates composed of two neutrons and two protons, identical to the nucleus of a helium atom. Due to its comparatively large mass and double charge, an alpha particle interacts readily with matter and penetrates only a very short distance before coming to rest, causing intense ionization along its path.

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Beta particles are negatively charged free electrons moving at high speeds. Due to its comparatively small mass and single charge, a beta particle's penetration through matter is intermediate between that of the alpha particle and the gamma-ray, causing fewer ionizations per unit path length than an alpha particle.

B. Sources of Radiation

Ionizing radiations arise from terrestrial radioactive materials (both naturally-occurring and man-made), extra-terrestrial (cosmic) sources, and radiation-producing machines. The sources of ionizing radiation important to this report are radioactive materials and cosmic sources.

Most atoms of the elements in our environment remain structurally stable. With time, an atom of potassium, for instance, may change its association with other atoms in chemical reactions and become part of other compounds, but it will always remain a potassium atom. Radioactive atoms, on the other hand, are not stable and will spontaneously emit radiation in order to achieve a more stable state. By spontaneously transforming itself, the ratio of protons and neutrons in the nucleus is altered toward a more stable condition. Radiation may be emitted from the nucleus as alpha particles, beta particles, neutrons, or gamma-rays, depending uniquely upon each particular radionuclide. Radionuclides decay at characteristic rates dependent upon the degree of stability and characterized by a period of time called the half-life. In one half-life, the number of radioactive atoms and, therefore, the amount of radiation emitted, decrease by one half.

The exposure of man to terrestrial radiation is due to naturally occuring radionuclides and also to "man-made" or technologically enhanced radioactive materials. Several dozen radionuclides occur naturally, some having half-lives of at least the same order of magnitude as the estimated age of the earth. The majority of these naturally occurring radionuclides are isotopes of the heavy elements and belong to three distinct radioactive series headed by uranium-238, uranium-235, and thorium-232. Each of these decays to stable isotopes of lead (Pb) through a sequence of radionuclides of widely varying half-lives. Other naturally occurring radionuclides, which decay directly to a stable nuclide, are potassium-40 and rubidium-87. It should be noted that even though the isotopic abundance of potassium-40 is less than 0.012%, potassium is so widespread that potassium-40 contributes about one-third of the radiation dose received by man from natural background radiation. A major portion of the exposure (dose) of man to external terrestrial radiation is due to the radionuclides in the soil, primarily potassium-40 and the radioactive decay chain products of thorium-232 and uranium-238. The naturally occurring radionuclides deposited internally in man through uptake by inhalation/ingestion of air, food, and drinking water containing the natural radioactive material also contribute significantly to his total dose. Many other radionuclides are referred to as "man made" in the sense that they can be produced in large quantities by such means as nuclear reactors, accelerators, or nuclear weapons tests.

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The term "cosmic radiation" refers both to the primary energetic particles of extra-terrestrial origin that are incident on the earth's atmosphere and to the secondary particles that are generated by the interaction of these primary particles with the atmosphere and reach ground level. Primary radiation consists of "galactic" particles, externally incident on the solar system, and "solar" particles emitted by the sun. This radiation is composed primarily of energetic protons and alpha particles. The first generation of secondary particles (secondary cosmic radiation), produced by nuclear interactions of the primary particles with the atmosphere, consists predominantly of neutrons, protons, and pions. Pion decay, in turn, results in the production of electrons, photons, and muons. At the lower elevations, the highly penetrating muons and their associated decay and collision electrons are the dominant components of the cosmic-ray particle flux density. These particles, together with photons from the gamma-emitting, naturally occurring radionuclides in the local environment, form the external penetrating component of the background environmental radiation field which produces a significant portion of the whole-body radiation dose to man.

In addition to the direct cosmic radiation, cosmic sources include cosmic-ray produced radioactivity, i.e., cosmogenic radionuclides. The major production of cosmogenic radionuclides is through interaction of the cosmic rays with the atmospheric gases through a variety of spallation or neutron-capture reactions. The four cosmogenic radionuclides that contribute a measurable radiation dose to man are carbon-14, sodium-22, beryllium-7, and tritium (hydrogen-3), all produced in the atmosphere.

III. BACKGROUND RADIATION DOSES

Background radiation doses are comprised of an external component of radiation impinging on man from outside the body and an internal component due to radioactive materials taken into the body by inhalation or ingestion.

Radiation dose may be expressed in units of rads or rems, depending upon whether the reference is to the energy deposited or to the biological effect. A rad is the amount of radiation that deposits a certain amount of energy in each gram of material. It applies to all radiations and to all materials which absorb that radiation.

Since different types of radiation produce ionizations at different rates as they pass through tissue, differences in damage to tissues, and hence the biological effectiveness of different radiations, has been noticed. A rem is defined as the amount of energy absorbed (in rads) from a given type of radiation multiplied by the factor appropriate for the particular type of radiation in order to approximate the biological damage that it causes relative to a rad of x or gamma radiation. The rem permits evaluation of potential effects from radiation exposure without regard to the type of radiation or its source. One rem received from cosmic radiation results in the same biological effects as one rem from medical x-rays or one rem from the radiations emitted by naturally occurring or man-made radioactive materials.

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The external penetrating radiation dose to man derives from both terrestrial radioactivity and cosmic radiation. The terrestrial component is due primarily to the gamma dose from potassium-40 and the radioactive decay products of thorium-232 and uranium-238 in soil as well as from the beta-gamma dose from radon daughters in the atmosphere. Radon is a gaseous member of the uranium-238 chain. The population-weighted external dose to an individual's whole body from terrestrial sources in the United States has been estimated as 15 mrem per year for the Atlantic and Gulf Coastal Plain, 57 mrem per year for an indeterminate area along the Rocky Mountains, and 29 mrem per year for the majority of the rest of the United States. The overall population-weighted external dose for the U.S. population as a whole has been estimated to be 26 mrem per year.

The cosmic radiation dose, due to the charged particle and neutrons from secondary cosmic rays, is typically about 30% to 50% of the total from all external environmental radiation. The cosmic-ray dose to the population is estimated to be 26 mrem per year for those living at sea level, and increases with increasing altitude. Considering the altitude distribution of the U.S. population, the population-weighted external cosmic-ray dose is 28 mrem per year. The population-weighted total external dose from terrestrial plus cosmic sources is thus 54 mrem per year for the U.S. population as a whole.

The internal radiation doses derive from terrestrial and cosmogenic radionuclides deposited within the body through uptake by inhalation/ingestion of air, food, and drinking water. Once deposited in the body, many radioactive materials can be incorporated into tissues because the chemical properties of the radioisotopes are identical or similar to stable isotopes in the tissues. Potassium-40, for instance, is incorporated into tissues in the same manner as stable potassium atoms because the chemical properties are identical; radioactive radium and strontium can be incorporated into tissues in the same manner as calcium because their chemical properties are similar. Once deposited in tissue, these radionuclides emit radiation that results in the internal dose to individual organs and/or the whole body as long as it is in the body.

The internal dose to the lung is due primarily to the inhalation of polonium-218 and -214 (radon daughters), lead-212 and bismuth-212 (thoron daughters) and polonium-210 (one of the longer-lived radon decay products). The dose to the lung is about 100 mrem per year from inhaled natural radioactivity. The internal dose from subsequent incorporation of inhaled or ingested radioactivity is due to a beta-gamma dose from incorporation of potassium-40, rubidium-87, and cosmogenic nuclides, and an alpha dose from incorporation of primarily polonium-210, radium-226 and -228, and uranium-238 and -234. The dose to man from internally incorporated radionuclides is about 28 mrem per year to the gonads, about 25 mrem per year to the bone marrow, lung, and other soft tissues, and about 117 mrem per year to the bone (osteocytes). The bone dose arises primarily from the alpha-emitting members of the naturally occurring series, with polonium-210 being the largest contributor. The gonadal and soft tissue doses arise primarily

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from the beta and gamma emissions from potassium-40. The total internal dose from inhaled plus incorporated radioactivity is about 28 mrem per year to the gonads (or whole-body dose), about 125 mrem per year to the lung, about 25 mrem per year to the bone marrow, and about 117 mrem per year to the bone (osteocytes).

The total natural background radiation dose is the sum of the external and internal components. The population-weighted dose for the U.S. population as a whole is about 82 mrem per year to the gonads or whole body, about 179 mrem per year to the lung, about 79 mrem per year to the bone marrow, and about 171 mrem per year to the bone (osteocytes).

Besides the natural background radiation, background radiation doses include contributions from man-made or technologically enhanced sources of radiation. By far, the most significant are x-ray and radiopharmaceutical medical examinations. These contribute a population-averaged dose estimated to be 70 mrem per year for the U.S. population as a whole. Fallout from nuclear weapons testing through 1970 has contributed 50-year dose commitments estimated as 80 mrem external, and 30, 20, and 45 mrem internal to the gonads, lung, and bone marrow, respectively. Contributions from the use of fossil fuels (natural gas and coal) and nuclear reactors; mining, milling, and tailings piles; television sets, smoke detectors, and watch dials could be responsible for an additional 5 mrem per year, averaged over the U.S. population as a whole. In addition, the use of radiation or radioactivity for scientific, industrial, or medical purposes may cause workers in the industry, and, to a lesser extent, members of the general public to receive some radiation exposure above natural background.

IV. EVALUATION OF RADIATION DOSE AND POTENTIAL HAZARD

Radiation, regardless of its sources, is considered to be a hazard because of its potential for producing adverse effects on human life. Very large amounts of radiation received over a brief period, i.e., hundreds of rem delivered within a few hours, can produce severe injury or death within days or weeks. Distributed over longer intervals, however, these same doses would not cause early illness or fatality. At doses and rates too low to produce these immediate symptoms, chronic or repeated exposure to radiation can bring about biological damage which does not appear until years or decades later. These low-level effects are stochastic in nature; their probability rather than their severity increases with dose. Primary among these latent or delayed effects are somatic effects, where insults such as cancers occur directly to the individual exposed, and genetic defects, where, through damage to the reproductive cells of the exposed individual, disability and disease ranging from subtle to severe are transmitted to his offspring.

Clinical or observed evidence of a relationship between radiation and human cancers arise from several sources. The most important data come from the victims of Hiroshima and Nagasaki, patients exposed during medical therapy, radium dial painters, and uranium miners. Data exist only for relatively large doses; there have been no direct measurements of increased

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incidence of cancer for low-level radiation exposures. Evaluation of the available data has lead to estimates of the risk of radiation-induced cancer; estimated risks for the lower doses have been derived by linear extrapolation from the higher doses. All radiation exposures then, no matter how small, are assumed to be capable of increasing an individual's risk of contracting cancer.

Data on genetic defects resulted from radiation exposure of humans is not available to the extent necessary to allow an estimate of the risk of radiation-induced effects. Data from animals, along with general knowledge of genetics, have been used to derive an estimate of the risks of genetic effects.

Estimates of health effects from radiation doses are usually based on risk factors as provided in International Commission on Radiological Protection (ICRP), National Research Council Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), or United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports. Multiplying the estimated dose by the appropriate risk factor provides an estimate of the risk or probability of induction of health effects to an individual or his descendants as a result of that exposure. The evaluation of these risk factors is presently subject to large uncertainties and, therefore, potential continual revision. The risk factors recommended by the ICRP for cancer mortality and hereditary ill health to the first and second generations are 10^{-4} per rem of whole body dose and 4×10^{-5} per rem of gonadal dose, respectively. As an example, a whole-body dose of 1 rem would be estimated to add a risk of cancer mortality to the exposed invididual of 10^{-4}, i.e., 1 chance in 10,000. However, a precise numerical value cannot be assigned with any certainty to a particular individual's increase in risk attributable to radiation exposure. The reasons for this are numerous and include the following: (1) uncertainties over the influence of the individual's age, state of health, personal habits, family medical history, and previous or concurrent exposure to other cancer-causing agents, (2) the variability in the latent period (time between exposure and physical evidence of disease), and (3) the uncertainty in the risk factor itself.

To be meaningful, an attempt should be made to view such risk estimates in the appropriate context. One useful comparison is with risks encountered in normal life. Another comparison, potentially more useful, is with an estimation of the risks attributable to natural background radiation. Radiation from natural external and internal radioactivity results in the same types of interactions with body tissues as that from "man-made" radioactivity. Hence, the risks from a specified dose are the same regardless of the source. Rather than going through an intermediate step involving risk factors, doses can also be compared directly to natural background radiation doses.

APPENDIX 8
(Cont'd.)

Besides estimation of risks and comparisons to natural background, doses may be compared to standards and regulations. The appropriate standards, the Department of Energy "Requirements for Radiation Protection," give limits for external and internal exposure for the whole body and specified organs which are expressed as the permissible dose or dose commitment annually in addition to natural background and medical exposures. There are in general two sets of limits, one applicable to occupationally exposed persons and the second applicable to individuals and population groups of the general public. The limits for individuals of the public are one-tenth of those permitted for occupationally exposed individuals. The set of limits important to this report are those applicable to individuals and population groups of the public. The limits for individuals of the public are 500 mrem per year to the whole body, gonads, or bone marrow and 1500 mrem per year to other organs. The limits for population groups of the public are 170 mrem to the whole body, gonads, or bone marrow and 500 mrem per year to other organs, averaged over the group. In either case, exposures are to be limited to the lowest levels reasonably achievable within given limits.

V. RESULTS OF SITE RADIOLOGICAL SURVEY

A comprehensive radiological survey of the Jones Chemical Laboratory, University of Chicago, was conducted in June 1977. Direct instrument surveys and smear surveys indicated that some areas of radioactive contamination were present in the facility. Contamination possibly due to MED/AEC occupancy was found at 46 locations in 17 rooms or areas. Most of the contamination, except for that in the fourth-floor attic, consisted of small localized spots (< 500 cm^2) on floors and walls. The attic, a concrete-floored 18 m by 27 m (60 ft x 90 ft) room, was the only area where extensive and widespread ($< 10^5$ cm^2) contamination was found. A gamma-spectral analysis indicated that the contaminant in that area was normal uranium. Except in one instance, the contamination at Jones Laboratory was "fixed" and not easily removable when smeared. Air sampling indicated ranges of radon and daughter concentrations within normally expected background concentrations. No long-lived radionuclides were detected in any air sample. Soil sampling about the grounds of Jones Laboratory indicated uranium concentrations essentially the same as natural background.

The survey data may be evaluated in terms of the potential doses that exposed persons could receive. Doses were calculated for a scenario involving the fourth-floor attic that could result in the presumed maximum internal radiation dose from inhalation of radioactivity. The maximum potential internal dose was calculated to be 4.3 mrem to the lung, 0.88 mrem to the bone, 0.21 mrem to the kideny, and 0.053 mrem to the whole body. For the lung, bone, and kidney, these represent an increase of about 2.4%, 0.5% and 0.25% above the 179 mrem, 171 mrem, and 82 mrem annual natural background lung, bone, and kidney (soft tissue) doses, respectively, and 0.3%, 0.06%, and 0.014% of the 1500-mrem limit for an individual of the public. For the whole body, this represents about 0.065% of the 82 mrem annual natural background whole body dose and 0.011% of the 500-mrem limit for an individual of the public.

APPENDIX 8
(Cont'd.)

In order to reduce the potential for radiation exposures, remedial measures such as stabilization of the contamination in place would be applicable as a short-term measure. In order to reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution to the problem would involve decontamination by removal of the radioactive residues from the 17 rooms or areas in the facility where contamination possibly resulting from MED/AEC activities was found.

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