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Formerly Utilized MED/AEC Sites Remedial Action Program

Radiological Survey of the Museum of Science and Industry, 57th Street and Lake Shore Drive, Chicago, Illinois

February 1979

Final Report

Prepared for

U.S. Department of Energy
Assistant Secretary for Environment
Division of Environmental Control Technology

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PREFACE

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

This report contains the results of surveys of the current radiological condition of the Museum of Science and Industry, 57th Street and Lake Shore Drive, Chicago, Illinois. Findings of this survey indicate there is no identifiable residual radioactivity remaining at this facility from operations conducted by the MED and AEC during the period 1946 thru 1953.

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. J. Mayes, P. C. Gray, D. W. Reilly.

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RADIOLOGICAL SURVEY OF THE MUSEUM OF SCIENCE AND INDUSTRY, 47TH STREET AND LAKE SHORE DRIVE, CHICAGO, ILLINOIS

INTRODUCTION

During the Manhattan Engineer District/Atomic Energy Commission (MED/AEC) Era, Argonne National Laboratory (ANL) occupied space at the Museum of Science and Industry, Chicago, Illinois. From August 15, 1946 until July 1, 1949, ANL occupied 36,000 square feet on the ground, first, and balacony floors of the East Pavilion. From August 15, 1946 until July 15, 1953, ANL also occupied 16,000 square feet in the 2nd Balcony of the West Court. The actual use of the facility is unknown. Although most of the area was believed to be occupied as office space, some handling of radioactive materials was known to have taken place. The type and activity of these materials is unknown.

Personnel involved with the facility during ANL's occupation recalled at least one spill of radioactive material near the service elevator on the ground floor of the East Pavilion and its subsquent decontamination.

Due to the uncertainty of the use of the facility, a radiation survey of the above area was undertaken from January 11, 1977 until April 13, 1977. This survey was performed on an intermittent basis to minimize the disturbance of the Musuem's daily operations. The purpose of this survey was to determine if any detectable contamination remains as a result of the MED/AEC operation.

Part of the ground and main floors of the East Pavilion are presently occupied by the University of Chicago for storage and office space or are used for support of the Museum's operations. The 2nd Balcony of the West Court is now occupied as office space by the Museum of Science and Industry and the Academy of Interscience Methodology.

SURVEY TECHNIQUES

Areas

All accessible original walls were surveyed to a height of seven feet and all accessible floor areas were surveyed. In many areas, the floors and walls were covered tiled or painted. Even though these were not the original surfaces, these areas were surveyed since the capability of detection was adequate to see activity in the original structures underneath. A representative selective survey of overheads such as pipes, vents and light fixtures was performed in areas where the original structures were available. The roof of the East Pavilion was not surveyed. See Table 1 and Figure 1 for locations of accessible areas surveyed.

Instrumentation

Three types of survey instruments were used (Table 2). An Eberline FM-4G having a detection area of 325 square centimeters (cm^2), utilizing the Eberline PAC-4G-3 electronics, was used to survey the floors. A PAC-4G-3 with a hand-held detector, $61 cm^2$ in area, was used to survey the walls and other accessible areas. Double aluminized mylar [~ 0.85 milligrams per square centimeter (mg/cm^2)] probes were used in both detectors. This allows for low energy detection and greater instrument sensitivity. Both of these instruments were initially used in the beta mode. In this mode, the detector responds to a wide energy range of electromagnetic and particulate radiations. When areas were found which indicated a higher count rate than the average instrument background, the instrument was then switched to the alpha mode and a reading of the alpha activity was obtained.

An End Window Geiger-Müeller (G-M) Detector, Eberline Model E-500B with a nominal 1 3/8 inch diameter window held three feet above the floor, was used to determine general background radiation levels throughout the surveyed area. If an area was found that had an elevated count rate, a contact reading was obtained.

The End Window G-M Detector was calibrated using the gamma emissions from a Radium-226 (^{226}Ra) calibration source. The PAC-4G-3 instruments were calibrated in the alpha mode using a flat plate infinitely thin Plutonium-239 (^{239}Pu) standard and in the beta mode with a flat plate infinitely thin Strontium-90-Yttrium-90 (^{90}Sr-^{90}Y) standard. The instruments were calibrated to an apparent 50% geometry.

It must be realized that the numerous isotopes that could be encountered will exhibit emission energies differing from that of ^{239}Pu and ^{90}Sr-^{90}Y utilized in the calibration. When detecting known isotopes that emit alpha and beta energies differing from that of the standards, a conversion factor is developed to determine the appropriate yield.

Smear Surveys

Smears were taken throughout the East Pavilion and West Balcony areas of the Museum. Only original structures and components such as walls, floors, pipes and vents were smeared. All smears were taken with No. 1 Whatman filter paper, 4.25 centimeters (cm) in diameter. Smears of one square foot were normally taken. If an area was found which had a higher than normal background, a smear of $100cm^2$ was taken. A smear of $100cm^2$ was also taken if an area indicated excessive dirt loading. The smears were counted in groups of ten using the 10-Wire Flat Plate Gas Proportional Detector, developed at ANL, utilizing an Eberline Mini Scaler Model MS-2. One smear of each group was removed and counted in a Nuclear Measurement Corporation Proportional Counter - 3A (PC-3A) 2π Internal Gas Flow Counter using a mylar spun top. This procedure was used as an additional means of checking the smear samples. In addition, any smears indicating elevated amounts in the 10-Wire Assembly, were also counted in the more sensitive PC-3A counter. Smears were counted in both detectors for alpha and beta activity. Appendix 1 includes the instrumentation and smear count conversion factors used.

Table 1 includes the room survey readings while the maps in Figure 1 indicate the location of the smears. A number, n, indicates the location of that smear in the room. A number, (n), indicates a smear of an overhead structure. A number [n], indicates an elevated direct reading.

Air Samples

Air samples were collected using a Filter Queen air sampling device. The air samples were taken at a flow rate of 15 cubic meters per hour (M^3/hr) on a 200cm^2 sheet of Hollingsworth-Vose (HV-70-9 mil) filter media which collected the particulates present in the air. A 10% portion, 5cm in diameter, was removed from the filter media and counted in the NMC PC-3A 2π Internal Gas Flow Counter, utilizing a mylar spun top for both alpha and beta activity. Sampling results were used to determine radon concentrations and the presence of any long-lived activity. Air sample data is presented in Appendix 2.

Soil Samples

In addition to the survey inside the building, soil corings were taken at selected locations outside the East Pavilion of the Museum to determine the deposition, if any, of isotopes that could have been spilled or released from the East Pavilion. Radiochemical (fluorometric) and gamma spectrum analysis were conducted on these soil samples.

The corings were effected using a four (4) inch in diameter by six (6) inch in length right circular cylinder; commonly called a hole cutter. This device is normally used for cutting holes for the cups in golf courses.

Each core was 1 foot in length and divided into four (4) segments. Starting from the surface, three (3) separate two (2) inch segments are cut, bagged, and marked A, B and C respectively; the final segment a six (6) inch section was marked D.

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

Three soil samples were taken from the grounds adjacent to the East Pavilion of the Museum. Figure 1F indicates the soil sample locations.

Background data for the soil sample analysis (Table 8) were obtained from a number of soil samples taken from the Chicago area. This information was obtained from the Environmental Monitoring Section of the Occupational Health and Safety (OHS) Division of ANL.

All soil samples were processed at ANL (Figure 3) and shipped to a commercial laboratory (LFE Environmental Analysis Laboratories) for radiochemical (fluorometric) and gamma spectrum analysis. Their soil analysis procedure is described in Table 6.

Sample preparation consisted of weighing the samples in their entirety and then drying for approximately 24 hours at 80^{o} Centigrade. All samples were then reweighed, put into mill jars (2.3 gallon) and milled until a sufficient amount of the soil sample would pass a No. 30 standard sieve. At no point were the rocks and heavy material ground or pulverized since this material would act as a diluent and hence lower the concentration per unit volume of deposited material.

After sufficient milling, the material was sieved using a No. 30, 600 micron (μ) standard stainless sieve. The rocks and dross vs. sieved material (< 600 μ) was segregated, bagged, and weighed separately. Soil sample weights are given in Table 5.

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

ANALYSIS OF SURVEY RESULTS

General

All data, including diagrams of survey locations, are attached to this report. This section discusses the results of the survey and the findings therein. Instrument readings and smear results were normalized to units of disintegrations per minute per one hundred square centimeters (dpm/100cm^2). (See Appendix 1 for the conversion factors used.) All data is reported in net counts, i.e., the background counts have been subtracted from the gross counts prior to converting from counts per minute per one hundred square centimeters (cpm/100cm^2) to dpm/100cm^2. The beta mode readings are compensated for any alpha contribution. The room background levels varied somewhat due to the construction materials in them. Table 3 provides an average background reading for all modes of the different instruments used.

The areas accessible for survey varied from room to room. Areas accessible for survey are presented in Table 1. The average percent of the total accessible areas was 50% for the floors and 40% for the walls.

Instrument Surveys

All indicated areas were surveyed and no radioactivity above background levels could be detected except in the following four rooms.

Room C-340 - This room is a small instrument shop where a marked Cobalt-60 (^{60}Co) source was found in the cabinet. A direct reading with an End Window G-M Detector was 80 milliRoentgens per hour (mR/hr) at contact. When the detector was held three feet away from the source in its shielded container, no radiation above background levels, < 0.03 mR/hr, could be detected.

Room E-201 and Restrooms on 2nd Balcony - These washrooms contained a white tile on the floors. This tile was also noted in other restrooms of the Museum. These tiles indicated 8.1 x 10^3 dpm/100cm^2 Potassium-40 (^{40}K) with the PAC-4G-3 in the beta mode. No alpha activity was detected. No radiation above background levels could be found from the tile using the End Window G-M Detector. No activity was detected from floor tile smears. It was determined from a gamma spectral analysis that the tile contained elevated amounts of (^{40}K) which would cause an elevated reading. (See Figure 2 for gamma emission spectra.) All general background readings taken at three feet above the floor level were less than 0.03 mR/hr.

Smear Surveys

No contamination above background levels was detected on any smears.

Air Samples

The air sampling results are presented in Table 4. The variation of the data results do not appear to be a result of any MED/AEC operation, but rather the variation reflects the differences in the construction materials used throughout the facility. Other factors such as the ventilation of the room can cause the radon concentrations to vary. All radon concentrations determined are below the maximum permissible concentrations (MPC) for an uncontrolled area as listed in the "Standards for Protection Against Radiation," Code of Federal Regulations, Title 10, Part 20,

Appendix B (April 30, 1975), (10CFR20). These concentrations are found to be within the normal expected levels of radon.

Soil Samples

Results submitted by LFE Environmental Analysis Laboratories, as listed in Table 7, are reported in picocuries per gram (pCi/g) for the Germanium (Lithium) [Ge(Li)] spectral analysis and in micrograms per gram (μg/g) for the uranium fluorometric analysis. The latter concentrations were converted to pCi/g by means of the example calculation as shown in Appendix 3.

The background data is presented in Table 8. The background samples indicate normal uranium concentrations ranging from 0.03 to 2.0 pCi/g. Results of soil samples taken at the Museum of Science and Industry indicate a gerneral normal uranium background concentration in the soil.

FINDINGS

The survey results show that no radioactive contamination above background was detected throughout the areas used for MED/AEC activities. However, a small ^{60}Co source which was used as a static eliminator was found in Room C-340. The floor tiles which were used in the restrooms, showed elevated levels of naturally occurring ^{40}K. Neither of these are a result of any MED/AEC operations. The results of the soil sample analysis shows no elevated readings above the natural background levels present in the soil from this region.

TABLE I
DATA SHOWING ROOM SURVEY RESULTS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings (dpm/100cm²) Floors	Walls	Overhead	Other	Alpha Mode Direct Readings (dpm/100cm²) Floors	Walls	Overhead	Other	End Window (mR/hr) Contact	3 feet	Smear Results (dpm/100cm²)	Comments
E-1	70	20	NS[2]	BKGD[3]	BKGD	OSU[4]	BKGD	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
E-2	80	25	1.25	BKGD	BKGD	OSU	NE[5]	NA	NA	NA	NA	NN	BKGD	BKGD	
E-3	70	20	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-4	60	25	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-4A	40	25	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-4AA	40	30	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-7	95	30	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-8	40	40	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-9	50	50	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-11	50	50	NS	BKGD	BKGD	KBGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-12	40	40	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-14	60	50	0.48	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-15	20	10	0.48	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-16	20	20	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-17	50	50	NS	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-18	30	20	1.5	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-19	20	20	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

[1] Beta Mode detects both electromagnetic and particulate radiation.

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

[3] BKGD (Background) Instrument Background Readings

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

G-M End Window Detector read <0.03 mR/hr at 3 feet above floor.

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

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

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

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

TABLE 1
DATA SHEETS SHOWING ROOM SURVEY RESULTS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample	Beta Mode[1] Direct Readings (dpm/100cm²)				Alpha Mode Direct Readings (dpm/100cm²)				End Window (mR/hr)		Smear Results	Comments
	Floor	Wall	(pCi/ℓ)	Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	3 feet	(dpm/100cm²)	
E-20	80	50	NS[2]	BKGD[3]	BKGD	OSU[4]	BKGD	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
E-21S	1	5	NS	BKGD	BKGD	BKGD	NE[5]	NA	NA	NA	NA	NN	BKGD	BKGD	
E-21N	20	20	NS	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
Stairwell off E-14	90	40	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-100	40	10	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-101	30	30	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-102	70	30	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-103	50	30	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-104	40	20	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-105	30	30	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-105B	30	20	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-106	40	30	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-108	50	75	NS	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-109	30	50	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-110 112	40	40	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-114 117N	75	50	0.49	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	

[1] Beta Mode detects both electromagnetic and particulate radiation

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

[3] BKGD (Background) Instrument Background Readings.

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

G-M End Window Detector read <0.03 mR/hr at 3 feet above floor.

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

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

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

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

TABLE I
DATA SHEETS SHOWING ROOM SURVEY RESULTS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample	Beta Mode[1] Direct Readings (dpm/100cm^2)				Alpha Mode Direct Readings (dpm/100cm^2)				End Window (mR/hr)		Smear Results	Comments
	Floor	Wall	(pCi/ℓ)	Floors	Walls	Overhead	Other	Floors	Walls	Overhead	Other	Contact	3 feet	(dpm/100cm^2)	
E-117S	20	10	0.71	BKGD[3]	BKGD	OSU[4]	NE[5]	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
E-115	80	60	BLGD	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-116	50	10	NS[2]	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
Auditorium of Circus	50	50	NS	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
E-201	80	50	1.04	$8.3x10^3$	BKGD	OSU	NE	BKGD	NA	NA	NA	BKGD	BKGD	BKGD	Floor tile in washroom
E-202	50	30	0.67	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
E-203	50	30	NS	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
2nd Floor Balcony West Hall C-330	100	50	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
2nd Floor Balcony South Hall	100	60	0.31	BKGD	BKGD	OSU	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
C-304 Restroom	100	60	NS	$8.3x10^3$	BKGD	BKGD	NE	BKGD	NA	NA	NA	BKGD	BKGD	BKGD	Floor Tile
C-332 Restroom	60	50	NS	$8.3x10^3$	BKGD	BKGD	NE	BKGD	NA	NA	NA	BKGD	BKGD	BKGD	Floor Tile
C-340	80	10	NS	BKGD	BKGD	OSU	$9.6x10^2$	NA	NA	NA	BKGD	80	BKGD	NST[8]	^{60}Co Source Reading Taken with source in container
C-341	80	20	NS	BKGD	BKGD	OSU	BKGS	NA	NA	NA	NA	NN	BKGD	BKGD	
C-342	60	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	

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

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

(3) BKGD (Background) Instrument Background Readings

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

G-M End Window Detector read <0.03 mR/hr at 3 feet above floor.

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

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

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

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

(8) NST (No Smear Taken)

TABLE I
DATA SHEETS SHOWING ROOM SURVEY RESULTS

Room or Area No.	Percent of Area Accessible for Survey Floor	Percent of Area Accessible for Survey Wall	Air Sample (pCi/ℓ)	Beta Mode[1] Direct Readings (dpm/100cm²) Floors	Walls	Overhead	Other	Alpha Mode Direct Readings (dpm/100cm²) Floors	Walls	Overhead	Other	End Window (mR/hr) Contact	3 feet	Smear Results (dpm/100cm²)	Comments
C-343 C-244A C-345	15	15	NS[2]	BKGD[3]	BKGD	OSU[4]	BKGD	NA[6]	NA	NA	NA	NN[7]	BKGD	BKGD	
C346, 347 348, 349, 354,355, 356, 357 358	30	20	NS	BKGD	BKGD	BKGD	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
2nd Floor Balcony West Hall	100	50	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
2nd Floor Balcony North Hall	100	50	0.31	BKGD	BKGD	OSU	NE[5]	NA	NA	NA	NA	NN	BKGD	BKGD	
C-359	15	20	NS	BKGD	BKGD	BKGD	NE	NA	NA	NA	NA	NN	BKGD	BKGD	
C-360	30	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
C-361	30	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
C-362	30	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
C-363	30	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
C-364	30	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
C-365	30	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
C-366 C-367	30	40	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	
Roof	100	100	NS	BKGD	BKGD	OSU	BKGD	NA	NA	NA	NA	NN	BKGD	BKGD	

[1] Beta Mode detects both electromagnetic and particulate radiation.

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

[3] BKGD (Background) Instrument Background Readings

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

G-M End Window Detector read <0.03 mR/hr at 3 feet above floor.

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

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

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

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

FIGURE 1A

SURVEY LOCATIONS OF EAST PAVILION - GROUND FLOOR

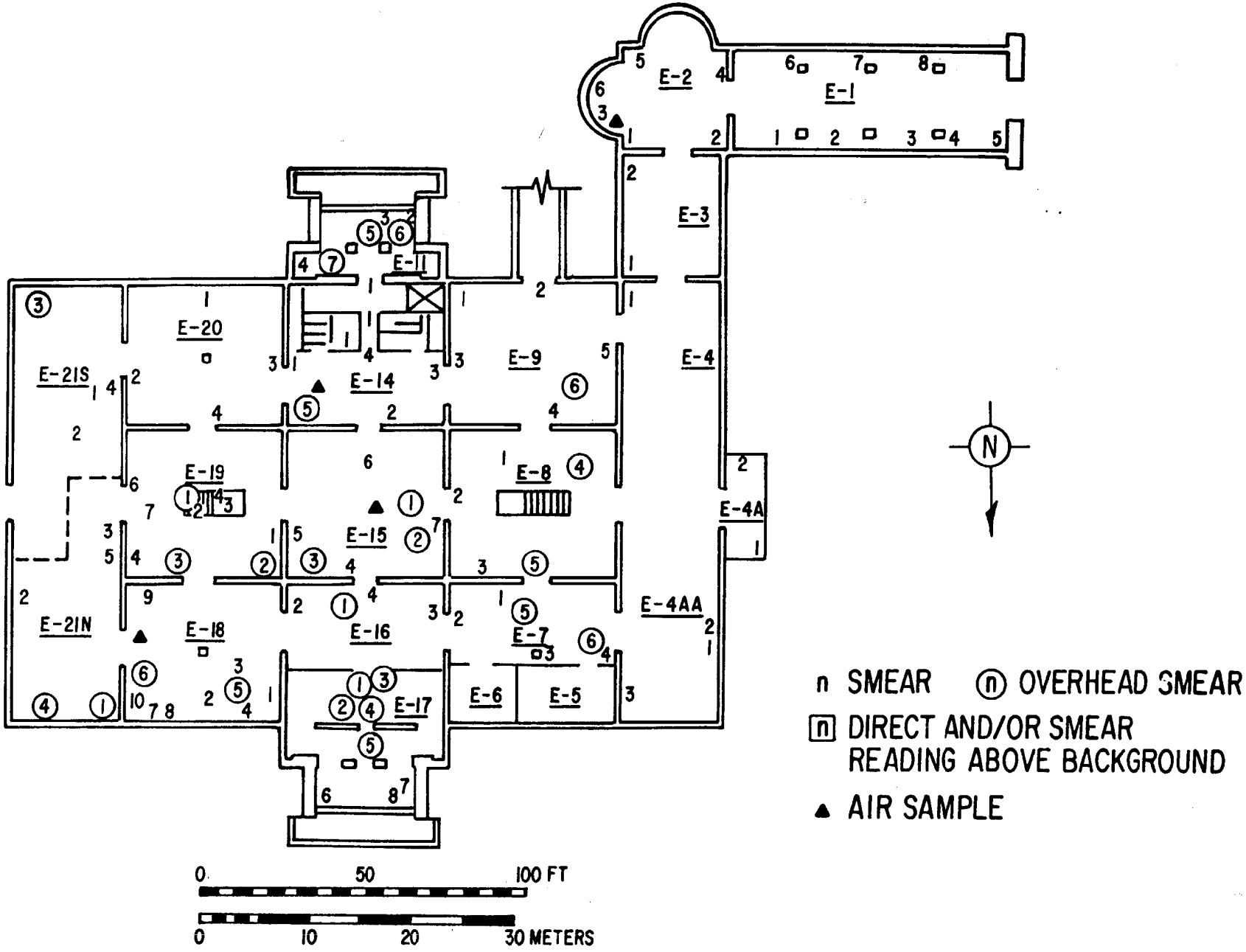

FIGURE 1B

SURVEY LOCATIONS OF EAST PAVILION - FIRST FLOOR

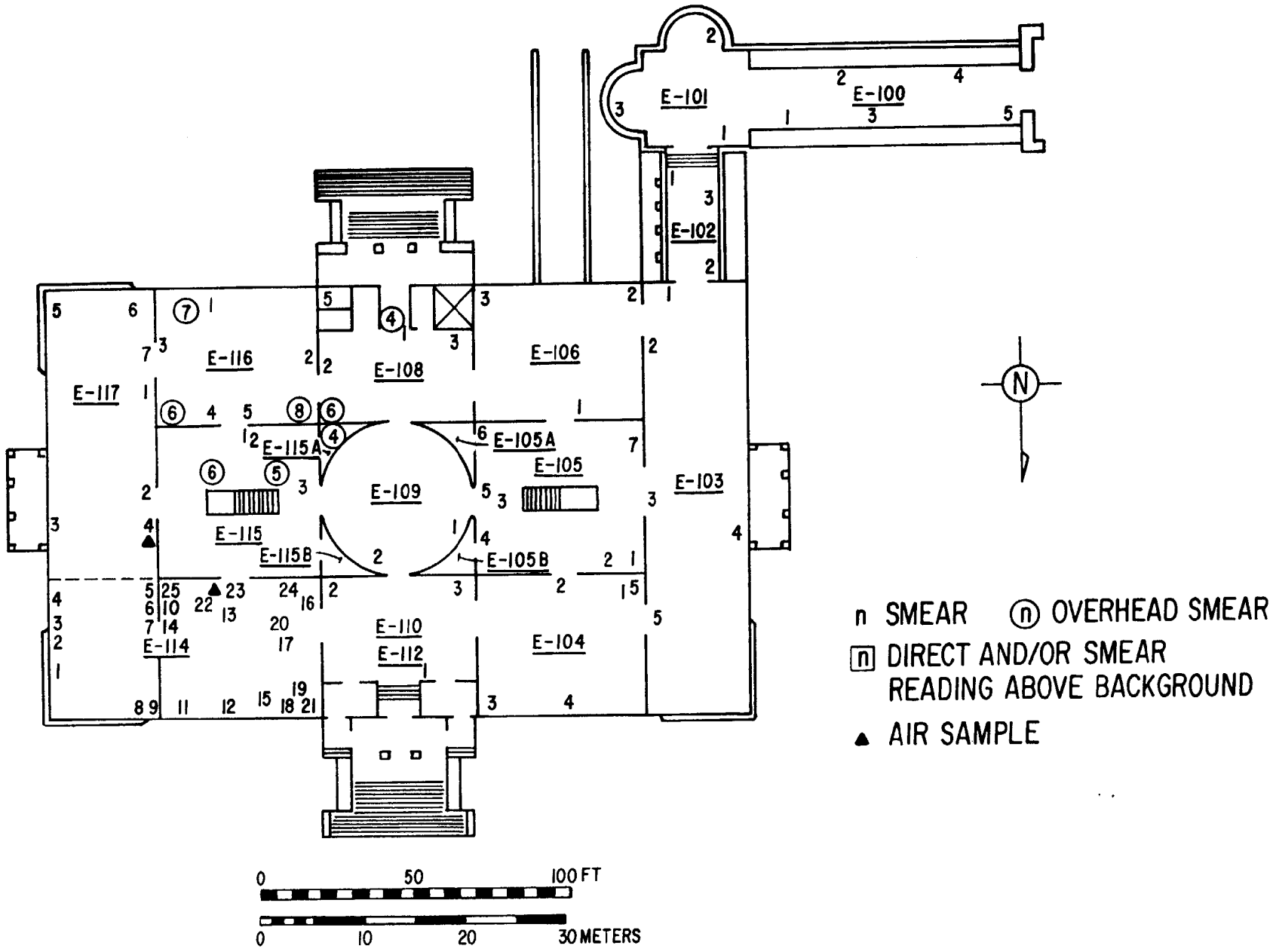

FIGURE 1C

SURVEY LOCATIONS OF EAST PAVILION - FIRST BALCONY

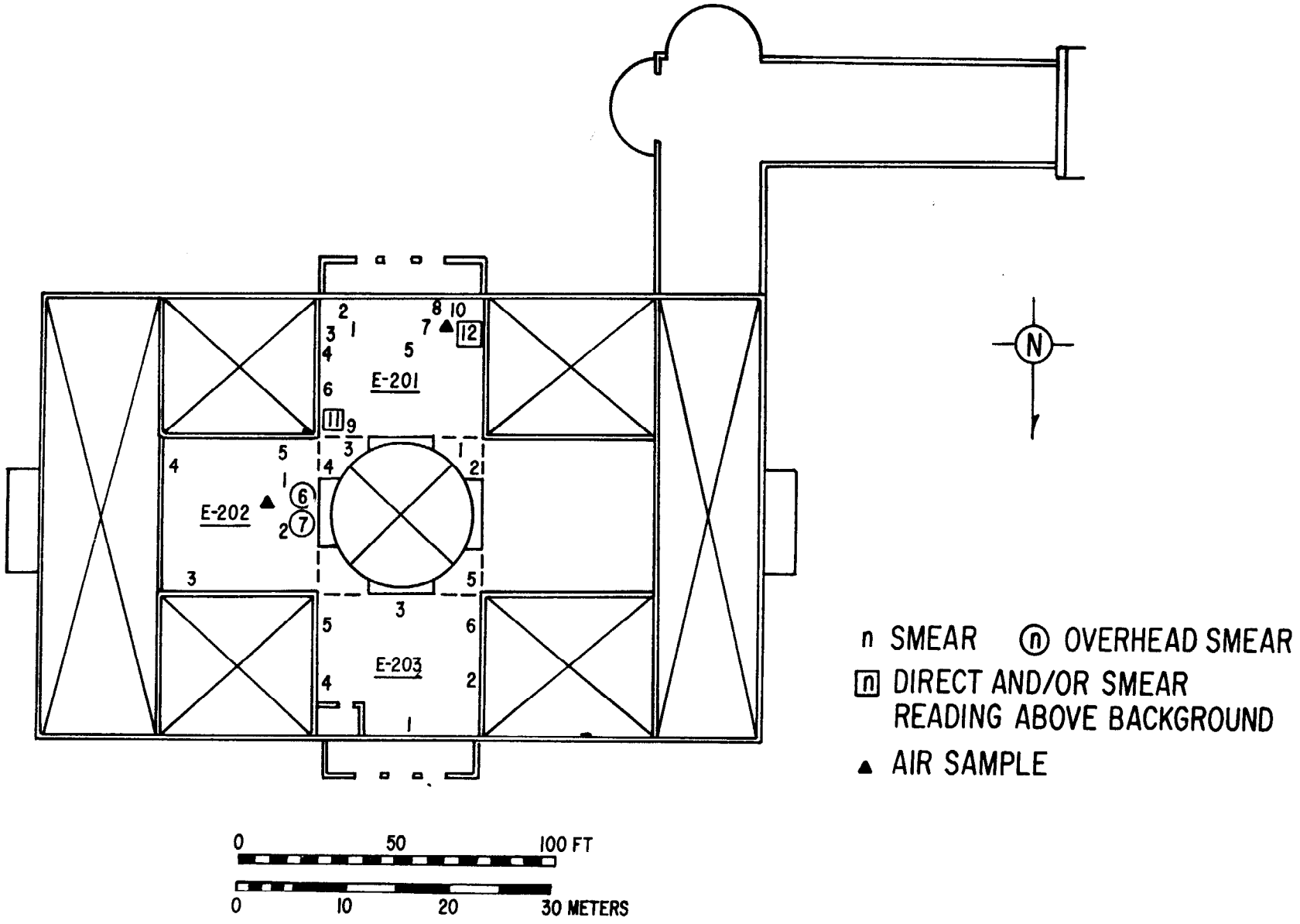

FIGURE 1D

SURVEY LOCATIONS OF EAST PAVILION - ROOF

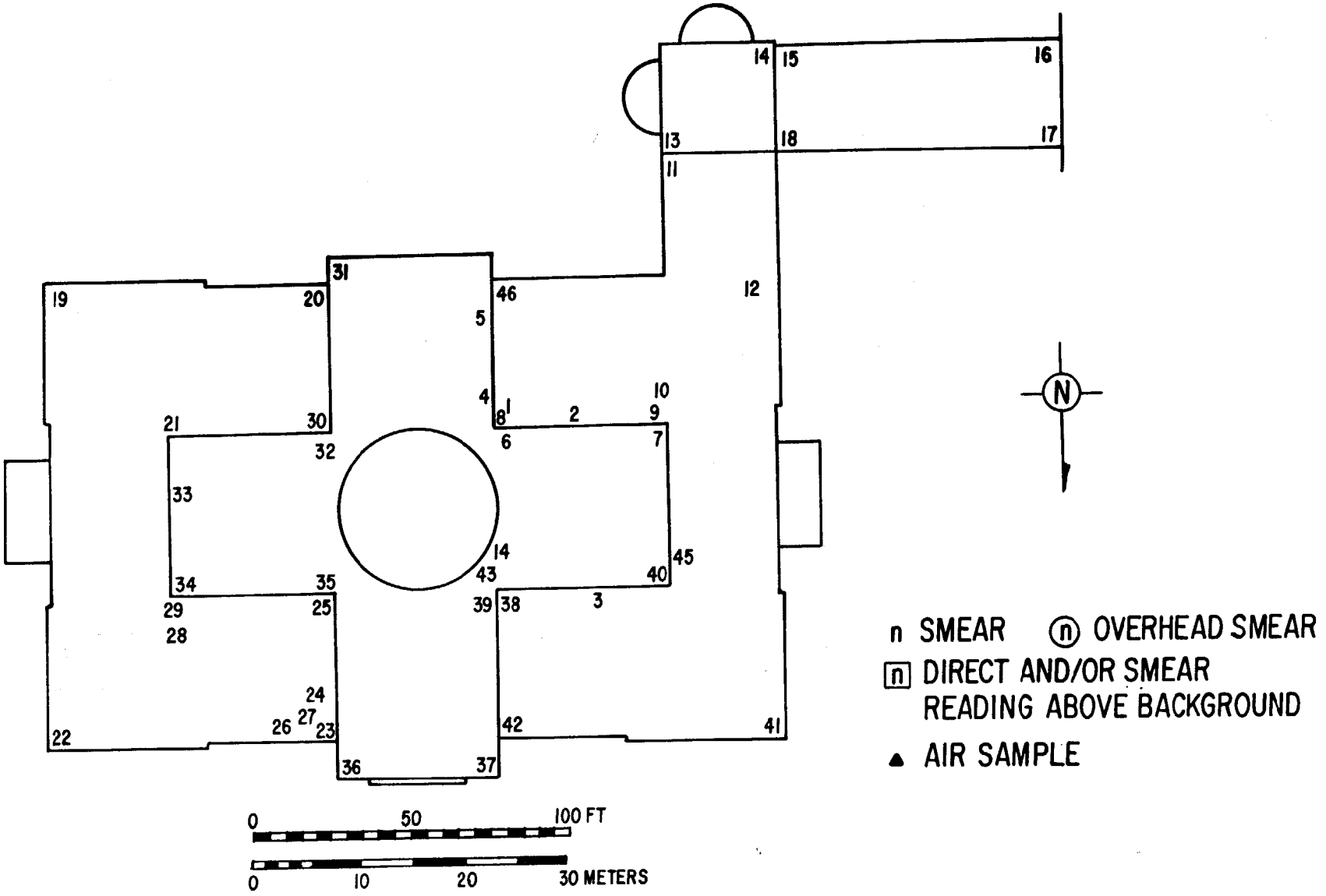

FIGURE 1E

SURVEY LOCATIONS OF CENTRAL PAVILION - SECOND BALCONY

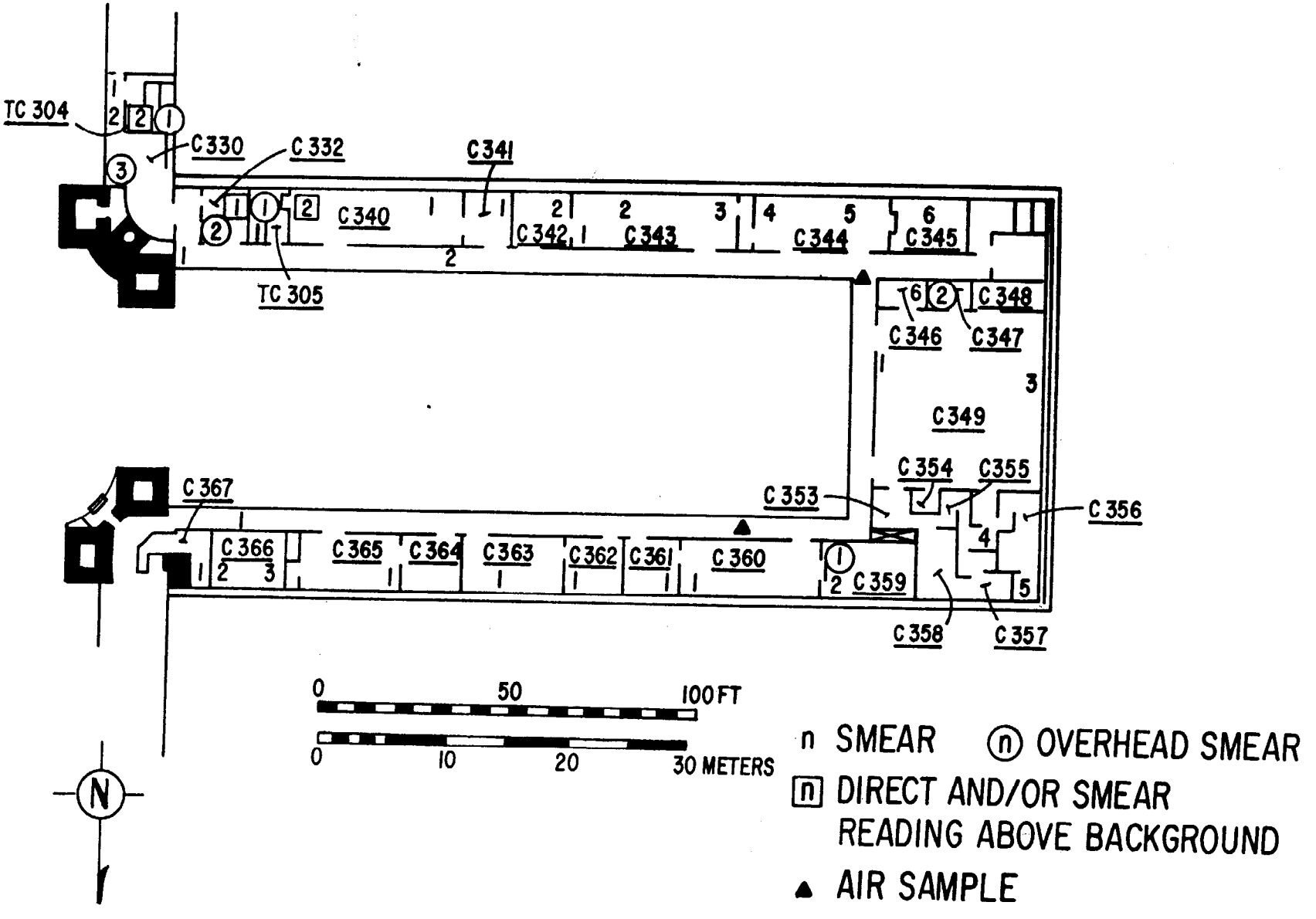

FIGURE 1F

SURVEY LOCATIONS OF SOIL SAMPLES

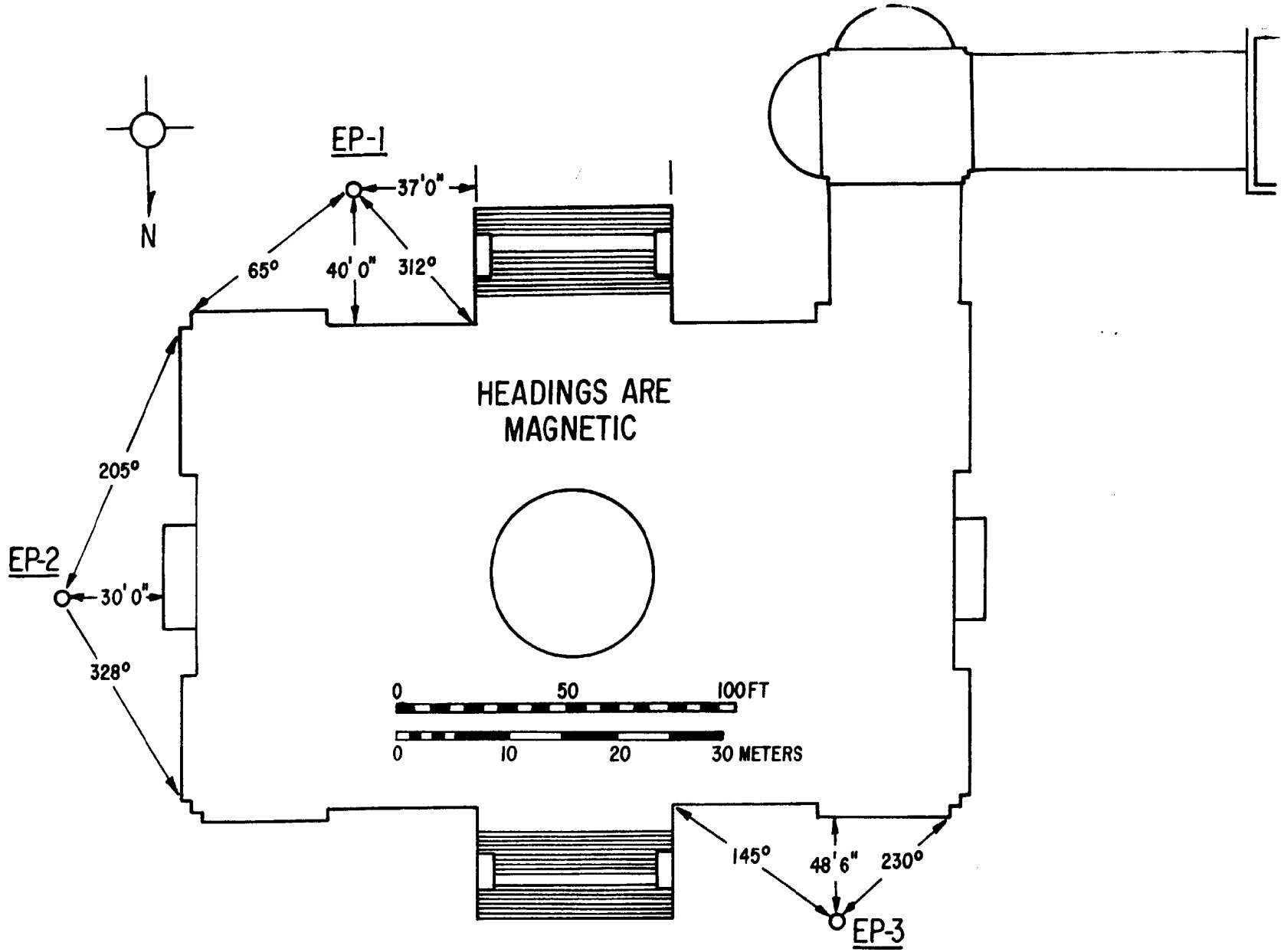

TABLE 2

INSTRUMENTATION USED IN SURVEY

Type	Inventory Number	Probe Area	Window
Eberline Floor Monitor FM-4G utilizing a PAC-4G-3	181501	325cm^2	0.85mg/cm^2
Eberline Floor Monitor FM-4G utilizing a PAC-4G-3	181581	325cm^2	"
PAC-4G-3	165251	61cm^2	"
"	165252	"	"
"	165255	"	"
"	165256	"	"
"	183413	"	"
"	183414	"	"
Eberline HP-90 Beta-Gamma End Window	159006	-	1.4 - 2mg/cm^2
Nuclear Measurement Corporation PC-3A-2π Internal Gas Flow Counter	114969	-	0.85mg/cm^2
Argonne National Laboratory Filter Queen Air Sampler using HV-70 filter media	-	-	-
Argonne National Laboratory 10 Wire Flat Plate Gas Proportional Detector with Eberline Mini Scaler MS-2	184343	-	0.85mg/cm^2

TABLE 3

INSTRUMENT BACKGROUND READINGS

Instrument	Readings * Alpha Mode (cpm)	Beta Mode (cpm)	3 feet above floor mR/hr
Eberline Floor Monitor FM-4G using PAC-4G-3			
#181501	0 - 50	1500 - 2000	
#181581	0 - 50	1500 - 2000	
PAC-4G-3			
#165251	0 - 50	150 - 200	
#165252	"	"	
#165255	"	"	
#165256	"	"	
#183413	"	"	
#183414	"	"	
Eberline HP-90 Beta-Gamma End Window			< 0.03
Nuclear Measurement Corporation PC-3A-2π Internal Gas Flow Counter	0.4	50	
Argonne National Laboratory 10 Wire Flat Plate Gas Proportional Detector with Eberline Mini Scaler MS-2	10	500	

*Background readings were initially taken in the mobile laboratory and rechecked throughout the various areas inside the Museum of Science and Industry while surveying.

FIGURE 2
GAMMA SPECTRUM ANALYSIS OF FLOOR TILE

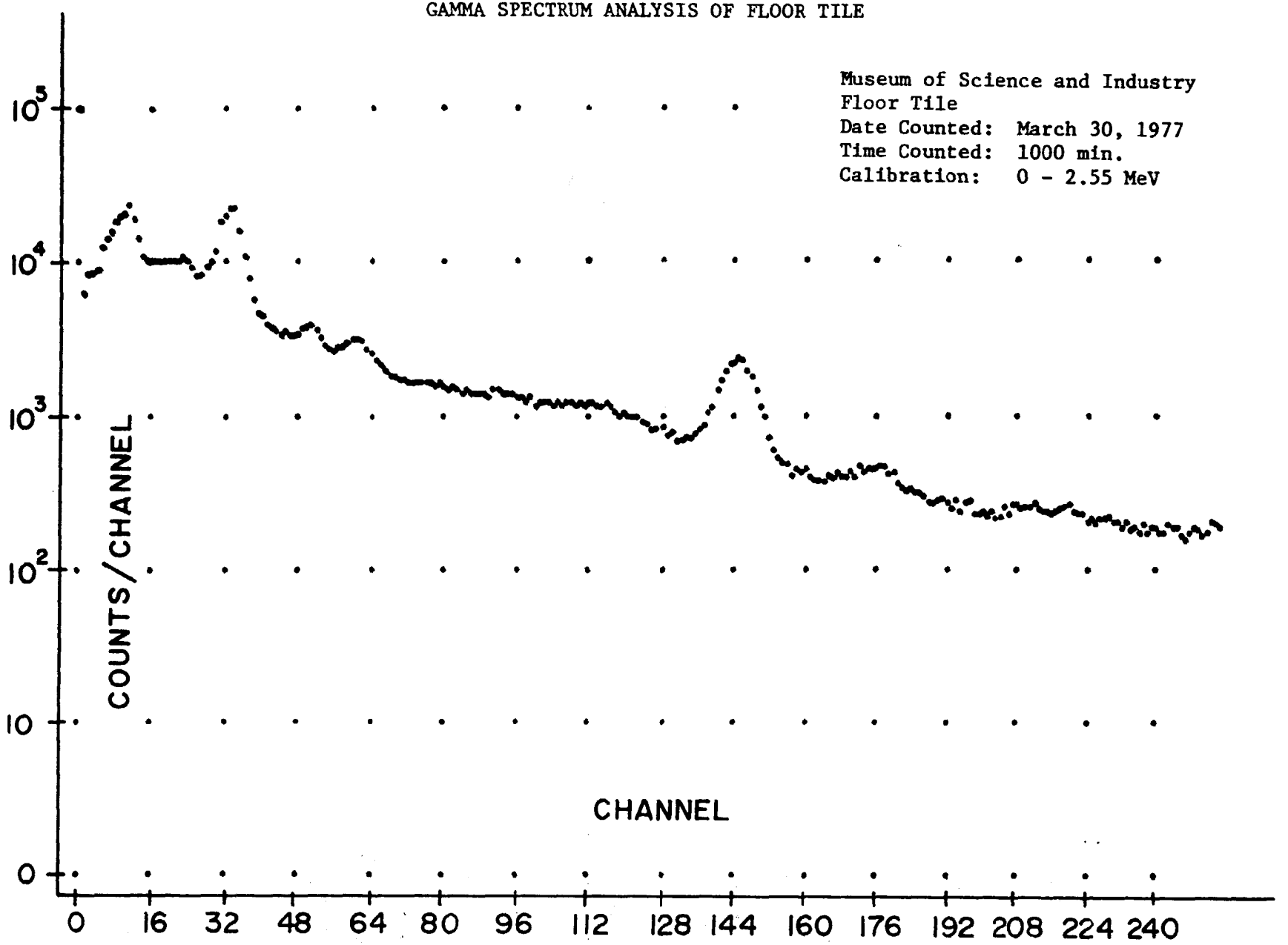

TABLE 4

RADON CONCENTRATION DETERMINATIONS

Location	dpm/M^3	pCi/l	% of MPC*
E-2	2744	1.25	42
E-14	1057	0.48	16
E-15	1057	0.48	16
E-18	3372	1.5	51
E-114	1075	0.49	16
E-117	1567	0.71	24
E-201	2277	1.04	35
E-202	1476	0.67	22
South Hall (2nd Balcony West Court)	683	0.31	10
North Hall (2nd Balcony West Court)	671	0.31	10

*The 10CFR20 MPC for Radon-222 (^{222}Rn) in an uncontrolled area is 3×10^{-9} µCi/cc which equals 3 pCi/l.

Example Calculation Room E-15

$$1057 \text{ dpm/M}^3 \times \frac{1 \text{ pCi}}{2.22 \text{ dpm}} \times \frac{M^3}{10^3 1} = 0.48 \text{ pCi/l}$$

FIGURE 3
SOIL SAMPLING PROCEDURE AND PROCESSING DIAGRAM

ANL-HP-DWG. 78-2

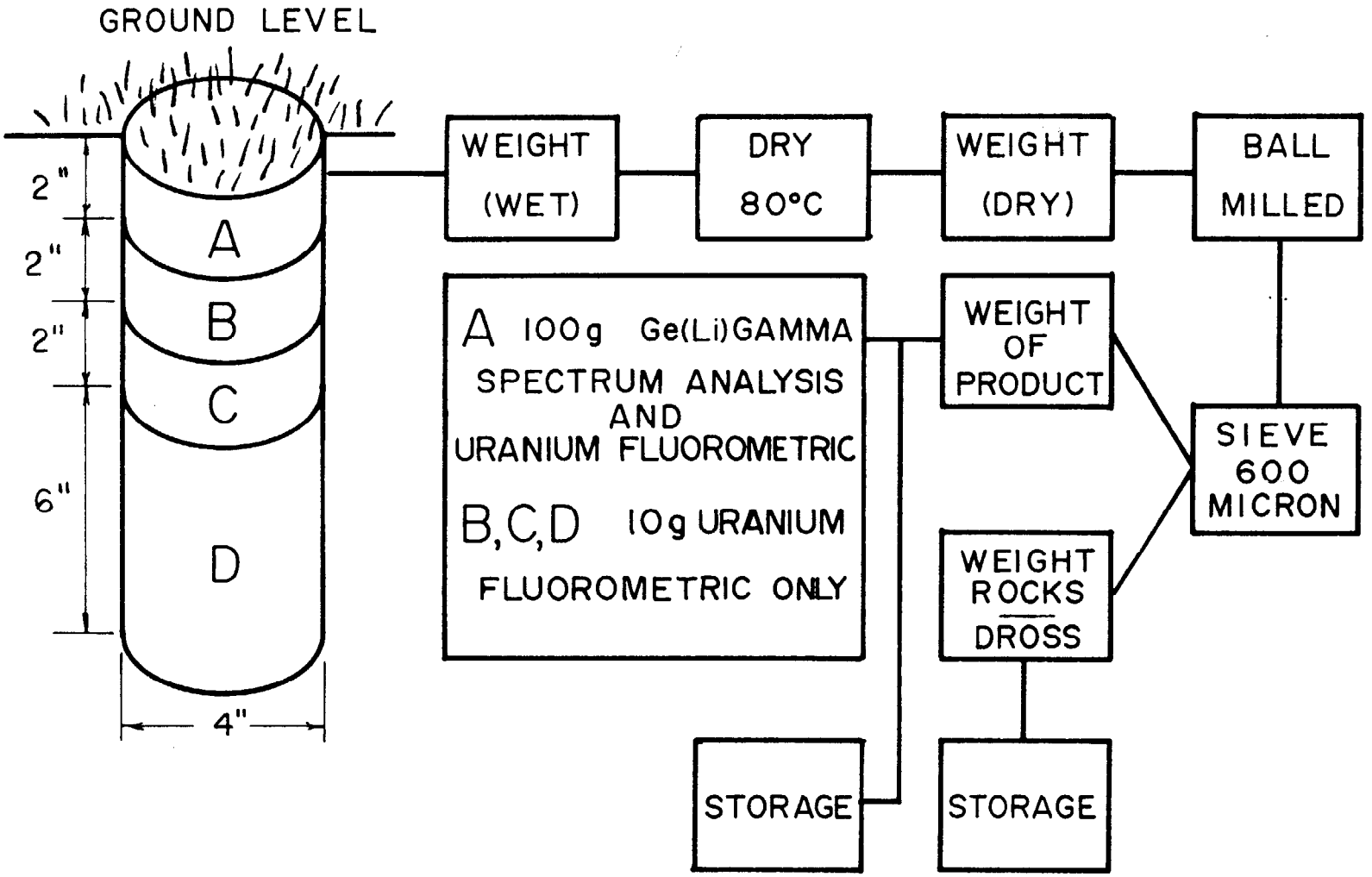

TABLE 5

SOIL SAMPLE WEIGHTS

Sample No.	Net Weight (grams)	Dry Weight (grams)	Sieved Weight (grams)	Rocks and Dross Weight (grams)
EP-1A	887.8	688.9	666.0	145.0
EP-1B	749.0	582.0	551.6	3.5
EP-1C	740.8	579.6	557.2	13.5
EP-1D	1642.2	1281.8	1161.8	94.3
EP-2A	616.1	435.2	376.0	55.3
EP-2B	764.8	593.5	541.1	44.7
EP-2C	1050.0	833.0	766.4	60.0
EP-2D	2375.3	1944.5	1750.0	189.7
EP-3A	677.8	495.9	417.1	72.2
EP-3B	907.2	717.2	649.3	65.3
EP-3C	962.3	785.5	750.4	26.9
EP-3D	2142.2	1800.5	1563.3	222.9

TABLE 6

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

Summary of Methods

A 60 milliliter (ml) volume of the received soil was counted in a petri dish for 500 minutes on a Ge(Li) detector over the energy range 0 - 1.5 MeV. This corresponded to between 60 to 100g of soil, depending upon bulk soil density. Positive photopeaks above instrument background were converted to dpm using a line efficiency curve based upon a National Bureau of Standards Multi Gamma standard. The natural Thorium-232 (^{232}Th) and ^{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.

TABLE 7

Ge(Li) SPECTRUM AND URANIUM FLUOROMETRIC ANALYSES RESULTS

Sample No.	Ge(Li) Spectra pCi/g received wt ± σ(1)			Uranium	
	^{137}Cs	^{232}Th Decay Chain	^{226}Ra Decay Chain	μg/g ± σ(2)	pCi/g ± σ(3)
EP-1A	1.43 ± 0.07	0.8 ± 0.2	0.75 ± 0.08	3.5±0.4	2.4±0.3
EP-1B				2.6±0.4	1.8±0.3
EP-1C				1.3±0.4	0.9±0.3
EP-1D				3.1±0.4	2.2±0.3
EP-2A	0.98 ± 0.05	0.9 ± 0.1	0.83 ± 0.07	2.2±0.4	1.5±0.3
EP-2B				2.2±0.5	1.5±0.3
EP-2C				1.9±0.6	1.3±0.4
EP-2D				1.9±0.4	1.3±0.3
EP-3A	1.05 ± 0.06	0.6 ± 0.2	0.93 ± 0.09	2.6±0.4	1.8±0.3
EP-3B				3.5±0.5	2.4±0.3
EP-3C				4.1±0.5	2.9±0.3
EP-3D				2.4±0.4	1.7±0.3
LFE Blank	0 ± 0.06	0 ± 0.1	0 ± 0.06	0±0.2	0±0.1

(1) One standard deviation due to counting statistics.

(2) Data Results from LFE.

(3) ANL Conversion from Appendix 3.

TABLE 8

BACKGROUND SOIL SAMPLE DATA*

Cesium-137, Thorium, and Uranium in Soil 1976

concentrations in pCi/g

Date Collected	Location	Cesium-137	Thorium-232	Uranium
July 22	Argonne Area	0.3 ± 0.1	0.21 ± 0.04	1.3 ± 0.1
July 22	Argonne Area	0.1 ± 0.1	0.49 ± 0.04	2.0 ± 0.1
July 22	Argonne Area	0.3 ± 0.1	0.48 ± 0.04	1.5 ± 0.1
October 18	Argonne Area	0.1 ± 0.1	0.65 ± 0.07	1.5 ± 0.1
October 18	Argonne Area	0.3 ± 0.1	0.43 ± 0.04	1.4 ± 0.1
October 18	Argonne Area	0.4 ± 0.1	0.39 ± 0.04	1.3 ± 0.1
	Average	0.2 ± 0.1	0.44 ± 0.14	1.5 ± 0.3
	Off-Site			
June 22	McKinley Woods State Park, IL	0.4 ± 0.1	0.16 ± 0.02	0.9 ± 0.1
June 23	McCormick Woods Brookfield, IL	0.3 ± 0.1	0.22 ± 0.02	1.2 ± 0.1
June 23	Bemis Woods Hinsdale, IL	0.4 ± 0.1	0.18 ± 0.01	1.6 ± 0.1
October 12	St. Joseph, MI	0.4 ± 0.1	0.20 ± 0.02	0.3 ± 0.1
October 13	Willow Springs, IL	0.5 ± 0.2	-	1.0 ± 0.1
October 14	Dresden Lock & Dam, IL	0.4 ± 0.1	0.45 ± 0.03	1.6 ± 0.1
	Average	0.4 ± 0.1	0.24 ± 0.14	1.1 ± 0.5

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

APPENDIX I

CONVERSION FACTORS

INSTRUMENTATION

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

I Conversion Factors

	Floor Monitor (FM-4G)	PAC-4G-3
To $100cm^2$	0.31	1.6
cpm to dpm (alpha)	2	2
cpm to dpm (beta)	2	2
cpm to dpm (K^{40})	-	16.5

II Derivation of Conversion Factors

Floor Monitor (FM-4G)

Window Area: ~$325cm^2$

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

PAC-4G-3

Window Area: ~$61cm^2$

Conversion to $100cm^2$ = 1.6 times PAC reading

2π Internal Gas Flow Counter, PC-3A

Geometry: Mylar Spun Top - 0.43

Mylar Spun Top Counting (window double aluminized mylar ~0.85 mg/cm^2) utilizes the well of the PC-3A and is a method developed and used by the Argonne National Laboratory Health Physics Section for negating the dielectric effect in counting samples on non-conducting media.

APPENDIX I (cont'd.)

SMEAR COUNT

The conversion factors for cpm/100cm^2 to dpm/100cm^2 are given below.

I CONVERSION EQUATION (ALPHA)

$$\frac{\text{cpm-Bkgd}}{\text{g x bf x sa x waf}} = \text{dpm Alpha}$$

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

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

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

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

II CONVERSION EQUATION (BETA)

$$\frac{\text{cpm - (Beta Bkgd + Alpha cpm)}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$$

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

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

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

If the energies of the isotopes were known, the appropriate window air factor (waf) was used; if the energies of the isotopes were unknown, the waf of ^{90}Sr-^{90}Y, which is 0.85 was used.

APPENDIX I (cont'd.)

RADON DETERMINATION

This attachment summarizes the air sampling calculations for samples collected using Argonne National Laboratory designed air sampler with HV-70 filter media. The attachment 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.

1. RaA, RaB, RaC, RaC', are in equilibrium.
2. RaA is evident only in the first count and not the 100 minute decay count.
3. That one-half of the Radon progeny is not adhered to airborne particulate, and therefore, not evident on the filter media.
4. The geometry factor (g) is 0.43 for both the alpha and beta activity.
5. The backscatter factor (bf) of 1.0 is used for the alpha activity which is determined from RaC'.
6. The sample absorption factor (sa) for RaC' is 0.77.
7. The window air factor (waf) for RaC' is 0.8.
8. RaB and RaC being beta emitters, are not counted in the alpha mode.
9. The half-life of the Radon progeny is approximately 36 minutes, based on the combined RaB and RaC half-lives.
10. No long-lived alpha emitters present as evidenced by the final recount.
11. For all practical purposes, RaC' decays at the rate of the composite of RaB and RaC which is approximately 36 minutes.

APPENDIX I (cont'd.)

RADON DETERMINATION (cont'd.)

II. Equations Used to Derive Air Concentrations

$$N_o = \frac{N}{e^{-\lambda t}}$$

Where: N_o = Activity present at the end of the sampling period

N = Activity at some time interval, after end of sampling

t = Time interval N_o to N

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

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

$$C = \frac{A\ \lambda}{f}\ \frac{1}{(1-e^{-\lambda t})}$$

Where: C = Concentration per unit volume

A = Activity of filter media at end of sampling period (N_o from previous equation)

f = Sampling rate (M^3/minute)

t = Time sampling was taken

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

$t_{1/2}$ = Half life of isotope or controlling parent

APPENDIX I (cont'd.)

RADON DETERMINATION (cont'd.)

III. Example Calculations - Room E-15

$$N_o = \frac{498 \text{ dpm}}{e^{-\frac{.693 \times 104}{36}}} = 3687 \text{ dpm}$$

$$C = \frac{3687 \times \frac{.693}{36}}{15/60} \frac{}{1-e^{-\frac{.693 \times 40}{36}}} = 529 \text{ dpm/M}^3 \times 2 = 1057 \text{ dpm/M}^3$$

APPENDIX 2A

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY E-2

SAMPLE COLLECTION DATE: 4/15/77

TIME OF COLLECTION: 1242

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1322 MINUS TIME STARTED 1242 TOTAL TIME 40 MINUTES

VOLUME: $\frac{\text{COLLECTION RATE } 15 \text{ } M^3/hr}{60} \times \text{TOTAL TIME } 40 \text{ MINUTES} = \text{VOLUME } 10 \text{ } M^3$

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	d/m/M^3	TYPE OF ACTIVITY	DECAY TIME
4/15	1324	118	2	59	0.03	59	.43	1	.77	.8	2226	223	α	2 min.
4/15	1502	74	2	37	0.03	37	.43	1	.77	.8	1396	140	α	100 min.
4/21	1300	0	2	0	0.5	BKGD.	.43	1	.77	.8	BKGD.	BKGD.	α	6 days
4/15	1326	2114	2	1057	$\overset{47.3}{+\ 59}$	590.7	.43	1.1	1	.95	21,174	2117	β	4 min.
4/15	1504	634	2	317	$\overset{47.3}{+\ 37}$	232.7	.43	1.1	1	.95	5182.6	518	β	102 min.
4/21	1300	80	2	40	53.3	BKGD.	.43	1.1	1	.95	BKGD.	BKGD.	β	6 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}} = \text{dpm Alpha}$

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

REMARKS: *10% of sample counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 2B

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY E-14

SAMPLE COLLECTION DATE: 2/1/77

TIME OF COLLECTION: 1046

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1126 MINUS TIME STARTED 1046 TOTAL TIME 40 MINUTES

VOLUME: COLLECTION RATE 15 M^3/hr X TOTAL TIME 40 MINUTES - VOLUME 40 ft^3
60

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	$d/m/M^3$	TYPE OF ACTIVITY	DECAY TIME
2/1	1135	176	2	88	0.3	87.7	.43	1	.77	.8	3311	331	α	9 min
2/1	1315	27	2	13.5	0.3	13.2	.43	1	.77	.8	498	50	α	109 min
4/21	1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	79 days
2/1	1133	909	2	455	91.6 + 88.	275.4	.43	1.1	1	.95	6133	613	β	7 min
2/1	1313	384	2	192	91.6 + 13.5	85.9	.43	1.1	1	.95	1935	4	β	107 min
4/21	1300	68	2	34	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	79 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}}$ = dpm Alpha

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}}$ = dpm Beta

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}}$ = dpm Beta

REMARKS: *10% of sample counted using PC-3A & mylar spun top (0.85 mg/cm^2)

APPENDIX 2C

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY E-15

SAMPLE COLLECTION DATE: 2/1/77

TIME OF COLLECTION: 1149

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1229 MINUS TIME STARTED 1149 TOTAL TIME 40 MINUTES

VOLUME: $\frac{\text{COLLECTION RATE } 15 \text{ M}^3/\text{hr}}{60} \times \text{TOTAL TIME } 40 \text{ MINUTES} = \text{VOLUME } 10 \text{ M}^3$

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	d/m/M^3	TYPE OF ACTIVITY	DECAY TIME
2/1	1233	179	2	89.5	0.3	89.2	.43	1	.77	.8	3366	337	α	4 min
2/1	1413	27	2	13.5	0.3	13.2	.43	1	.77	.8	498	50	α	104 min
4/21	1300	1	2	0.5	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	79 days
2/1	1235	929	2	462	91.6 + 89.5	280.9	.43	1.1	1	.95	6256	626	β	6 min
2/1	1415	291	2	145.5	91.6 + 13.5	40.4	.43	1.1	1	.95	899	90	β	106 min
4/21		87	2	43.5	54.0	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	79 days

ALPHA: $\frac{\text{cpm} - \text{Bkdg}}{\text{g} \times \text{bf} \times \text{sa} \times \text{waf}} = \text{dpm Alpha}$

BETA: Pure Beta emitters $\frac{\text{cpm} - \text{Bkgd}}{\text{g} \times \text{bf} \times \text{sa} \times \text{waf}} = \text{dpm Beta}$

COMPOSITE: Beta determination $\frac{\text{cpm} - \text{Beta Bkgd} + \text{Alpha cpm}}{\text{g} \times \text{bf} \times \text{sa} \times \text{waf}} = \text{dpm Beta}$

REMARKS: *10% of sample counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 2D

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY E-18

SAMPLE COLLECTION DATE: 2/16/77

TIME OF COLLECTION: 1100

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1140 MINUS TIME STARTED 1100 TOTAL TIME 40 MINUTES

VOLUME: $\frac{\text{COLLECTION RATE } 15 \text{ } M^3/hr}{60} \times \text{TOTAL TIME } 40 \text{ MINUTES} = \text{VOLUME } 10 \text{ } M^3$

DATE AND TIME OF COUNT	GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	$d/m/M^3$	TYPE OF ACTIVITY	DECAY TIME
2/16 1150	292	2	146	0.5	145.5	.43	1	.77	.8	5490	549	α	10 min
2/16 1330	76	2	38	0.5	37.5	.43	1	.77	.8	1415	145	α	110 min
4/21 1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	64 days
2/16 1152	1599	2	799	87 + 146	566	.43	1.1	1	.95	12605	1261	β	12 min
2/16 1332	466	2	233	87 + 38	108	.43	1.1	1	.95	2405	241	β	112 min
4/21 1300	99	2	43.5	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	64days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}} = \text{dpm Alpha}$

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

REMARKS: *10% of sample counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 2E

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY 114

SAMPLE COLLECTION DATE: 3/2/77

TIME OF COLLECTION: 1030

SUSPECTED ISOTOPE:

LENGTH OF RUN: TIME STOPPED 1110 MINUS TIME STARTED 1030 TOTAL TIME 40 MINUTES

VOLUME: COLLECTION RATE $\frac{15}{60}$ M^3/hr X TOTAL TIME 40 MINUTES = VOLUME 10 M^3

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	d/m/M^3	TYPE OF ACTIVITY	DECAY TIME
3/2	1119	1555	2	77.5	0.3	77.2	.43	1	.77	.8	2913	291	α	9 min
3/2	1259	25	2	12.5	0.3	12.2	.43	1	.77	.8	460	46	α	109 min
4/21	1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	50 days
3/2	1117	853	2	426.5	$\frac{83}{+ 77.5}$	266	.43	1.1	1	.95	5924	592	β	7 min
3/2	1257	284	2	142	$\frac{83}{+ 12.5}$	46.5	.43	1.1	1	.95	1035	4	β	107 min
4/21	1300	64	2	32	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	50 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}}$ = dpm Alpha

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}}$ = dpm Beta

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}}$ = dpm Beta

REMARKS: *10% of sample counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 2F

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY E-117 South

SAMPLE COLLECTION DATE: 3/1/77

TIME OF COLLECTION: 1026

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1106 MINUS TIME STARTED 1026 TOTAL TIME 40 MINUTES

VOLUME: COLLECTION RATE $\frac{15}{60}$ M^3/hr X TOTAL TIME 40 MINUTES = VOLUME 10 M^3

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	$d/m/M^3$	TYPE OF ACTIVITY	DECAY TIME
3/1	1111	149	2	74.5	0.5	74.0	.43	1	.77	.8	2792	279	α	5 min
3/1	1251	59	2	19.7	0.5	19.2	.43	1	.77	.8	724	72	α	105 min
4/21	1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	51 days
3/1	1113	835	2	417.5	$\frac{79}{+74.5}$	264	.43	1.1	1	.95	5879	588	β	7 min
3/1	1253	426	2	142	$\frac{79}{+19.7}$	43.3	.43	1.1	1	.95	964	96	β	107 min
4/21	1300	42	2	21	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	51 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}}$ = dpm Alpha

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}}$ = dpm Beta

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}}$ = dpm Beta

REMARKS: *10% of smaple counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 2G

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY E-201

SAMPLE COLLECTION DATE: 3/15/77

TIME OF COLLECTION: 1100

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1142 MINUS TIME STARTED 1100 TOTAL TIME 42 MINUTES

VOLUME: $\frac{\text{COLLECTION RATE } 15 \text{ } M^3/hr}{60} \times \text{TOTAL TIME } 42 \text{ MINUTES} = \text{VOLUME } 10.5 \text{ } M^3$

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	d/m/M^3	TYPE OF ACTIVITY	DECAY TIME
3/15	1149	312	2	156	0.2	155.8	.43	1	.77	.8	5879	560	α	7 min
3/15	1338	47	2	23.5	0.2	23.3	.43	1	.77	.8	879	84	α	116 min
4/21	1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	36 days
3/15	1151	1526	2	762	57.8 + 156	549.2	.43	1.1	1	.95	12231	1165	β	9 min
3/15	1340	337	2	168.5	57.8 + 23.5	87.2	.43	1.1	1	.95	1942	185	β	118 min
4/21	1300	42	2	21	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	36 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}} = \text{dpm Alpha}$

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

REMARKS: *10% of sample counter using PC-3A and mylar spunt top (0.85 mg/cm^2)

APPENDIX 2H

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY E-202

SAMPLE COLLECTION DATE: 3/15/77

TIME OF COLLECTION: 10/10

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1050 MINUS TIME STARTED 1010 TOTAL TIME 40 MINUTES

VOLUME: $\frac{\text{COLLECTION RATE } 15 \text{ } M^3/hr}{60} \times \text{TOTAL TIME } 40 \text{ MINUTES} = \text{VOLUME } 10 \text{ } M^3$

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	$d/m/M^3$	TYPE OF ACTIVITY	DECAY TIME
3/15	1100	157	2	78.5	0.2	78.3	.43	1	.77	.8	2954	295	α	10 min
3/15	1242	32	2	16	0.2	15.8	.43	1	.77	.8	596	60	α	112min
4/21	1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	36 days
3/15	1058	987	2	493.5	57.8 + 78.5	357.2	.43	1.1	1	.95	7955	796	β	8 min
3/15	1240	267	2	133,5	57.8 + 16	59.7	.43	1.1	1	.95	1329	133	β	110 min
4/21	1300	63	2	31.5	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	36 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}} = \text{dpm Alpha}$

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

REMARKS: *10% of sample counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 2I

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE AND INDUSTRY - South Hall (2nd Balcony West)

SAMPLE COLLECTION DATE: 4/15/77

TIME OF COLLECTION: 1052

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1133 MINUS TIME STARTED 1052 TOTAL TIME 41 MINUTES

VOLUME: $\frac{\text{COLLECTION RATE } 15 \text{ } M^3/hr}{60} \times \text{TOTAL TIME } 41 \text{ MINUTES} = \text{VOLUME } 10.25 \text{ } M^3$

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	$d/m/M^3$	TYPE OF ACTIVITY	DECAY TIME
4/15	1140	80	2	40	0.03	40	.43	1	.77	.8	1509	147	α	7 min
4/15	1315	18	2	9	0.03	9	.43	1	.77	.8	339.6	33	α	102 min
4/21	1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	6 days
4/15	1138	2263	2	1131.5	$+\frac{47.3}{40}$	1044.2	.43	1.1	1	.95	23256	2268	β	5 min
4/15	1313	613	2	306.5	$+\frac{47.3}{9}$	250.2	.43	1.1	1	.95	557.2	54	β	100 min
4/21	1300	78	2	39	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	6 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}} = \text{dpm Alpha}$

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

REMARKS: *10% of sample counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 2J

AIR SAMPLE DATA

LOCATION: MUSEUM OF SCIENCE INDUSTRY - (North Hall - 2nd Balcony W.)

SAMPLE COLLECTION DATE: 4/15/77

TIME OF COLLECTION: 1023

SUSPECTED ISOTOPE: Unidentified

LENGTH OF RUN: TIME STOPPED 1106 MINUS TIME STARTED 1023 TOTAL TIME 43 MINUTES

VOLUME: $\frac{\text{COLLECTION RATE } 15 \text{ } M^3/hr}{60} \times \text{TOTAL TIME } 43 \text{ MINUTES} = \text{VOLUME } 10.75 \text{ } M^3$

DATE AND TIME OF COUNT		GROSS COUNTS: TOTAL COUNTS	GROSS COUNTS: COUNT TIME Min.	GROSS COUNTS: COUNTS / MIN.	BKGD: COUNTS / MIN.	NET: COUNTS / MIN.	GEOMETRY	BACKSCATTER FACTOR	SAMPLE ABSORPTION	WINDOW AIR FACTOR	DISINTEGRATIONS PER MINUTE *	d/m/M^3	TYPE OF ACTIVITY	DECAY TIME
4/15	1127	43	2	21.5	0.03	21.5	.43	1	.77	.8	811	75	α	4 min
4/15	1246	19	2	9.5	0.03	9.5	.43	1	.77	.8	358	33	α	100 min
4/21	1300	0	2	0	0.5	BKGD	.43	1	.77	.8	BKGD	BKGD	α	6 days
4/15	1129	434	2	717	47.3 + 21.5	648.2	.43	1.1	1	.95	1342	1342	β	6 days
4/15	1248	352	2	176	9.5 + 47.3	119.2	.43	1.1	1	.95	247	247	β	102 min
4/21	1300	95	2	47.5	53.5	BKGD	.43	1.1	1	.95	BKGD	BKGD	β	6 days

ALPHA: $\frac{\text{cpm - Bkdg}}{\text{g x bf x sa x waf}} = \text{dpm Alpha}$

BETA: Pure Beta emitters $\frac{\text{cpm - Bkgd}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

COMPOSITE: Beta determination $\frac{\text{cpm - Beta Bkgd + Alpha cpm}}{\text{g x bf x sa x waf}} = \text{dpm Beta}$

REMARKS: *10% of sample counted using PC-3A and mylar spun top (0.85 mg/cm^2)

APPENDIX 3

NORMAL URANIUM CALCULATIONS

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 following values used are:

^{234}U half-life	2.47×10^5 years
^{235}U half-life	7.1×10^8 years
^{238}U half-life	4.51×10^9 years
^{234}U percent abundance	0.0057
^{235}U percent abundance	0.7196
^{238}U percent abundance	99.2760

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

Avagadro's Number Used - 6.025×10^{23}

$SA = \lambda N$

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

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

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

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

APPENDIX 3 (cont'd.)

NORMAL URANIUM CALCULATIONS

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

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

therefore, 1 μgram of normal uranium contains

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

$$= \frac{1.552\ \text{dpm/}\mu\text{gram}}{2.22\ \text{dpm/pCi}} = .6991\ \text{pCi/}\mu\text{gram normal uranium}$$

Conversion of μg/gm to pCi/g

Example Calculation - EP-1A

$$3.5 \pm 0.4\ \frac{\mu\text{gram}}{\text{gram}} \times \frac{0.6991\ \text{pCi}}{\mu\text{gram}} = 2.4 \pm 0.3\ \text{pCi/gram}$$

* U. S. GOVERNMENT PRINTING OFFICE : 1979 281-704/1020