S1135

PA.7-8

DOE/EV-0005/33

ANL-OHS/HP-82-104

ARGONNE NATIONAL LABORATORY

FORMERLY UTILIZED MED/AEC SITES REMEDIAL ACTION PROGRAM

RADIOLOGICAL SURVEY OF UNIVERSAL CYCLOPS, INC. TITUSVILLE PLANT (Formerly Vulcan Crucible Steel Company) ALIQUIPPA, PENNSYLVANIA

May 2-8, 1978

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

Prepared for the U. S. DEPARTMENT OF ENERGY
under Contract W-31-109-Eng-38

The facilities of Argonne National Laboratory are owned by the United States Government. Under terms of a contract (W-31-109-Eng-38) among the U. S. Department of Energy, Argonne Universit Association and The University of Chicago, the University employs the staff and operates the Laboratory accordance with policies and programs formulated, approved and reviewed by the Association.

MEMBERS OF ARGONNE UNIVERSITIES ASSOCIATION

The University of Arizona
Carnegie-Mellon University
Case Western Reserve University
The University of Chicago
University of Cincinnati
Illinois Institute of Technology
University of Illinois
Indiana University
The University of Iowa
Iowa State University
The University of Kansas
Kansas State University
Loyola University of Chicago
Marquette University
The University of Michigan
Michigan State University
University of Minnesota
University of Missouri
Northwestern University
University of Notre Dame
The Ohio State University
Ohio University
The Pennsylvania State University
Purdue University
Saint Louis University
Southern Illinois University
The University of Texas at Austin
Washington University
Wayne State University
The University of Wisconsin-Madi

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A04
Microfiche copy: A01

Distribution Category:
Remedial Action Program
(UC-70A)

DOE/EV-0005/33

ANL-OHS/HP-82-104

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

FORMERLY UTILIZED MED/AEC SITES REMEDIAL ACTION PROGRAM

RADIOLOGICAL SURVEY OF UNIVERSAL CYCLOPS, INC. TITUSVILLE PLANT (Formerly Vulcan Crucible Steel Company) ALIQUIPPA, PENNSYLVANIA

May 2-8, 1978

Prepared by

R. A. Wynveen	Health Physics Manager
W. H. Smith	Senior Health Physicist
R. L. Mundis	Senior Health Physicist
C. Boggs Mayes*	Health Physicist

Radiological Survey Group
Health Physics Section
Occupational Health and Safety Division

May 1982

Work Performed under

Budget Activity DOE KN-03-60-40
and ANL 73706

*Now at Exxon Nuclear Idaho, Inc.

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 utilized 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 if the decontamination work done at the time nuclear activities ceased is adequate by current guidelines. The Universal Cyclops Titusville Plant (formerly Vulcan Crucible Steel Co.), Aliquippa, Pennsylvania is such a site. During the period that Vulcan Crucible Tool and Steel Co. was under AEC contract (July 1948 to late 1949), Building 3 on the site was used to roll uranium billets. The building, measuring 110 m by 43 m (360 ft by 140 ft),* contained two furnaces for heating billets, a rolling mill, plus cutting and extruding equipment. The items were used to roll uranium billets into rods. At the time of this survey, the two furnaces, rollers from the rolling mill, and cutting equipment were still present at the site. Although owned by Universal Cyclops, when the survey was made, most of the building was being used as a material-storage area by the Precision-Kidd Co., with a small part rented to the Heritage Box Company.

Radioactive contamination was found on the dirt floor, concrete floor, steel floor plates, and on the overhead beams above the furnaces that had been used in the uranium processing. In addition, some contaminated steel floor plates were found outside the buildings around a cooling pond. The highest contamination levels detected with a portable gas-flow proportional counter (Eberline PAC-4G-3), were found at one small localized area (100 cm^2) on a dirt floor. The activity levels at this location were 2.2×10^5 dis/min-100 cm^2 beta-gamma and 1.1×10^4 dis/min-100 cm^2 alpha as equated to normal uranium.

---

*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.

The highest reading on a GM end-window survey meter (2.0 mR/h) also was o at this location. Gamma-spectral analysis of a sample of this dirt in the contaminant to be normal uranium; therefore, in this report, all P readings and smear results are equated to normal uranium. "Loose" contam was found at nine locations within the building, with the highest leve overhead beam (80 dis/min-100 cm^2 alpha and 284 dis/min-100 cm^2 beta-

All the survey data were compared with limits and guidelines i Standard N13.12, "Control Of Radioactive Surface Contamination On Mat Equipment, And Facilities To Be Released For Uncontrolled Use," and th "Guidelines For Decontamination Of Facilities And Equipment Prior To Rele Unrestricted Use Or Termination Of Licenses For By-Product, Source, Or Nuclear Material." The surface contamination limit for natural uranium a in the ANSI Standard N13.12 is 5000 dis/min-100 cm^2 total, of whic 1000 dis/min-100 cm^2 can be removable. Fourteen spots of contamination (in size from about 500 to 2000 cm^2) exceeded ANSI Standard levels fo activity. Two of the spots also exceeded the NRC Guideline for maximum ra level (1.0 mrad/h at 1 cm) associated with surface contamination with bet emitters. One spot on the dirt floor was 2.0 mR/h; a spot on a steel pl 1.3 mR/h.

Concentrations of radon daughters in air samples collected at s locations in the building ranged from 0.0011 to 0.0027 Working Level Under the Surgeon General's Guidelines, need for remedial action indicated when concentrations of radon daughters are less than 0.01 W background. Radon concentrations ranging from 0.11 to 0.27 pCi/ℓ, we culated from the radon daughter determinations. These are well be concentration guide in DOE 5480.1, Chapter XI.

Analyses of the five soil samples collected on the grounds of U Cyclops showed uranium concentrations from 0.3 ± 0.2 to 109.9 ± 5.5 pCi four segments of a soil sample collected close to the west side of the contained elevated levels of uranium (15.1 ± 0.7 to 109.9 ± 5.5 pCi/g) of the segments contained uranium concentrations in excess of the interim limit proposed in LA-UR-79-1865 Rev. Background samples ta comparative purposes contained uranium concentrations ranging from 1.3 8.1 ± 0.3 pCi/g.

To evaluate the radiation exposure potential, a hypothetical scenario was developed involving the aerosolization of the radioactive material on the surface that exhibited the maximum level of contamination based on results of the survey. It was calculated that the airborne uranium concentration would be 3300 times greater than the Maximum Permissible Concentration in Air for uranium in an uncontrolled area. However, a person breathing this aerosol for 15 minutes would receive only 1.1% of the Maximum Permissible Burden based on the kidneys as the critical organ.

After evaluation of results of the survey, it was concluded that although some areas of the Universal Cyclops facility are contaminated, these areas do not pose a significant risk to the present occupants of the building. Nonetheless, in a few cases the contamination does exceed accepted guidelines. Remedial measures are indicated to bring the contaminated areas within the guidelines. This would include the removal of radioactive residues from 12 locations within the building. In addition, in-place stabilization and restriction of future use to avoid those activities that would require building modifications (thereby resulting in disturbance of remaining radioactive materials) might be indicated.

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

CONTENTS

LIST OF FIGURES

LIST OF TABLES

RADIOLOGICAL SURVEY OF UNIVERSAL CYCLOPS, INC.
TITUSVILLE PLANT
(Formerly Vulcan Crucible Steel Company)
ALIQUIPPA, PENNSYLVANIA

ABSTRACT

A radiological survey was conducted at the Universal Cyclops, Inc. Titusville Plant (formerly Vulcan Crucible Steel Company), in Aliquippa, Pennsylvania, to determine the location and quantities of any radioactive materials remaining on the site as a result of MED/AEC activities in the late 1940s. This facility was used for rolling uranium billets during the MED/AEC era. It now is owned by Universal Cyclops, Inc., but at the time of the survey, was leased for operations by the Heritage Box Company and for storage by the Precision-Kidd Company.

The survey included measurements of alpha and beta-gamma contamination, both fixed and removable; beta-gamma exposure readings at contact and at 1 m (3 ft) above the floor or ground level; and measurements of the concentrations of radon daughters in air and concentrations of ^{137}Cs, the ^{232}Th decay chain, the ^{226}Ra decay chain, and uranium in the soil on the site.

Fourteen spots of contamination exceeded the allowable limits for natural uranium as given in ANSI Standard N13.12 (Ref. 1). Except in a few instances, the contamination was "fixed to," or under existing surfaces, and was not available for transfer to other locations. Under current use conditions, the potential for radiation exposure of occupants of the building from these sources of contamination is remote.

Concentrations of radon daughters were below the 0.01 WL limit as given in the Surgeon General's Guidelines and incorporated into 10 CFR 712 (Ref. 2). Calculated radon concentrations based on the radon-daughter determinations ranged from 0.11 to 0.27 pCi/ℓ. The concentration guide for ^{222}Rn in uncontrolled areas as stated in the DOE document "Requirements for Radiation Protection," Chapter XI (Ref. 3) is 3×10^{-9} μCi/mℓ, or 3 pCi/ℓ.

Analysis of soil samples from the site indicated elevated concentrations of uranium (15.1±0.7 to 109.9±5.5 pCi/g) at one sampling location near the building. There currently are no regulatory limits for uranium concentration in soil, but, a proposed guide value of 40 pCi/g is contained in the report "Interim Soil Limits for D&D Projects" (Ref. 4).

To evaluate the radiation exposure potential, a hypothetical scenar developed involving the aerosolization of the radioactive material surface that exhibited the maximum level of contamination based on resu the survey. It was calculated that the airborne uranium concentration wo 3300 times greater than the Maximum Permissible Concentration in Air for u in an uncontrolled area. However, a person breathing this aerosol for 1 utes would receive only 1.1% of the Maximum Permissible Burden based kidneys as the critical organ.

After evaluation of results of the survey, it was concluded that al some areas of the Universal Cyclops facility are contaminated, these ar not pose a significant risk to the present occupants of the building. No less, in a few cases the contamination does exceed accepted guide Remedial measures are indicated to bring the contaminated areas with guidelines. This would include the removal of radioactive residues f locations within the building. In addition, in-place stabilizatio restricting of future use to avoid those activities that would require bu modifications (thereby resulting in disturbance of remaining radio materials) might be indicated.

INTRODUCTION

A radiological survey was performed during the period May 2 to May 8 at the Universal Cyclops Titusville Plant (formerly Vulcan Crucible Company) at the request of the Energy Research and Development Administr Chicago Operations Office (now DOE/CORO). The plant is located between Pe vania Highway 51 on the east and the Ohio River on the west. It is south Jones and Laughlin Complex and is located north of the Pittsburgh and Lak Railroad between Russell and First Streets in Aliquippa. (See Fig. 1 for view of the facility.)

In the late 1940s, the Manhattan Engineer District/Atomic Energy Comm (MED/AEC) used Building 3 of the Vulcan Crucible Steel Company facility uranium-rolling operation. Uranium billets produced at Electromet and Ma krodt were sent to the site to be rolled into rods. The billets were 71 cm (15 to 28 in) long, 10 to 13 cm (4 to 5 in) in diameter, and weighe 55 to 120 kg (120 to 270 lb). At the Vulcan Crucible Steel facility the rolled into rods about 4 cm (1.5 in) in diameter, resulting in about a ni

increase in length. The finished rods were boxed and shipped out for use elsewhere. A review of correspondence between the AEC and Vulcan Crucible Steel Co. indicated that a major decontamination effort was completed at the site in 1950.

The present owner of the site is Universal Cyclops, Inc., and portions of the building were leased for operations by Heritage Box Company and for storage by the Precision-Kidd Company at the time of this radiological survey.

SURVEY AND ANALYTICAL TECHNIQUES

General

Portable instruments were used to conduct a radiological survey of the building's accessible floor areas and original interior wall surfaces to a height of 2 m (7 ft). Some of the floor areas consisted of poured concrete pads, some consisted of hard packed dirt, and the rest had steel plates over dirt. A representative selection of overhead beams was also surveyed. Locations of accessible areas surveyed are listed in Table 1 and shown in Figures 1 through 3.

Instrumentation

Three types of survey instruments were used. Floors were surveyed with gas-flow proportional counters with a detection area of 325 cm^2 (Eberline Model FM-4G) using the Eberline PAC-4G-3 electronics package. Walls and other accessible surfaces were surveyed with a hand-held gas-flow proportional counter with a detection area of 51 cm^2 (Eberline Model PAC-21) also using the PAC-4G-3 electronics. Gamma radiation intensities were measured with an end-window Geiger-Mueller (GM) detector utilizing an Eberline Model 530 count-rate meter. Contact readings were made on all contaminated surfaces. In addition, readings were taken at 1 m (3 ft) above the floor to determine general ambient radiation levels throughout the area. The instruments and their calibrations are described in detail in Appendices 1 and 2.

When possible, gamma-spectral analysis was performed on either a contaminated item or on a sample of material taken from a contaminated area in order to identify the contaminating radionuclide. A multichannel analyzer (described in Appendix 1) was used.

Smear Surveys

Dry smears were taken on surfaces at representative locations throug the building using 4.75-cm-diameter filter paper (Whatman #1). Smear sur were taken on original structural components such as walls, floors, pipes, vents. A standard smear is performed by applying moderate pressure with tips of the first two fingers to the back of the filter paper and wiping surface. Smears of about 930 cm^2 (1 ft^2) were normally taken. However, sm of 100 cm^2 were taken if an area or object was found to have a higher normal radiation level during the portable instrument survey or if the sur was extremely dusty.

Two different instruments were used to count the activity on the smears large-area, thin-window, gas-flow proportional counter sensitive to alpha, b and gamma radiations was used to make an initial count on groups of smears. more sensitive counts on individual smears, a Nuclear Measurement Corporat Model PC-5, 2π Internal Gas-Flow Proportional Counter with a thin alumi Mylar window (referred to as a Mylar spun top) was used.

Initial counts were made with the large-area counter on groups of smears at a time. When a reading above the instrument background was obt for any set, the smears in that set were then counted individually in the counter. In addition, at least one smear from each group of ten was select random and counted in the PC-5 counter. All smears from areas or objects elevated direct readings also were counted individually in the PC-5 counte more complete description of the counters used and of the counting and cal tion techniques is provided in Appendicies 1 and 2.

Air Samples

Air particulate samples were collected at four locations in the bui (see Fig. 4) with a commercial vacuum cleaner modified at ANL to collect sa by pulling air through a filter paper (HV-70) sampling medium. A total v of 26.7 m^3 of air was sampled at a flow rate of 40 m^3/h. A 10% portion (5 diameter) of the filter media was removed after collection and counted for alpha and beta-gamma activity in the PC-5 counter. Radon concentrations ar presence of any long-lived particulate radionuclides were determined o basis of several counts taken of each sample at specified intervals. Det

information and assumptions used to determine the radon and radon-daughter concentrations are summarized in Appendix 3. Results are presented in Table 2.

Soil Samples

Single soil samples were collected at each of five locations (see Fig. 6) in undisturbed areas about the immediate periphery of the building to determine if radionuclides were present as a result of spillage or other modes of release. Another location [a residence at 869 Chapel Road, about 4.75 km northwest of the Universal Cyclops site (see Fig. 7)] was selected for determination of normal background concentration of radionuclides in soil of the area. At this background location, duplicate samples (6-SB-6 and 6-SB-7) were taken about 13 m apart.

All samples were obtained with a 10-cm (4-in) diameter, 15-cm (6-in) long, right-circular-cylinder cutting tool normally used to cut golf-green holes. Each soil core was 30 cm deep, and each was segmented into four samples. Starting from the surface, three separate 5-cm segments were cut, bagged, and marked A, B, and C; the final segment of 15 cm was marked D (see Fig. 8).

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 had been added over the years.

The soil samples were prepared at ANL and shipped to a commercial laboratory (LFE Environmental Analysis Laboratories) for radiochemical (uranium fluorometric) and gamma-spectral analyses. The procedures are described in Appendix 4. Sample preparation (see Fig. 8) consisted of weighing the samples in their "as collected" state, drying them for about 24 hours at 80°C, and then reweighing to determine dry weight. Each sample was then put into a mill jar (8.7 ℓ), and milled until a sufficient amount of material would pass through a standard No. 30 (600 micron) stainless-steel sieve. (At no time were the rocks in the sample crushed, ground or pulverized since this would act to dilute, hence, lower the reported concentration of deposited material.) After milling, each fraction (rocks and dross vs. fines) was bagged and weighed separately (weights are given in Table 3).

Aliquots of the fines were loaded into screwtop plastic conta
Aliquots of 100 g were prepared for gamma-spectral and radiochemical (f
metric) analyses, and 10 g for radiochemical (fluorometric) only. Every
was made throughout the sample preparation to eliminate potential cros
tamination. Soil samples suspected of containing elevated amounts of
activity were processed in separate equipment from that used to proces
samples considered to contain background levels of radioactivity. Additic
all processing equipment was scrubbed and air dried before the introduct
the next sample.

Results of the analyses of the samples collected at the site are cc
to results from background samples in Table 4.

SURVEY RESULTS

General

Results of the radiological survey are discussed in this section. R
obtained with the gas-flow, proportional-counter survey instruments ha
converted to surface-contamination values by the following general proc
The net beta-gamma count rates were determined by subtracting any alp
tribution from the gross readings taken in the beta mode; net alpha coun
were determined by subtracting background from gross readings taken in th
mode. Smear samples were counted for both alpha and beta-gamma activity,
appropriate background was subtracted from the gross readings. In all
net count rates were converted to disintegrations per minute and normaliz
surface area of 100 cm^2 (dis/min-100 cm^2). A detailed description of the
ing and computational procedures and tables of the sensitivity and area-r
zation factors are presented in Appendix 2. The gamma exposure ra
measured by the GM portable instruments, are given in Table 1 and incl
normal instrument background of 0.03-0.05 mR/h. The background bet
levels varied somewhat, due primarily to differences in construction ma
in each room. The average background readings for each mode of operatio
instruments used are given in Part VI of Appendix 1.

The percent of the total floor and wall areas accessible for su
indicated in Table 1. The average percent of total surface area t
accessible was 80% for the floors and 85% for the walls.

Instrument and Smear Surveys

Measurable contamination was found at various locations on the dirt floor, concrete floor, steel floor plates, and on the overhead beams in Building 3. Additionally, contaminated items were found outside the east wall of the building and in the area around the cooling pond (see Figs. 2 & 3 for locations). In general, the contamination was confined to the north end of the building.

The maximum beta-gamma and alpha instrument readings were obtained on the dirt floor at Location 13. The readings were 2.2×10^5 dis/min-100 cm^2 beta-gamma and 1.1×10^4 dis/min-100 cm^2 alpha. The highest GM End Window exposure reading (2.0 mR/h at contact) also was obtained at this location. Gamma-spectral analysis of a sample of the floor dirt at Location 13 indicated the contaminant to be normal uranium* (see Fig. 9). Therefore, all PAC-4G-3 readings and smear results cited in this document are reported as normal uranium.

Smear survey results indicated that loose contamination was present at nine of the locations surveyed. These findings are summarized in Table 5. No other smears indicated detectable contamination above the instrument background of the PC counter, as given in Appendix 1.

Contamination levels determined by the instrument and smear surveys were compared with both the ANSI Standard N13.12, "Control Of Radioactive Surface Contamination Of Materials, Equipment, and Facilities To Be Released For Uncontrolled Use," (Ref. 1) 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" (Ref. 5). Since normal uranium was identified as the contaminant in the building, the surface-contamination guidelines for natural uranium were used for comparative purposes. The NRC Guidelines state that the radiation dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed an average of 0.2 mrad/h and a maximum of 1.0 mrad/h at 1 cm, measured through not more than

*The term "normal uranium," refers to uranium which has been separated from its radioactive decay daughter products and other impurities, and which has the normal isotopic percent abundance as found in nature. The normal percent abundances are 0.0054% ^{234}U, 0.720% ^{235}U, and 99.275% ^{238}U (Ref. 8) The less precise definition of normal uranium as 0.7% ^{235}U, 99.3% ^{238}U, and a trace of ^{234}U is sometimes used for brevity in discussions. The term natural uranium denotes uranium and all daughter products as found in its natural state in the earth, and is sometimes incorrectly referred to as normal uranium. Appendix 5 contains the detailed calculation of the specific activity of normal U.

7 mg/cm^2 of total absorber. The ANSI Standard for acceptable natural ura activity is 5000 dis/min-100 cm^2 total, of which only 1000 dis/min-100 cm^2 be "removable." These levels may be averaged over 1.0 m^2, provided the max activity in any area of 100 cm^2 is less than three times the limit value.

As indicated in Table 6, contamination at 14 locations in the buil exceeded the acceptable surface-contamination levels for natural uranium (ei fixed or removable) as given in the ANSI Standard or the "maximum radia level of 1.0 mrad/h at 1 cm" as given in the NRC Guidelines.

Air Samples

Results of the analysis of the air samples collected at four locations presented in Table 2; detailed calculations are given in Appendix 3. The ra daughter Working Levels (WL) ranged from 0.0011 to 0.0027 WL; the radon cor tration derived from these determinations ranged from 0.11 to 0.27 pCi/ℓ. U the Surgeon General's Guidelines [as incorporated in 10 CFR 712 (Ref. remedial action is not required when concentrations of radon daughters are than 0.01 WL above background in any structures including private dwellin schools (see Appendix 6). The concentration guide for radon in air is 3 x μCi/mℓ, or 3 pCi/ℓ (Ref. 3).

No long-lived activity was detectable in these air samples.

Soil Samples

When this survey was conducted, the mission of the survey team was li to determining whether the site might be a candidate for remedial ac Therefore, the number and locations of the soil samples were chosen based the likelihood of finding contamination, and not with the intent of deline areas of contamination. Since no elevated radiation intensities were det on the soil surface anywhere outside the building, it was not possible to the sampling locations on anything but judgment of probabilities for spil On this basis, the dock area was chosen for soil sampling. Data on the samples collected at the site and on the background soil samples are pre in Tables 3 and 4; sampling locations are shown in Figures 6 and 7.

Uranium concentrations in the background samples ranged from 1.2 ± 0.2 to 8.0 ± 0.3 pCi/g. It is felt that the marginally elevated level of 8.0 ± 0.3 pCi/g reported for sample 6-SB6-D may have been a result of the presence of inorganic fertilizer in the soil. The uranium levels measured in the soil samples taken at the Universal Cyclops site ranged from 0.3 ± 0.2 to 109.9 ± 5.5 pCi/g. All four segments of the soil coring at 6-S4 contained elevated levels of uranium (15.1 ± 0.7 to 109.9 ± 5.5 pCi/g). The three segments from 5 to 30 cm in depth showed concentrations in excess of the proposed interim limit of 40 pCi/g (Ref. 4). This location had been selected for sampling because of the elevated radiation intensity found in the nearby loading dock doorway (Location 14).

ESTIMATED EXTENT OF CONTAMINATION

Any estimate of the total volume of radioactive material that would be generated by remedial action at this facility is subject to many uncertainties. In the case of this particular survey, which was performed prior to the establishment of the requirement that extent and volume of contaminated materials be estimated, only limited data are available. Therefore, arbitrary assumptions have been made on the basis of professional judgment to make some estimate that may be useful in the development of engineering assessments. For example, one can only guess at the actual depth of contamination involved at soil sample location 6-S4 (see Fig. 6) and in the floor inside Building 3 (Locations 1, 13, 15, 21, 22; Fig. 5). At sample location 6-S4, the uranium concentration increased with depth down to 30 cm. To estimate the volume of soil that would be removed in any remedial action, it has been assumed that excavation to a depth of 1 m would be sufficient to include all significant contamination. For the case of the contaminated steel floor plates and the structural iron overhead trusses and roof structure, two alternatives are possible. If decontamination proved to be feasible, the steel and iron would not become radioactive waste but the decontamination residues would. This is tabulated as Option A in Table 8. If decontamination was not feasible or proved to be unsuccessful, the steel and iron structures would need to be treated as radioactive waste as indicated by Option B in Table 8.

The estimated activity is based on various assumptions. For the soil surrounding sample location 6-S4, it is assumed that the entire volume (2 m

square by 1 m deep) of soil will have the same concentration of uran: sample 6-S4-D. For the cases of contamination on the dirt and concrete f it is arbitrarily assumed that half of the total activity is on the surfa measured, and an equal amount is deeper and not detected. The mass of active waste generated during decontamination of the steel and structura: is arbitrarily taken as 1% of the mass of the material being decontami: This value will be strongly influenced by the method of decontamination em assuming a successful method can be found.

Based on these assumptions, the volume, mass, and activity of materia: would be removed have been estimated and are listed in Table 7. As indica the table, Option A would generate 18.1 m^3 of material with a mass of 26,5: while Option B would generate 15.9 m^3 of material with a mass of 49,800 kg. activity of the material would be about the same for either option-- 1.2 mCi as normal uranium.

POTENTIAL HAZARD EVALUATION

Internal Exposure

To assess the potential radiological hazard resulting from the conta tion found in the Universal Cyclops facility, a hypothetical situation invc the aerosolization of contamination on an overhead beam has been consid The highest level of contamination found on the beams, at Location 9, was 10^4 beta-gamma dis/min-100 cm^2, reported as normal uranium. This contamin was found to be confined to an area of about 1000 cm^2. Thus, the total qua of uranium (A) can be calculated as follows:

$$A = \frac{3.1 \times 10^4 \text{ dis/min}}{100 \text{ cm}^2} \cdot 1000 \text{ cm}^2 = 3.1 \times 10^5 \text{ dis/min.}$$

Converting this to units of activity (B), we have:

$$B = 3.1 \times 10^5 \text{ dis/min} \cdot \frac{1 \text{ μCi*}}{4.54 \times 10^6 \text{ dis/min}} = 7.0 \times 10^{-2} \text{ μCi.}$$

---

*A curie of normal uranium is defined as the sum of 3.7×10^{10} dis/s from plus 3.7×10^{10} dis/s from ^{234}U plus 1.7×10^9 dis/s from ^{235}U. This e 4.54×10^{12} dis/min per Curie of normal uranium. A Curie for other isotop 2.22×10^{12} dis/min (Ref. 3).

The presumed worst situation that could be postulated as likely to happen would result from torch welding or cutting of the beam. If this happened, a radioactive aerosol would be created. It has been assumed for this analysis that 95% of the radioactivity present becomes airborne and respirable. Thus, the total level of radioactivity that would become airborne (C) is

$$C = 7.0 \times 10^{-2}\ \mu Ci \cdot 0.95 = 6.6 \times 10^{-2}\ \mu Ci.$$

Based on the assumption that the air would be stagnant at this height in the building, it is postulated that the radioactive aerosol is confined to an approximate volume of 10 m^3 of air. The concentration of the uranium aerosol (D) (if uniformly dispersed in this volume) would be

$$D = \frac{6.6 \times 10^{-2}\ \mu Ci}{10\ m^3} = \frac{6.6\ 10^{-3}\ \mu Ci}{m^3} = \frac{6.6 \times 10^{-9}\ \mu Ci}{cm^3}.$$

The Concentration Guide in Air (CG_a) in uncontrolled areas for uranium is 2 x 10^{-12} $\mu Ci/m\ell$ (Ref. 3). Comparing the postulated level to the CG_a we obtain the ratio (I)

$$I = \frac{6.6 \times 10^{-9}}{2 \times 10^{-12}} = 3.3 \times 10^3.$$

In the preceding hypothetical situation, an aerosol was generated that is about 3300 times the CG_a for natural uranium.

It is not likely that more than one person would be involved in an operation of this type for an extended length of time. A person involved in this job for a nominal 15-minute period without respiratory protection would inhale 0.3 m^3 of air, based on a breathing rate of 1.2 m^3/h (Ref. 6), containing the following quantity of uranium activity (J):

$$J = \frac{6.6 \times 10^{-3}\ \mu Ci}{m^3} \cdot 0.3\ m^3 = 2.0 \times 10^{-3}\ \mu Ci.$$

The fraction of the activity taken in which reaches the organ of reference, which in this case is the kidneys, would be 0.028 (Ref. 7). The radioactivity reaching the kidneys (K) would be:

$$K = 2.0 \times 10^{-3}\ \mu Ci \cdot 0.028 = 5.6 \times 10^{-5}\ \mu Ci.$$

The Maximum Permissible Organ Burden for the kidneys, q(μCi), is 5 x 10-
for natural uranium (Ref. 7). Comparing the total reaching the kidneys t
Maximum Permissible Kidney Burden, we obtain the following ratio (L).

$$L = \frac{5.6 \times 10^{-5}\ \mu Ci}{5 \times 10^{-3}\ \mu Ci} = 1.1 \times 10^{-2}.$$

Thus, a person would receive 1.1×10^{-2} or approximately 1.1% of a kidney b
from this operation.

Even though these calculations are based on a reasonable scenario, it
be realized that an actual total intake of activity would probably be less
the hypothesized value since several simplifying and conservative assumpt
have been made. The assumed value of 95% volitalized and respirable means
the activity on the entire section of beam would have been vaporized.
assumption that the aerosol remains stagnant in the immediate vicinity of
ignores the fact that the heat from the torch would result in natural up
convection and mixing with other air. Finally, it is assumed that no att
was made to wipe or clean off the surface of the beam before work was star

External Exposure

Since no GM End Window exposure readings at 1 m were distinguishable
the normal instrument background for uncontaminated areas (0.03-0.05 mR/h)
is concluded that none of these spots pose a detectable external radiolog
hazard.

REFERENCES

1. American National Standards Institute. 1978. "Draft American National Standard - Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use." ANSI N13.12.

2. U.S. Department of Energy. 1976. 10 CFR 712 "Grand Junction Remedial Action Criteria", Title 10--Energy, Chapter III.

3. U.S. Department of Energy. 1981. DOE 5480.1, Chapter XI "Requirements for Radiation Protection" Attachment XI-I.

4. J. W. Healy, J. C. Rogers, and C. L. Weinke. 1979. "Interim Soil Limits for D&D Projects." LA-UR-79-1865-Rev.

5. U.S. Nuclear Regulatory Commission. 1976. 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."

6. U. S. Department of Health, Education and Welfare; Public Health Service. 1970. "Radiological Health Handbook--Revised Edition."

7. International Commission on Radiological Protection. 1960. "Report of ICRP Committee II on Permissible Doses for Internal Radiation (1959)." Health Physics Vol. 3, June 1960.

8. C. M. Lederer and V. S. Shirley (Eds.), 1978. "Table of Isotopes--7th Edition."

Figure 1

OVERALL PLAN OF UNIVERSAL CYCLOPS, INC. TITUSVILLE PLANT, ALIQUIPPA, PENNSYLVANIA

ANL-HP DWG.NO. 81-17

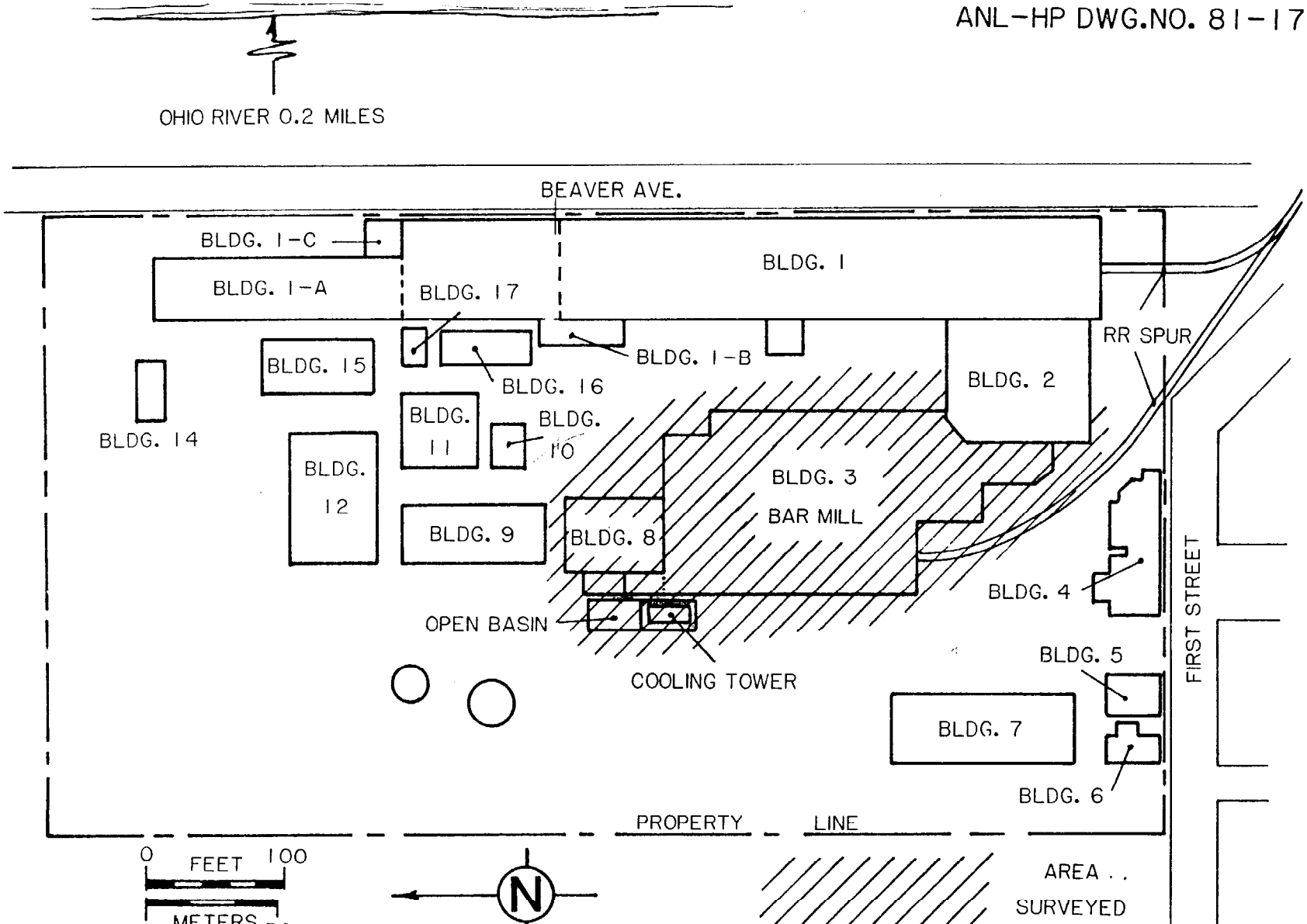

Figure 2

FLOOR LEVEL SMEAR AND SURVEY LOCATIONS - BLDG. 3

ANL-HP DWG.NO. 82-17

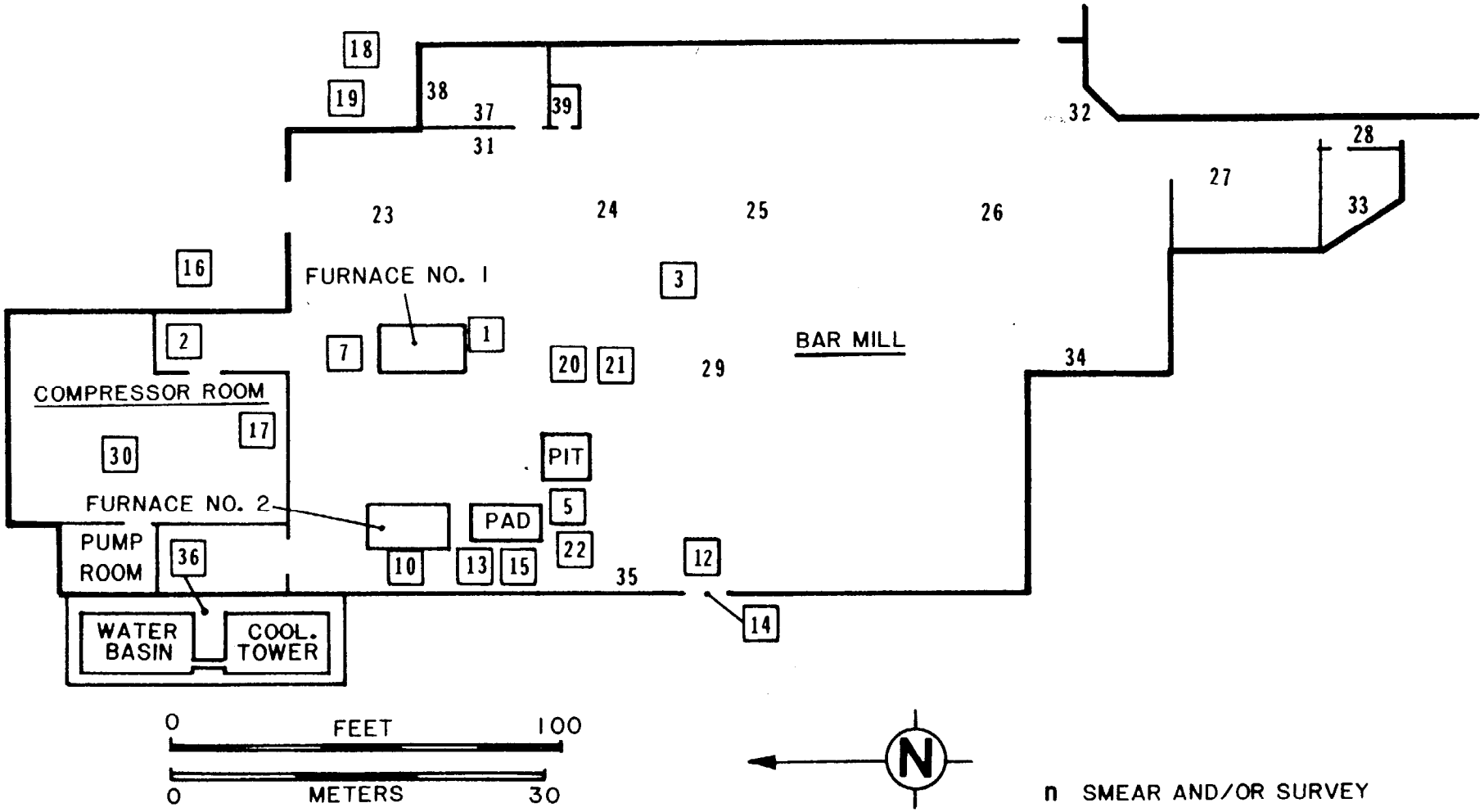

Figure 3
OVERHEAD SMEAR SURVEY LOCATIONS - BLDG. 3

ANL-HP DWG.NO. 82-18

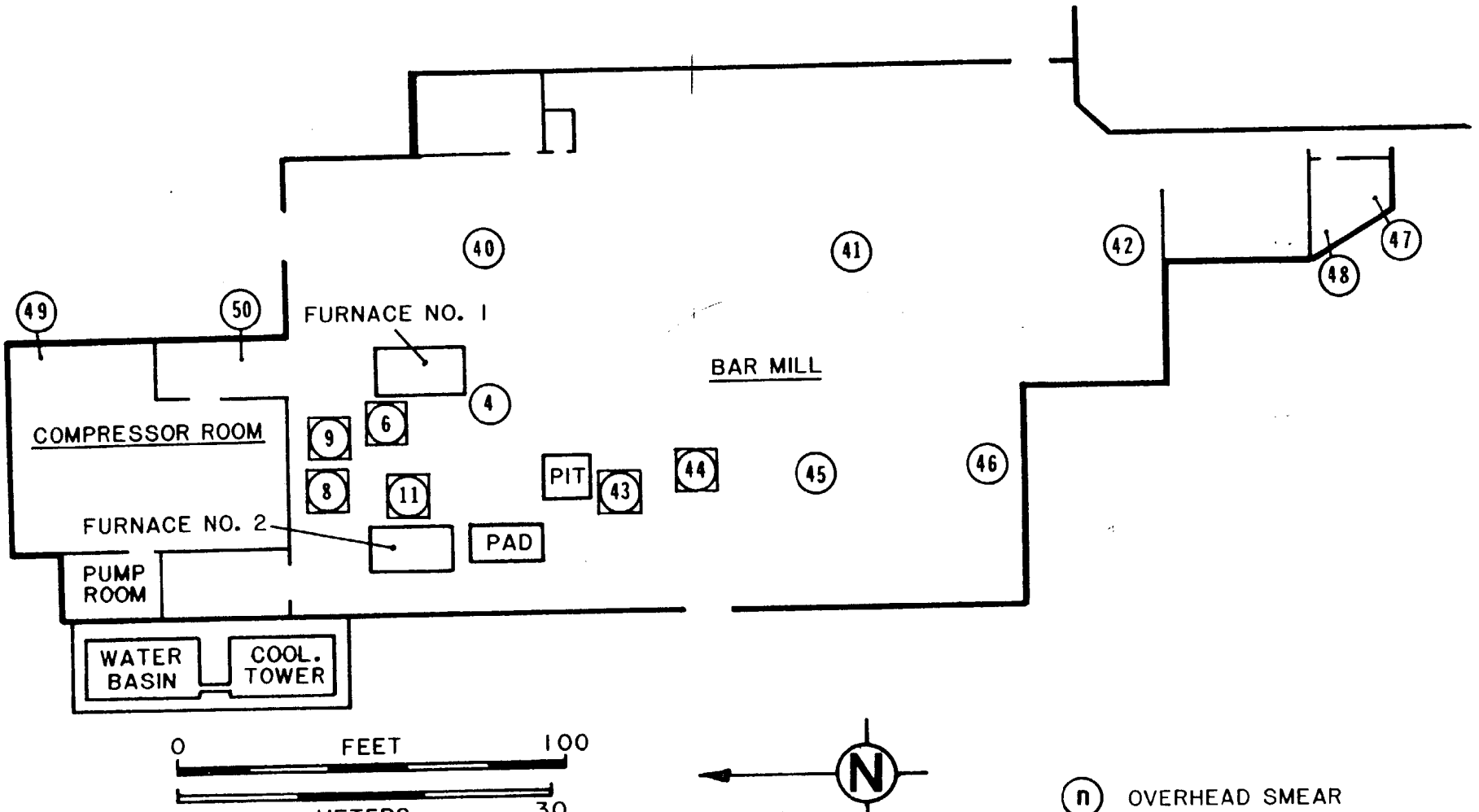

Figure 4

AIR SAMPLE LOCATIONS - BLDG. 3

ANL-HP DWG.NO. 82-19

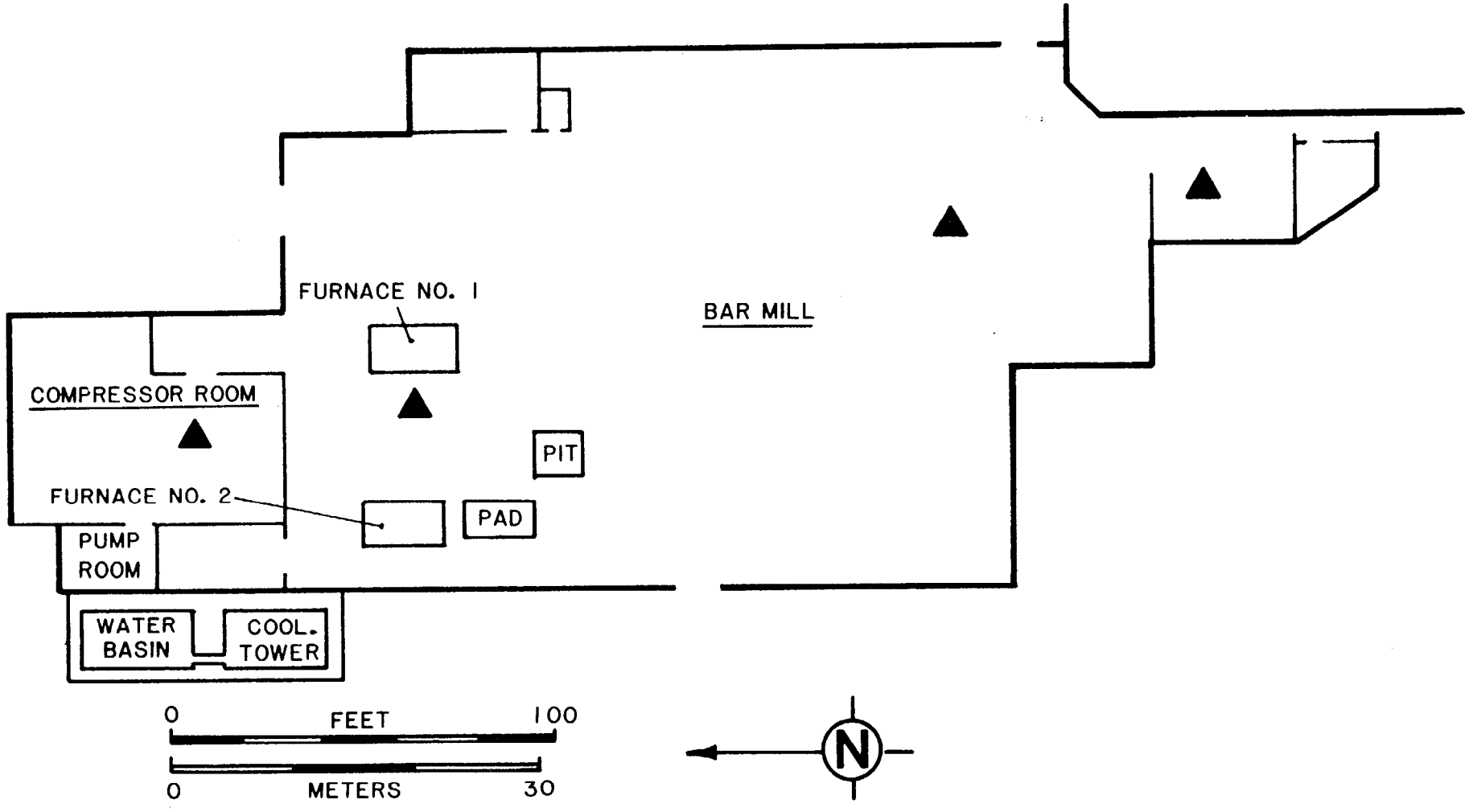

Figure 5

SURVEY LOCATIONS INDICATING CONTAMINATION IN EXCESS OF GUIDELINES

ANL-HP DWG.NO. 82-20

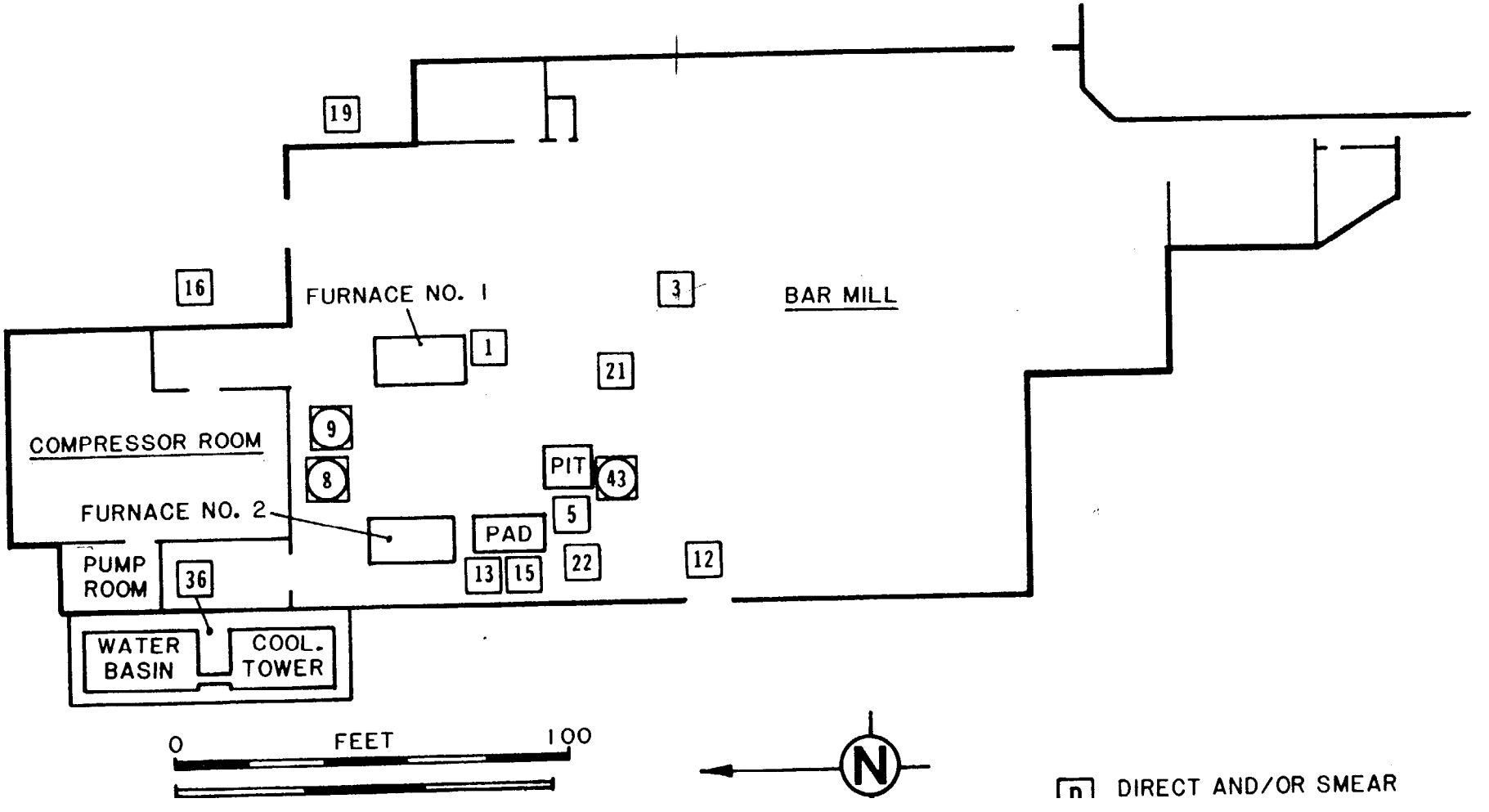

Figure 6

SOIL SAMPLE LOCATIONS

ANL-HP DWG. NO. 78-48

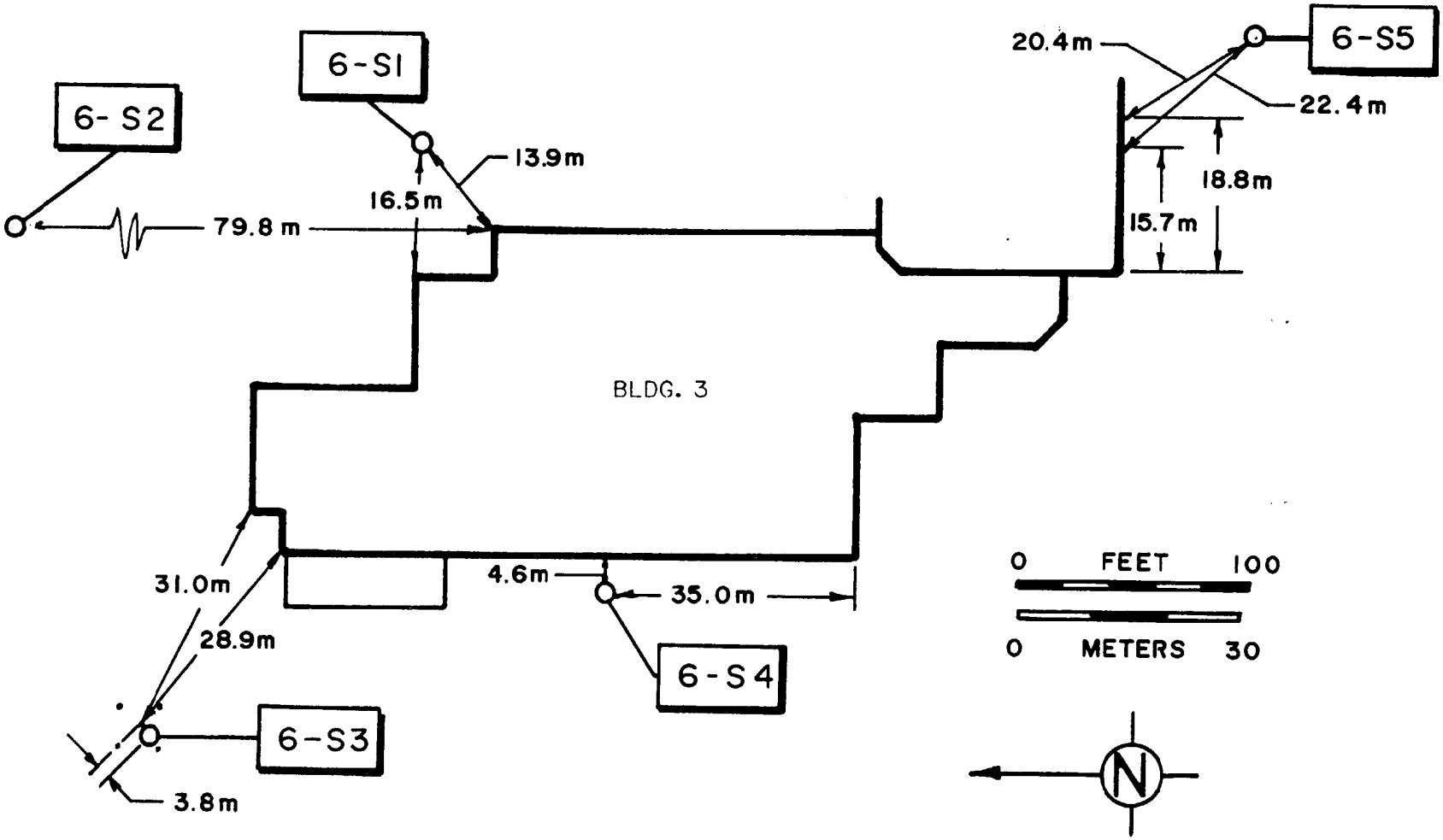

Figure 7

BACKGROUND SOIL SAMPLE LOCATION

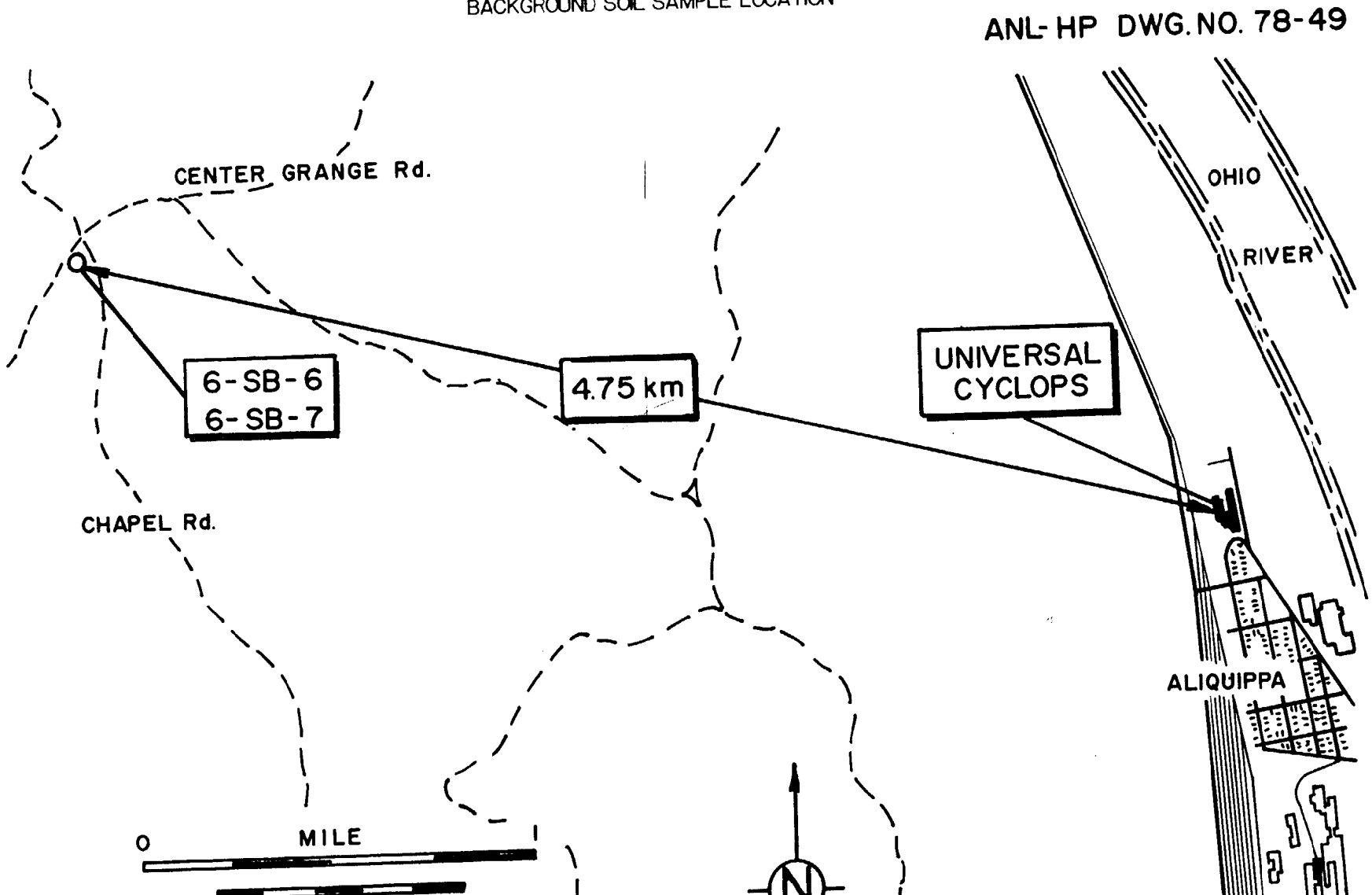

Figure 8

SOIL SAMPLING PROCEDURE AND PROCESSING DIAGRAM

ANL-HP-DWG. 78-2

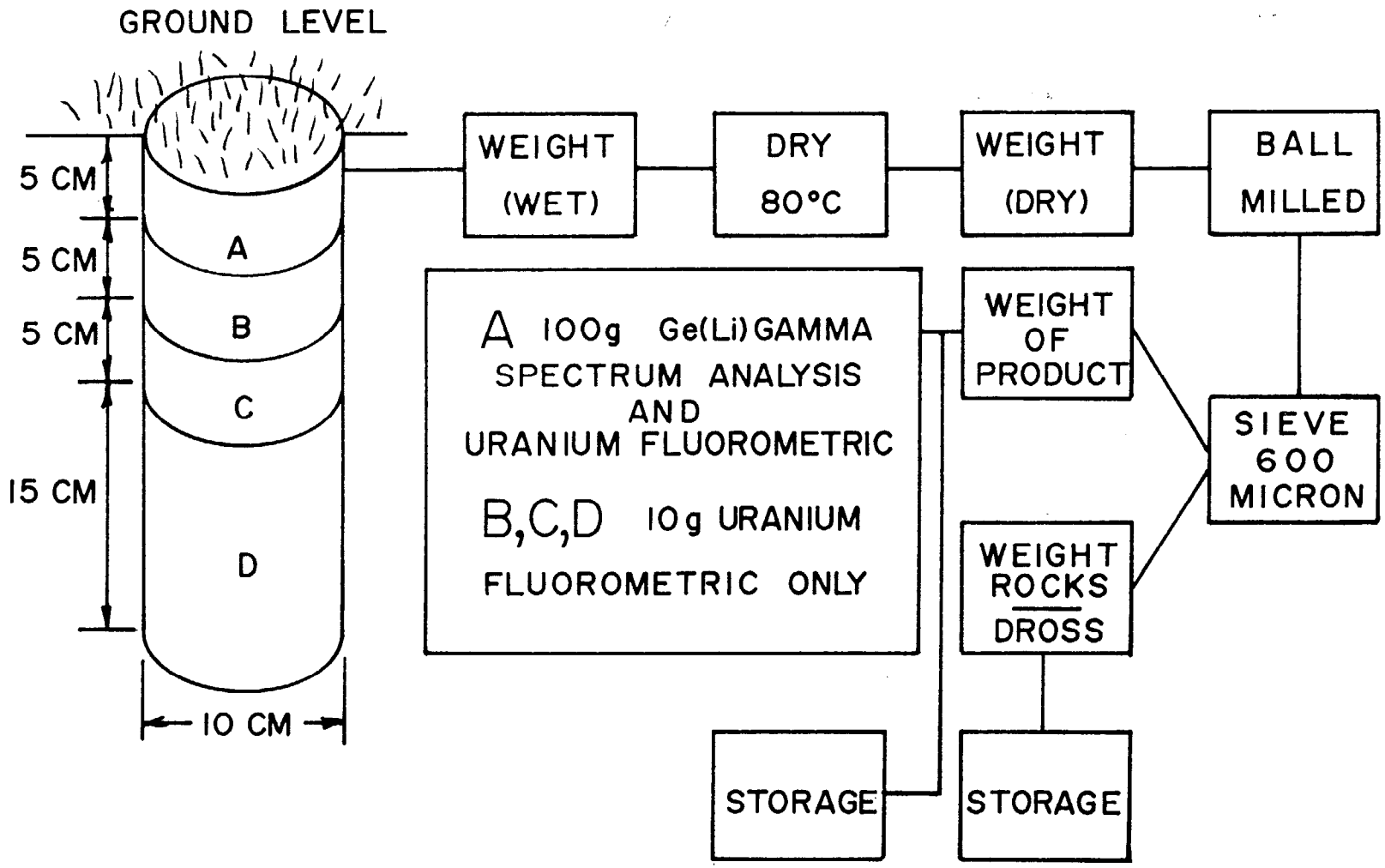

Figure 9

GAMMA SPECTRUM ANALYSIS OF CONTAMINATED FLOOR DIRT

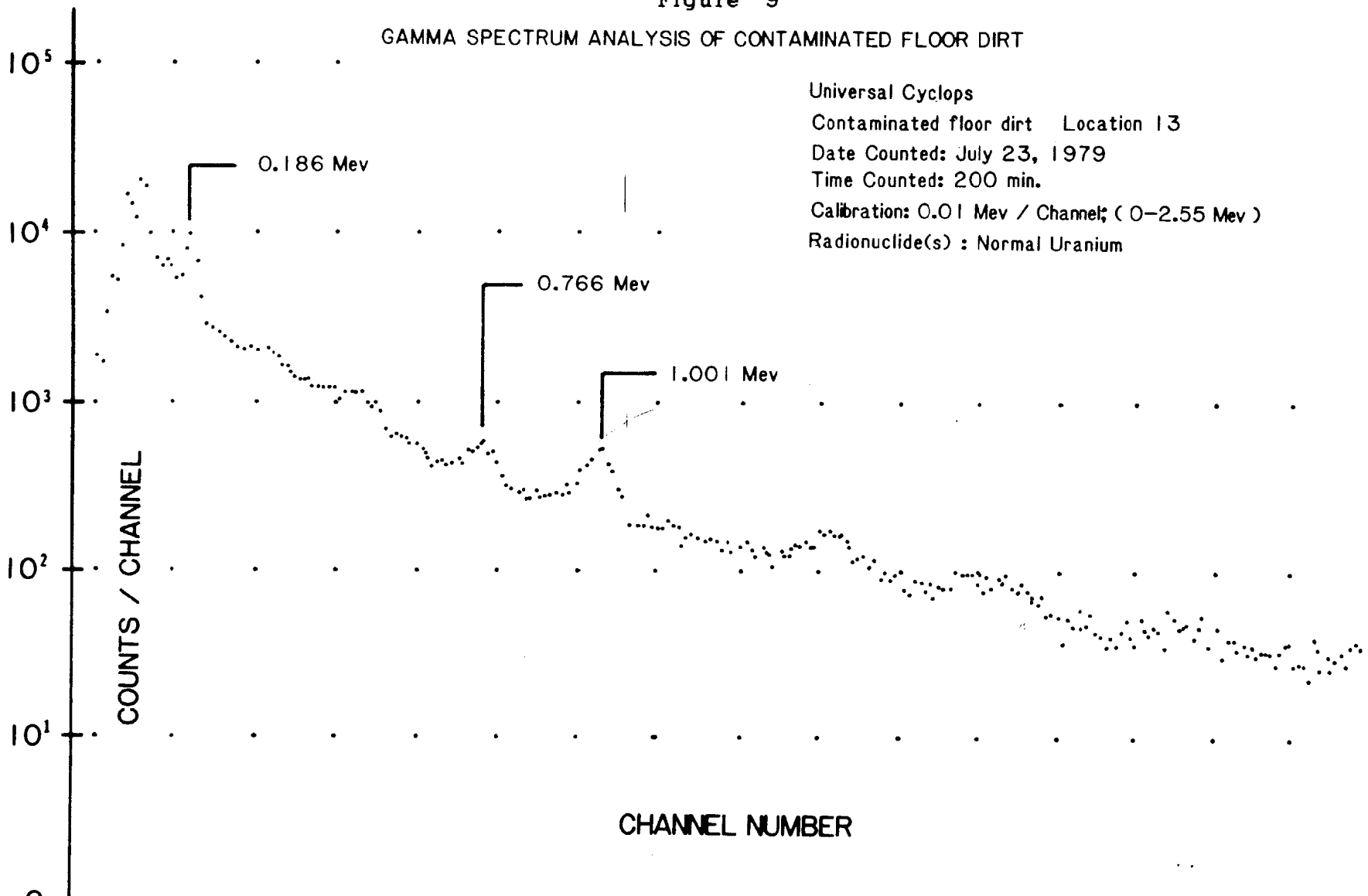

TABLE 1

INSTRUMENT SURVEY RESULTS

Room No. or Area	Percent of Area Accessible for Survey		Direct Readings,[a] dis/min-100 cm²		Beta Gamma Exposure Level, mR/h		Smears, dis/min-100 cm²	Comments
	Floors	Walls	Beta	Alpha	Contact	1 Meter		
Bar Mill	85	90	1.8×10^4	BKGD[b]	0.3	BKGD	α =76[d] $\beta\gamma$=72	Location 1 Dirt floor
			1.6×10^3	BKGD	0.5	BKGD	BKGD	Location 2 Floor
			5.9×10^4	1.6×10^3	0.3	BKGD	BKGD	Location 3 Steel floor plate
			4.3×10^4	BKGD	0.6	BKGD	BKGD	Location 5 Floor
			1.6×10^3	BKGD	NRR[f]	BKGD	BKGD	Location 6 Blower
			BKGD	NA[c]	NA	BKGD	α =BKGD $\beta\gamma$=22	Location 7 Dirt floor
			2.4×10^4	BKGD	NRR	NRR	α =17 $\beta\gamma$=84	Location 8 Overhead beam
			3.1×10^4	BKGD	NRR	NRR	α =20 $\beta\gamma$=106	Location 9 Overhead beam
			4.5×10^3	BKGD	0.5	BKGD	BKGD	Location 10 Dirt floor
			4.5×10^3	BKGD	NRR	NRR	α =22 $\beta\gamma$=121	Location 11 Overhead beam

*See notes at end of table.

TABLE 1

INSTRUMENT SURVEY RESULTS

Room No. or Area	Percent of Area Accessible for Survey		Direct Readings,[a] dis/min-100 cm²		Beta Gamma Exposure Level, mR/h		Smears, dis/min-100 cm²	Comments
	Floors	Walls	Beta	Alpha	Contact	1 Meter		
Bar Mill (cont'd)			9.7×10^3	BKGD[b]	NRR[f]	BKGD	BKGD	Location 12 Concrete floor
			2.2×10^5	1.1×10^4	2.0	BKGD	NST[e]	Location 13 Dirt floor, Sample for analysis
			4.6×10^3	BKGD	BKGD	BKGD	BKGD	Location 14 Floor
			6.1×10^4	BKGD	0.3	BKGD	α =30[d] $\beta\gamma$=188	Location 15 Dirt floor
			6.4×10^2	BKGD	BKGD	BKGD	BKGD	Location 20 Dirt floor
			5.8×10^4	BKGD	0.8	BKGD	BKGD	Location 21 Dirt floor
			1.8×10^4	BKGD	0.1	BKGD	BKGD	Location 22 Dirt floor
			2.8×10^4	5.6×10^3	BKGD	BKGD	α =80 $\beta\gamma$=284	Location 43 Overhead beam
			1.6×10^3	BKGD	BKGD	BKGD	α=18 $\beta\gamma$=BKGD	Location 44 Overhead beam

*See notes at end of Table.

TABLE 1

INSTRUMENT SURVEY RESULTS

Room No. or Area	Percent of Area Accessible for Survey		Direct Readings,[a] dis/min-100 cm^2		Beta Gamma Exposure Level, mR/h		Smears, dis/min-100 cm^2	Comments
	Floors	Walls	Beta	Alpha	Contact	1 Meter		
Compressor Room	80	80	1.6×10^3	BKGD[b]	BKGD	BKGD	BKGD	Location 17 Brick Floor
			BKGD	BKGD	BKGD	BKGD	α =BKGD[d] $\beta\gamma$=30	Location 30 Brick floor
Cooling Tower Area	95	No Walls	1.1×10^4	BKGD	BKGD	BKGD	BKGD	Location 36 Steel floor
Outside Building			1.4×10^4	1.6×10^3	0.1	BKGD	BKGD	Location 16 Vent pipe on ground
			4.9×10^3	BKGD	BKGD	BKGD	BKGD	Location 18 Steel floor plate on ground
			4.8×10^3	5.5×10^3	1.3	BKGD	BKGD	Location 19 Steel floor plate on ground
			BKGD	NA[c]	BKGD	BKGD	BKGD	All other surfaces and areas surveyed indicated BKGD levels.

*See notes at end of Table

FOOTNOTES FOR TABLE 1

[a]The Beta Mode Direct Readings and Alpha Mode Direct Readings were taken with PAC-4G-3 instruments. The beta mode detects both electromagnetic and particulate radiation. If an area indicated a higher count rate than the area 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 are compensated for any alpha contribution by subtracting the alpha-mode reading from the beta-mode reading. The area background is subtracted in both the alpha- and beta-mode readings to obtain the net readings.

[b]BKGD = Background. The following are the normal area background readings for each instrument.

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

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

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

[d] 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. The background count rate is subtracted in both readings.)

[e]NST = No smear taken.

[f]NRR = No reading recorded.

*One standard deviation due to counting statistics.

Table 2. Radon Determinations

Location[a]	dis/min-m^3	pCi/ℓ	WL[b]
North End at Furnace #1	304	0.14	0.0014
Compressor Room	600	0.27	0.0027
South End Storage Area	277	0.12	0.0012
South End Bar Mill Room	242	0.11	0.0011

Example Calculation--Compressor Room:

$$\frac{600 \text{ dis/min}}{m^3} \times \frac{1 \text{ pCi}}{2.22 \text{ dis/min}} \propto \frac{m^3}{10^3 \text{ ℓ}} \times \frac{\text{WL}}{100 \text{ pCi/ℓ}} = 0.0027 \text{ WL}$$

[a] Location are shown in Figure 4.

[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. (Ref. 2)

Table 3. Soil-Sample Weights (grams)

Sample Number*	Wet Weight	Dry Weight	Fines	Rocks and Dross
		Site Soil Samples		
6-S1-A	417.5	348.2	103.9	242.8
6-S1-B	782.5	690.6	284.9	398.1
6-S1-C	440.7	382.6	130.6	250.0
6-S1-D	1491.5	1313.6	616.5	694.6
6-S2-A	640.3	575.4	140.5	434.3
6-S2-B	589.4	514.5	130.6	380.7
6-S2-C	764.5	668.1	147.3	520.0
6-S2-D	2370.4	1998.8	615.9	1332.2
6-S3-A	347.9	292.2	141.7	148.2
6-S3-B	304.1	275.1	143.1	130.0
6-S3-C	601.5	546.3	269.0	376.2
6-S3-D	1128.1	1101.4	681.0	420.2
6-S4-A	631.0	526.8	184.0	340.0
6-S4-B	637.4	526.3	148.9	377.1
6-S4-C	475.9	416.0	92.0	321.4
6-S4-D	1368.0	1182.7	444.6	736.0
6-S5-A	534.1	449.3	134.7	313.1
6-S5-B	580.2	511.4	170.3	338.7
6-S5-C	394.0	348.1	164.8	180.7
6-S5-D	2135.9	1799.0	342.8	1434.9
		Background Soil Samples		
6-SB6-A	560.9	459.7	33.6	423.8
6-SB6-B	457.4	385.1	21.7	361.8
6-SB6-C	884.2	744.2	24.6	714.1
6-SB6-D	2223.7	1837.0	223.9	1582.6
6-SB7-A	632.1	513.1	4.2	500.8
6-SB7-B	777.3	655.4	16.1	627.8
6-SB7-C	758.1	632.5	11.8	616.2
6-SB7-D	2260.0	1890.9	560.5	1232.5

*Sampling locations on the site are shown in Figure 6; background sampling locations are shown in Figure 7.

Table 4. Ge(Li)-Spectral[a] and Uranium-Fluorometric Analyses of Soil Samples

Sample Number	^{137}Cs (pCi/g)	^{232}Th Decay Chain (pCi/g)	^{226}Ra Decay Chain (pCi/g)	Uranium[b] μg/g ± 1σ[c]	Uranium[b] pCi/g ± 1σ[d]
			Site Soil Samples		
6-S1-A	2.28 ± 0.11	0.79 ± 0.13	0.47 ± 0.09	2.1 ± 0.8	1.4 ± 0.5
6-S1-B				4.2 ± 0.8	2.9 ± 0.5
6-S1-C				1.4 ± 0.4	1.0 ± 0.3
6-S1-D				1.5 ± 0.4	1.0 ± 0.3
6-S2-A	0.64 ± 0.05	0.70 ± 0.10	0.65 ± 0.07	1.2 ± 0.5	0.8 ± 0.3
6-S2-B				2.0 ± 0.6	1.4 ± 0.4
6-S2-C				1.4 ± 0.3	1.0 ± 0.2
6-S2-D				1.5 ± 0.3	1.0 ± 0.2
6-S3-A	4.01 ± 0.20	0.77 ± 0.15	0.70 ± 0.09	1.0 ± 0.4	0.7 ± 0.3
6-S3-B				2.1 ± 0.5	1.4 ± 0.3
6-S3-C				0.5 ± 0.3	0.3 ± 0.2
6-S3-D				3.7 ± 0.4	2.5 ± 0.3
6-S4-A	0.92 ± 0.05	0.78 ± 0.6	0.80 ± 0.04	22 ± 1	15.1 ± 0.7
6-S4-B	1.7 ± 0.2	0.6 ± 0.06	1.1 ± 0.1	121 ± 6	83.1 ± 4.1
6-S4-C	0.4 ± 0.04	0.8 ± 0.08	0.7 ± 0.07	62 ± 3	42.6 ± 2.1
6-S4-D	<0.06	0.8 ± 0.08	1.5 ± 0.2	160 ± 8	109.9 ± 5.5
6-S5-A	1.68 ± 0.08	0.78 ± 0.14	0.64 ± 0.09	1.9 ± 0.6	1.3 ± 0.4
6-S5-B				2.3 ± 0.4	1.6 ± 0.3
6-S5-C				5.5 ± 0.4	3.8 ± 0.3
6-S5-D				2.0 ± 0.3	1.4 ± 0.2
			BACKGROUND SOIL SAMPLES		
6-SB6-A	2.26 ± 0.11	0.97 ± 0.13	0.92 ± 0.07	2.2 ± 0.3	1.5 ± 0.2
6-SB6-B				2.3 ± 0.4	1.6 ± 0.3
6-SB6-C				2.1 ± 0.4	1.4 ± 0.3
6-SB6-D				11.6 ± 0.4	8.0 ± 0.3
6-SB7-A	2.09 ± 0.10	1.09 ± 0.09	0.96 ± 0.05	1.8 ± 0.3	1.2 ± 0.2
6-SB7-B				1.8 ± 0.3	1.2 ± 0.3
6-SB7-C				3.9 ± 0.7	2.7 ± 0.5
6-SB7-D				2.0 ± 0.3	1.4 ± 0.2

[a] Ge(Li)-spectral analyses were not performed on all of the B, C, and D components due to funding limitations in effect at the time of analysis and the fact that uranium was the only known material involved.

[b] Indicated errors are standard deviation due only to counting statistics.

[c] Data results from LFE Analytical Laboratory.

[d] ANL conversion per Appendix 5.

Table 5. Locations Where Loose Contamination Was Detected on Smears

Location Number[a]	Item Smeared	Smear Results (net dis/min-100 cm^2)	
		Alpha	Beta-Gamma
1	Floor	76	72
7	Floor	BKGD[b]	22
8	Overhead beam	17	84
9	Overhead beam	20	106
11	Overhead beam	22	121
15	Floor	30	188
30	Floor	BKGD	30
43	Overhead beam	80	284
44	Overhead beam	18	BKGD

[a]See Figure 5 for locations.

[b]The smear count was not greater than the instrument background.

Table 6. Locations Where Residual Contamination Exceeded Acceptable Levels[a,b]

Location Number	Area of Contamination (cm^2)	PAC Reading (dis/min-100 cm^2)		GM Contact Reading (mR/h)	Smear Results (dis/min-100 cm^2)	
		Beta-Gamma	Alpha		Beta-Gamma	Alpha
1	500	1.8×10^4	BKGD[c]	0.3	72	76
3	2000	5.9×10^4	1.6×10^3	0.3	BKGD	BKGD
5	1000	4.3×10^4	BKGD	0.6	BKGD	BKGD
8	1000	2.4×10^4	BKGD	-	84	17
9	1000	3.1×10^4	BKGD	-	106	20
12	2000	9.7×10^3	BKGD	-	BKGD	BKGD
13	1000	2.2×10^5	1.1×10^4	2.0	-	-
15	1000	6.1×10^4	BKGD	0.3	88	30
16	5000	1.4×10^4	1.6×10^3	0.1	BKGD	BKGD
19	2000	4.8×10^3	5.5×10^3	1.3	BKGD	BKGD
21	2000	5.8×10^4	BKGD	0.8	BKGD	BKGD
22	2000	1.8×10^4	BKGD	0.1	BKGD	BKGD
36	2000	1.1×10^4	BKGD	BKGD	BKGD	BKGD
43	1000	2.8×10^4	5.6×10^3	BKGD	294	80

[a] Locations are shown in Figure 5.

[b] Acceptable levels are as specified for natural uranium in ANSI Standard N13.12, or in NRC Guidelines.

[c] BKGD = Background.

Table 7. Estimated Volume, Mass, and Activity of Material That Could Be Generated by Remedial Action[a]

Area and Material Involved	Estimated Volume (m^3)	Estimated Mass (kg)	Estimated Activity (as μCi Normal U)
Soil around sample location #4 (ρ = 2 gm/cm^3)[b]	4	8,000	0.9
Dirt floors inside Building 3 (locations 1, 13, 15, 21, 22) (ρ = 2 gm/cm^3)	8	16,000	4.0
Concrete floor inside Building 3, around location 12 (ρ = 2.3 gm/cm^3)	1	2,300	0.2
Steel floor plates (locations 3, 5, and 19) 6' × 6' × ¼" thick (ρ = 7.86 gm/cm^3)			
Option A	0.1	5	1.5
Option B	<0.1[c]	500	1.5
Structural iron over head trusses and sheet metal roofing (ρ = 7.86 gm/cm^3)			
Option A	5	230	1,200
Option B	2.8[c]	23,000	1,200
Total			
Option A	18.1	26,535	~1,200
Option B	15.9	49,800	~1,200

[a]See text for assumptions upon which estimates are based.

[b]The assumed density for the purpose of calculating mass of material.

[c]The actual volume will depend upon the method and density of packing for shipment.

APPENDIX 1

INSTRUMENTATION

I. PORTABLE RADIATION SURVEY METERS

A. Gas Proportional Survey Meters

The Eberline PAC-4G-3 was the primary instrument used for surveying. This instrument is a portable count-rate meter that uses a gas proportional probe, either 51 or 325 cm^2 in area, with a thin double-aluminized Mylar window (~0.85 mg/cm^2). Since this instrument has three switch-selectable high-voltage settings, it can be used to distinguish between alpha and beta-gamma contamination. This instrument is initially operated in the beta mode. In this mode, the detector responds to alpha and beta particles and X- and gamma-rays. In the alpha mode, the instrument responds only to particles with high-specific ionization, such as alpha particles. When this instrument indicates a higher count rate than the average instrument background, the beta-mode reading is recorded, and the instrument is switched to the alpha mode to determine any alpha contribution. The 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% efficiency.

B. Beta-Gamma End Window Survey Meter

When an area of contamination is found with a PAC-4G-3, a reading is obtained with an Eberline Beta-Gamma Geiger-Mueller Detector Model E-530 with a HP-190 probe. This probe has a thin mica end window and is sensitive to alpha and beta particles and X-and gamma-rays. A thin piece of aluminum is added to the mica, increasing the window thickness to ~7 mg/cm^2 and making the instrument insensitive to alpha particles. A reading is obtained with the probe placed in contact with the surface at the area of maximum contamination, and another reading is obtained with the probe positioned at 1 m from the contaminated surface. This instrument is calibrated with a NBS traceable ^{137}Cs source.

II. SMEAR-COUNTING INSTRUMENTATION

The 10-wire instrument consists of a gas-flow proportional probe (ANL design) connected to 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 10 smears. The probe is placed over the smears, and a count is taken.

All smears of contaminated areas are counted in a Nuclear Measurements Corporation PC-5 Gas-Flow Proportional Counter (PC counter) with a double-aluminized Mylar window spun top. The Mylar window is placed over nonconducting sampling material such as filter 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 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.

III. AIR-SAMPLING EQUIPMENT

The air samples were collected with a commercial vacuum cleaner modified at ANL. The air was drawn at a flow rate of 40 m^3/h through the collection medium, which consisted of a 200-cm^2 sheet of Hollingsworth-Vose (HV-70-0.23 mm) filter paper. The collection efficiency at this flow rate for 0.3-micron airborne 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-high NaI(Tl) crystal was used for determining the gamma spectrum. This instrument was calibrated using the known gamma energies emitted by ^{60}Co and ^{137}Cs reference sources. Samples taken from contaminated areas were counted with the analyzer system to provide identification of gamma-emitting contaminants.

V. INSTRUMENTATION USED IN SURVEY

	Inventory Number	Probe Area, cm^2	Window Thickness, mg/cm^2
Eberline Floor Monitor FG-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 w/AC-21 probe	183416	51	~0.85
PAC-4G-3 w/AC-21 probe	184339	51	~0.85
PAC-4G-3 w/AC-21 probe	184340	51	~0.85
Eberline 530 with HP-190 Beta-Gamma End Window	184575	-	~7
Nuclear Measurements Corp. PC-5 2π Internal-Gas-Flow Counter	184065	-	~0.85
Argonne National Laboratory 10-Wire Flat-Plate Gas Proportional Detector Eberline Mini Scaler MS-2	184342 & 184343	400	~0.85
Argonne National Laboratory Filter Queen Air Sampler using HV-70 filter media			
Nuclear Data Multichannel Analyzer Model ND-100	184764	-	-

VI. AVERAGE INSTRUMENT BACKGROUND READINGS[a]

Instrument	Alpha Mode (c/min)	Beta Mode (c/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			
183416	0-50	150-200	
184339	0-50	150-200	
184340	0-50	150-200	
Eberline 530 with HP 190 Beta-Gamma End Window	-	-	0.03-0.05 mR/h
Nuclear Data Multichannel Analyzer Model 100	-	-	
Nuclear Measurements Corporation PC-5 2π Internal-Gas-Flow Counter	0.2 ± 0.1[b]	40.0 ± 1.4[b]	
Argonne National Laboratory 10-Wire Flat-Plate Gas Proportional Detector with Eberline Mini Scaler MS-2	5.2 ± 0.5[b]	443.0 ± 4.7[b]	

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

[b]Indicated error is one standard deviation due only to counting statistics.

APPENDIX 2

CONVERSION FACTORS

I. GAS-FLOW PORTABLE INSTRUMENTATION

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

A. Conversion Factors

	PAC-4G-3 with AC-21 Probe (Hand Pac)		PAC-4G-3 with FM-4G Probe (Floor Monitor)	
	Alpha	Beta	Alpha	Beta
To 100 cm^2	1.96	1.96	0.31	0.31
c/min to dis/min ^{239}Pu and ^{90}Sr-^{90}Y	2	2	2	2
c/min to dis/min for normal uranium	5.9	3.5	5.9	3.5

B. Derivation of Conversion Factors

- Floor Monitor (FM-4G Probe)

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

- Hand Pac (PAC-21 Probe)

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

- 2π Internal-Gas-Flow Counter, PC-5

  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)] utilizing the well of the PC-5 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.

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 PC Counter, with the source leveled to a 2π geometry. The alpha reading was found to be 4.7×10^4 cts/min or $4.7 \times 10^4 \div 0.50 = 9.4 \times 10^4$ dis/min with the PC counter. The operation of the PC counter is routinely verified using an NBS traceable ^{239}Pu standard.

The same uranium source, when counted in the alpha mode of the Hand Pac was found to be 1.6×10^4 cts/min at contact. The conversion factor for counts per minute (cts/min) to disintegrations per minute (dis/min) for the Hand Pac is $9.4 \times 10^4 \div 1.6 \times 10^4 = 5.9$ dis/min per cts/min. A similar reading was indicated on the floor monitor, thus, indicating the same factor for converting normal uranium cts/min to dis/min from either the Hand Pac or the Floor Monitor in the alpha mode.

The same normal-uranium source, 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.

The composite beta-gamma count was found to be 5.2×10^5 cts/min or $5.2 \times 10^5 \div 0.50 = 1.04 \times 10^6$ dis/min.

Using the Hand Pac in the beta mode and in contact with the covered uranium source and centered on the probe, the count was found to be 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 per cts/min.

A similar reading was obtained with the Floor Monitor, thus indicating the same factor for converting normal uranium cts/min to dis/min from either the Hand Pac or the Floor Monitor in the beta mode.

II. SMEAR-COUNTING INSTRUMENTATION

The conversion factors for cts/min-100 cm^2 to dis/min-100 cm^2 when counting smears with the Mylar spun top are given below.

A. Counting Efficiency--Alpha

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

A geometry (g) of 0.43 is standard for all flat-plate counting using the 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 1.0, 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.

B. Counting Efficiency--Beta

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

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

A backscatter factor (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.

APPENDIX 3

RADON-DETERMINATION CALCULATIONS

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

I. BASIC ASSUMPTIONS AND COUNTING PARAMETERS USED

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

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

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 present at the end of the sampling period (dis/min)

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

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

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

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

The 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/

f = Sampling rate (m^3/min = m^3/h · 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).

III. EXAMPLE CALCULATION: Compressor Room

Data obtained from an air sample collected in the compressor room have l used below to illustrate the application of the equations for determi activity and concentration.

$$A_o = \frac{812}{\exp \frac{-0.693 \cdot 100}{36}} = 5568 \text{ dis/min}$$

$$C = \frac{5568 \cdot \frac{0.693}{36}}{40/60} \cdot \frac{1}{1 - \exp \frac{-0.693 \cdot 40}{36}}$$

$$= 299 \text{ dis/min-m}^3$$

Since we assume that half of the radon progeny is not adhered to the a borne particulates, the above concentration of 299 dis/min-m^3 is multiplied two to determine the actual concentration. The resultant concentration thus 598 dis/min-m^3.

APPENDIX 4

ANALYTICAL PROCEDURES FOR TOTAL URANIUM AND GAMMA-EMITTING NUCLIDES IN SOIL*

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 in 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.

---

*The procedures used by LFE Environmental Analysis Laboratories to analyze the soil samples 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 per abundance for each isotope, were obtained from the "Table of Isotopes" - Edition by C. M. Lederer and V. S. Shirley, 1978. The values used are:

Isotope	Half-life (years)	% Abundance
^{234}U	2.446×10^{5}	0.0054
^{235}U	7.038×10^{8}	0.720
^{238}U	4.4683×10^{9}	99.275
		100.0004

Note that the abundance totals 100.0004%. Since it cannot be deter which isotope(s) are in error, the calculations are made with the 0.0004% e unaccounted for.

Specific activity, or activity per unit mass, is determined by the equa

$$SpA = \lambda N$$

Where:

SpA = Specific Activity

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

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:

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

$$SpA = \frac{0.693 \cdot 6.025 \times 10^{23}}{t_{\frac{1}{2}}\,(a) \cdot 5.2596 \times 10^{5} \frac{\text{min}}{\text{a}} \cdot \text{gram atomic weight}} = \text{dis/min-gram}$$

APPENDIX 5
(cont'd)

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

$$SpA\ ^{234}U = \frac{0.693 \cdot 6.025 \times 10^{23}}{2.446 \times 10^{5} \cdot 5.2596 \times 10^{5} \cdot 2.34 \times 10^{2}}$$

$$= 1.39 \times 10^{10} \text{ dis/min-gram}$$

$$= 1.39 \times 10^{4} \text{ dis/min-}\mu g \cdot 5.40 \times 10^{-5}$$

$$= 0.749 \text{ dis/min-}\mu g \text{ of normal uranium}$$

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

$$SpA\ ^{235}U = \frac{0.693 \cdot 6.025 \times 10^{23}}{7.038 \times 10^{8} \cdot 5.2596 \times 10^{5} \cdot 2.35 \times 10^{2}}$$

$$= 4.80 \times 10^{6} \text{ dis/min-gram}$$

$$= 4.80 \text{ dis/min-}\mu g \cdot 7.20 \times 10^{-3}$$

$$= 0.0346 \text{ dis/min-}\mu g \text{ of normal uranium}$$

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

$$SpA\ ^{238}U = \frac{0.693 \cdot 6.025 \times 10^{23}}{4.4683 \times 10^{9} \cdot 5.2596 \times 10^{5} \cdot 2.38 \times 10^{2}}$$

$$= 7.47 \times 10^{5} \text{ dis/min-gram}$$

$$= 0.747 \text{ dis/min-}\mu g \cdot 9.9275 \times 10^{-1}$$

$$= 0.741 \text{ dis/min-}\mu g \text{ of normal uranium}$$

Therefore, the activity of 1 μg of normal uranium is

$$0.749 \text{ dis/min } ^{234}U + 0.0346 \text{ dis/min } ^{235}U + 0.741 \text{ dis/min } ^{238}U$$

$$= 1.525 \text{ dis/min.}$$

APPENDIX 5
(cont'd)

Conversion of μg/g to pCi/g

$$= \frac{1.525 \text{ dis/min-}\mu g}{2.22 \text{ dis/min-pCi}} = 0.6869 \text{ pCi/}\mu g \text{ normal uranium}$$

Example Calculation: 6-S1-A

$$2.1 \pm 0.8 \frac{\mu g}{\text{gram}} \cdot \frac{0.6869 \text{ pCi}}{\mu g} = 1.4 \pm 0.5 \text{ pCi/gram}$$

APPENDIX 6

EVALUATION OF POTENTIAL RADIATION EXPOSURES

I. PREFACE

The U. S. Department of Energy has initiated a program to determine the present radiological condition of sites formerly used by the Manhattan Engineering District (MED) and the Atomic Energy Commission (AEC). One such facility is the Universal Cyclops, Inc., Titusville Plant (formerly Vulcan Crucible Steel Co.) in Aliquippa, Pennsylvania.

This facility was used in the 1940s by the Manhattan Engineering District/Atomic Energy Commission (MED/AEC) to roll uranium billets produced elsewhere. After rolling, the finished rods were boxed and shipped for use elsewhere.

Review of correspondence between the AEC and Vulcan Crucible Steel Company indicated that a major decontamination effort was completed in 1950. However, because documentation was insufficient to determine whether the decontamination work done at the time nuclear activities ceased is adequate by current guidelines, a comprehensive radiological assessment of the Titusville Plant was undertaken in May, 1978.

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.

APPENDIX 6
(Cont'd.)

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.

APPENDIX 6
(Cont'd.)

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.

APPENDIX 6
(Cont'd.)

The external penetrating radiation dose to man derives from both terrest rial radioactivity and cosmic radiation. The terrestrial component is du primarily to the gamma dose from potassium-40 and the radioactive decay product of thorium-232 and uranium-238 in soil as well as from the beta-gamma dose fro radon daughters in the atmosphere. Radon is a gaseous member of the uranium-23 chain. The population-weighted external dose to an individual's whole body fro terrestrial sources in the United States has been estimated as 15 mrem per yea for the Atlantic and Gulf Coastal Plain, 57 mrem per year for an indeterminat area along the Rocky Mountains, and 29 mrem per year for the majority of th rest of the United States. The overall population-weighted external dose fo 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 fro secondary cosmic rays, is typically about 30% to 50% of the total from al external environmental radiation. The cosmic-ray dose to the population i estimated to be 26 mrem per year for those living at sea level, and increase with increasing altitude. Considering the altitude distribution of the U.S population, the population-weighted external cosmic-ray dose is 28 mrem pe year. The population-weighted total external dose from terrestrial plus cosmi sources is thus 54 mrem per year for the U.S. population as a whole.

The internal radiation doses derive from terrestrial and cosmogenic radio nuclides deposited within the body through uptake by inhalation/ ingestion o air, food, and drinking water. Once deposited in the body, many radioactiv materials can be incorporated into tissues because the chemical properties o the radioisotopes are identical or similar to stable isotopes in the tissues Potassium-40, for instance, is incorporated into tissues in the same manner a stable potassium atoms because the chemical properties are identical; radio active radium and strontium can be incorporated into tissues in the same manne as calcium because their chemical properties are similar. Once deposited i tissue, these radionuclides emit radiation that results in the internal dose t 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 o polonium-218 and -214 (radon daughters), lead-212 and bismuth-212 (thoron daugh ters) and polonium-210 (one of the longer-lived radon decay products). The dos to the lung is about 100 mrem per year from inhaled natural radioactivity. Th internal dose from subsequent incorporation of inhaled or ingested radioactivit is due to a beta-gamma dose from incorporation of potassium-40, rubidium-87, an cosmogenic nuclides, and an alpha dose from incorporation of primaril polonium-210, radium-226 and -228, and uranium-238 and -234. The dose to ma from internally incorporated radionuclides is about 28 mrem per year to th 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 arise primarily from the alpha-emitting members of the naturally occurring series with polonium-210 being the largest contributor. The gonadal and soft tissu doses arise primarily from the beta and gamma emissions from potassium-40. Th total internal dose from inhaled plus incorporated radioactivity is about 2 mrem per year to the gonads (or whole-body dose), about 125 mrem per year to th lung, about 25 mrem per year to the bone marrow, and about 117 mrem per year t the bone (osteocytes).

APPENDIX 6
(Cont'd.)

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 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.

APPENDIX 6
(Cont'd)

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.

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

APPENDIX 6
(Cont'd)

one marrow and 1500 mrem per year to other organs. The limits for population roups of the public are 170 mrem to the whole body, gonads, or bone marrow and 00 mrem per year to other organs, averaged over the group. In either case, xposures are to be limited to the lowest levels reasonably achievable within iven limits.

V. RESULTS OF SITE RADIOLOGICAL SURVEY

A radiological survey was performed at the Universal Cyclops, Inc. Titus-ille Plant (formerly Vulcan Crucible Steel Company) from May 2 to May 8, 1978. ie results of the comprehensive radiological survey indicated that some con-amination was present on the floors and overhead beams in the facility.

A. Radiation Exposure Potential

The levels of radon-daughter products found in the Universal Cyclops facil-:y ranged from 0.0011 to 0.0027 WL. According to the Surgeon General's Guide-ines, concentrations of radon daughters of less than 0.01 WL do not require emedial action in any structures, including schools and private dwellings.

None of the GM exposure readings taken at 1 m were distinguishable from the :ea background of 0.03-0.05 mR/h. A person exposed to 0.05 mR/h for a normal)rk year of 2000 hours would receive 100 mR. A continual exposure of 100 mR/yr) penetrating gamma radiation is estimated to possibly increase the risk of :ath due to all types of cancer by less than 1%.* In Table 6.1 guide lines for ie general public and radiation workers are compared with typical background :vels and the levels found at the Cyclops site.

A hypothetical situation involving flame cutting or welding of a contam-iated overhead beam was considered in order to assess the potential radio-)gical hazard of a potential worst case scenario. If the situation involved ie entire surface area with the maximum contamination found (930 cm^2), a total 2.9 x 10^5 dis/min or 6.5 x 10^{-2} μCi (as normal uranium) would be available. suming 95% of this radioactivity became airborne when torched, and further suming stagnant air conditions at this height, it is postulated that the dioactive aerosol would be confined to 10 m^3 of air.

This disturbance would thus result in a uranium concentration that is 3300 mes greater than the Maximum Permissible Concentration in Air (MPC_a) for anium in an uncontrolled area. However, a person breathing this aerosol for min would receive only 1.1% of the Maximum Permissible Burden based on the dneys as the critical organ.

---

he Effects on Populations of Exposure to Low Levels of Ionizing Radiation, eport of the Advisory Committee of the Biological Effects of Ionizing Radia-ions (BEIR).

APPENDIX 6
(Cont'd)

B. Remedial Measures

Most of the contamination in the facility was confined to localized spots ($\leqq$ 2000 cm^2) on the dirt floor and steel floor plates. Most of contamination found on the floor was not easily removable. Loose contamination was found on the overhead beams and on the floor.

Although the risks associated with the present use of the facility, are acceptable, remedial measures would be indicated to bring the site within appropriate standards. This would include the removal of radioactive residues from 12 locations within the building. In addition, in-place stabilization and restriction of future use to avoid activities that would require building modifications (thereby resulting in disturbance of radioactive materials) might be indicated.

C. Summary

In summary, some areas of the former Vulcan Crucible Steel Facility are contaminated. These areas do not pose a significant risk to the present occupants, but do in a few cases exceed accepted guidelines. Remedial measures are indicated to bring the contaminated areas within these guidelines and to reduce the risk in the event that future building modifications take place.

Table 6.1. Comparison of Radiation at the Cyclops Site with Natural Background and Guideline Values

Exposure Source	Background Levels	Guideline Value for General Public[a]	Guideline Value for Radiation Workers	Level of Activity at Cyclops Site
Radon in air	Less than 1 picocurie[b] per liter of air	Continuous exposure to 3 picocuries per liter of air	Exposure for 40 hours per week to 30 picocuries per liter of air	0.11 to 0.27 picocurie per liter of air
Radon daughters in air	Less than 0.01 Working Level[c]	0.01 Working Level for residences and school rooms, and 0.03 Working Level for other structures	0.33 Working Level for uranium miners exposed for 40 hours per week and 50 weeks per year	0.0011 to 0.0027 Working Level
External gamma radiation	0.000011 Roentgens[d,e] per hour (0.10 Roentgens per year)	0.17 Roentgens per year, population average; equivalent to 20 micro-Roentgens per hour above natural background (0.50 Roentgens per year to an individual; equivalent to 60 micro-Roentgens per hour)	5 Roentgens per year	0.06 to 0.10 Roentgens per year

[a]Based on 40 hours per week, 52 weeks per year occupancy.

[b]The picocurie is a unit used to express the amount of radioactivity present in a substance (1 picocurie = 0.000000000001 curie or 10^{-12} curie).

[c]The Working Level is a unit defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

[d]The Roentgen is the unit of exposure to penetrating gamma radiation. A microRoentgen is one millionth of a Roentgen.

[e]This is the average value. It will vary from area to area.

Distribution

Internal:

E. S. Beckjord
J. G. Ello
P. R. Fields
K. F. Flynn
A. L. Justus
J. H. Kittel
R. L. Mundis
D. P. O'Neil
R. E. Rowland
C. M. Sholeen
W. H. Smith
R. A. Wynveen
OHS/HP Publications File (16)
ANL Patent Dept.
ANL Contract File
ANL Libraries (4)
TIS Files (6)

External:

DOE-TIC, for distribution per UC-70A (141)
Manager, Chicago Operations Office, DOE
E. J. Jascewsky, DOE-CH (10)
W. E. Mott, Office of Operational Safety, DOE (50)
President, Argonne Universities Association