EXPERIMENTAL STUDY OF RN-222
RELEASE CHARATERISTICS FROM
TAILINGS AND SEDIMENTS AT
KERR MCGEE WEST CHICAGO FACILITY

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1.0 INTRODUCTION

Kerr-McGee Chemical Corporation ceased operation of its Rare Earths Facility located in West Chicago, Illinois, in December, 1973. Since that time, the company has been seeking an acceptable plan for decommissioning the facility and restoring the property for beneficial use. During the proposed activities, two piles containing radioactive material located in one portion of the facility are to be relocated and stabilized. This report presents the results of an experimental field program conducted by Dames & Moore for Kerr Mc-Gee Nuclear Corporation to provide more detailed information on the radiological and soils characteristics of thorium milling waste materials pertinent to the assessment of radon-222 releases from these materials.

The program was conducted in two parts. The first part was a field program to determine the radon-222 emanation rate (i.e., flux) from the surface of the tailings and the sediment waste piles. The second part of the program was designed to experimentally determine the parameters needed to calculate the radon-222 flux from these materials based on diffusion theory. Site and material-specific parameter values are thus made available for use in calculating the radon-222 flux for anticipated reclamation configurations.

2.0 FIELD MEASUREMENT PROGRAM

A site visit was made by Dames and Moore personnel on October 16, 1980 to aid in establishing the field and experimental programs and to obtain preliminary samples of tailings and sludge for laboratory analyses (see Section 3.0). The field program was begun two weeks later and is described below.

2.1 Sampling Locations

The two waste piles located at the Kerr McGee, West Chicago, facility exhibit slightly different characteristics. The tailings pile has a barren surface with furrows along the lateral portions and depressions on the level upper portion of the pile. The pile is very moist but has a thin dry crust, which becomes easily dispersible when broken loose. It is sufficiently rigid to support personnel, however, it cannot support heavy machinery.

The sediment pile is similiar, but its surface supports vegetation. Walking on [illegible]ms like walking on a spongy bog. Machinery easily sinks int[illegible] pile material. There are a few bare spots and the material at these spots have the appearence of moist, flaky, easily malleable oatmeal. This pile had few level portions on its upper regions, which was a deciding factor in the selection of the sampling locations.

The sampling locations selected for the experimental program for the tailings and sediment piles are presented in Figure 1. The measurements for the tailings pile were performed at locations T-1, T-2, and T-3, while those for the sediment pile were performed at locations S-1, S-2, and S-3. These locations were selected based on the pile configurations and the availability of suitable level portions.

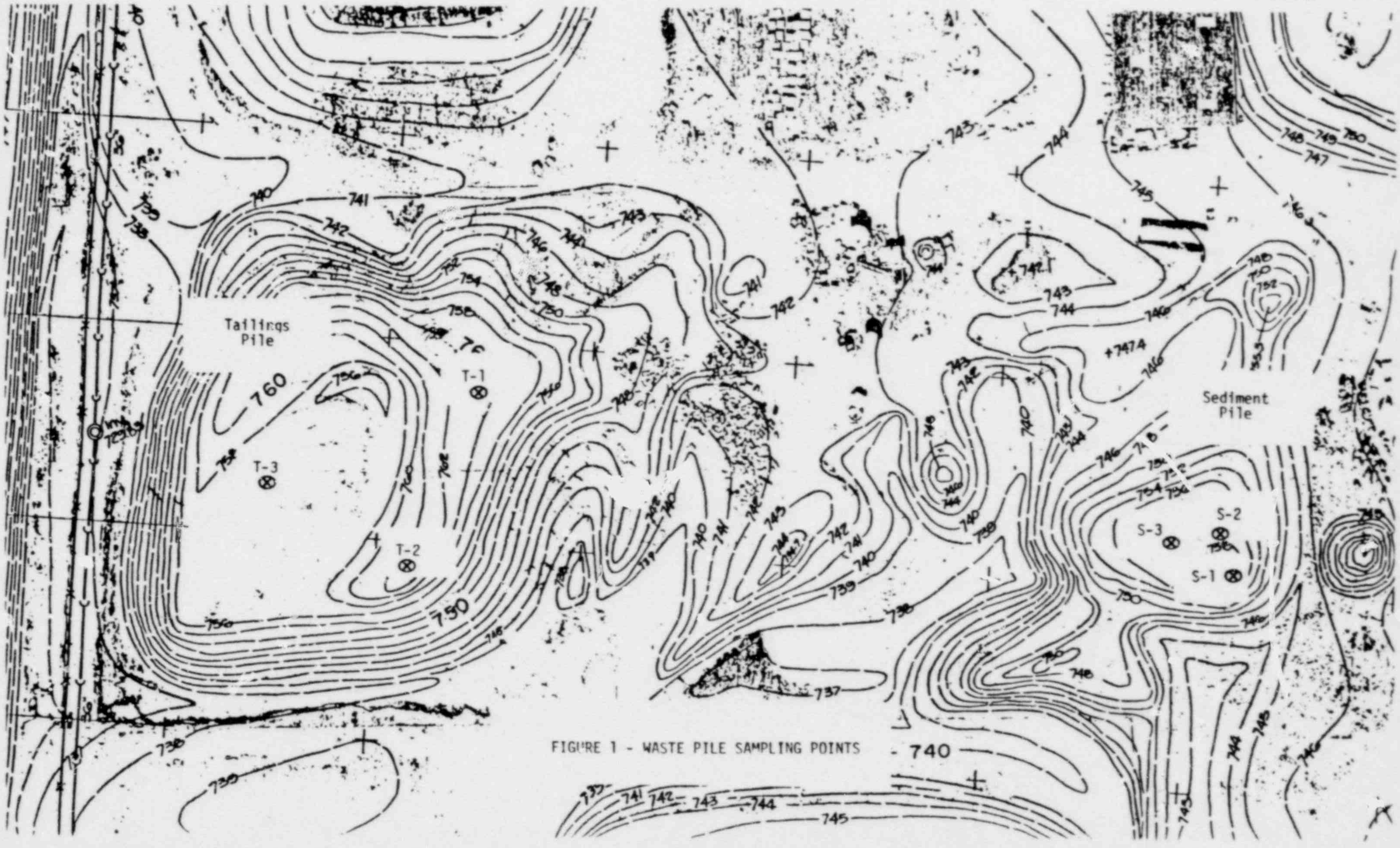


FIGURE 1 - WASTE PILE SAMPLING POINTS

2.2 Radon-222 Flux Measurements

Radon-222 flux measurements were performed by Dames and Moore personnel at the West Chicago facility during the period October 31 to November 9, 1980. The accumulator can method employed for flux determination is presented in Appendix A. The results of these measurements are presented in Table 1.

Relatively large variations in measured fluxes are seen in Table 1 for each pile. This is primarily caused by the non-homogeneous nature of the two piles as shown by the Ra-222 concentration data presented in the Kerr McGee stabilization plan. In that document, the tailings pile radium-226 content was shown to average 1172 ± 1068 pCi/g, and the sediment pile averaged 277 ± 123 pCi/g.

2.3 Moisture Profile

Moisture profiles were performed on cores taken from location T-2 on the tailings pile and location S-3 on the sediment pile. One foot depth increments, extracted using a post-hole digger, were placed in large plastic bags and tightly tied. After excavation of each depth interval, any loose material around the hole was removed to avoid contamination of the subsequent depths. After each core was finished, representive samples from the depth intervals were placed in zip-lock bags with the air "squeezed" out, and then doubled-bagged in zip-lock bags to minimize moisture loss. Moisture content analysis was performed the next day at a nearby Dames and Moore soils laboratory.

The results for the outside waste piles are presented in Table 2. The moisture content for the two piles varied very litle with depth, giving an overall average moisture content (± one standard deviation) for the tailings pile of 49.6 ± 3.6 percent by weight, and 61.0 ± 3.2 percent by weight for the sediment pile.

Table 1

Waste Pile Radon-222 Flux Measurements (pCi/m^2-s $\pm\sigma$)

Waste Pile	Site 1		Site 2		Site 3	
	date	flux	date	flux	date	flux
Tailings	10-31	672 ± 5	11-1	4,300 ± 1,230	11-2	11,700 ± 2,600
	10-31	696 ± 100	11-1	6,330 ± 590	11-2	6,600 ± 340
	11-1	400 ± 50	11-6	586 ± 40	11-2	10,100 ± 800
	11-6	69 ± 33	11-7	139 ± 59	11-7	517 ± 33
	11-6	565 ± 50			11-7	498 ± 14

Overall
Average: 3080 ± 4020

Waste Pile	Site 1		Site 2		Site 3	
	date	flux	date	flux	date	flux
Sediment	11-3	22 ± 31	11-4	7,510 ± 360	11-5	914 ± 1,676
	11-3	44 ± 10	11-4	5,970 ± 410	11-5	1,300 ± 140
	11-3	34 ± 7	11-4	6,120 ± 5,700	11-5	1,900 ± 150
	11-8	136 ± 50	11-8	99 ± 10	11-9	964 ± 248
	11-8	66 ± 5	11-9	1,870 ± 60	11-9	472 ± 87

Overall
Average: 1830 ± 2540

Table 2

Moisture Content Depth Profiles

Material	Location	Moisture Content (weight %) vs. Depth (feet) 0'-1'	1'-2'	2'-3'	3'-4'	0'-4'
Tailings	Outdoor Waste Pile-Site 2	44.9	50.0	49.9	53.8	49.6 ± 3.6
	Indoor Experimental Pile-Site 1	48.4	49.3	51.8	52.0	
	-Site 2	49.2	48.1	53.2	52.1	51.2 ± 2.4
	-Site 3	49.9	50.8	55.5	54.5	
	Average	49.2				
Sediment	Outdoor Waste Pile-Site 3	58.2	58.5	62.9	64.5	6.1 ± 3.2
	Indoor Experimental Pile-Site 1	70.9	68.8	64.6	67.9	
	-Site 2	66.0	65.6	67.2	72.3	67.9 ± 2.2
	-Site 3	67.8	66.6	68.7	68.5	
	Average	68.2				

3.0 EXPERIMENTAL PROGRAM

The outdoor waste piles appear sufficiently non-homogeneous to prevent adequate assessment of radiological and soils characteristics that are pertinent to radon-222 release parameters. Therefore an experiment was set up to measure these interrelated parameters in a controlled environment. The experimental program is described below.

3.1 Experimental Set-Up

Two large cylindrical steel tanks (5.5 ft diameter, 5.0 ft inside height) were set up in a heated warehouse (50-60°F range). Waste material was collected from each of the two piles by using a small backhoe. Excavated material was placed in a dumpster, which was then transported to the warehouse and its contents emptied into one of the tanks. About four trips were required to fill each tank, one with tailings material and one with sediment material. Therefore each load added approximately one foot of depth to the material in the tank. When the tanks were sufficiently full, the material was tamped down, more material added, and tamped down again to yield final material depths of just under five feet. Tamping was accomplished with the backhoe bucket.

3.2 Radon-222 Flux Measurements

The experimental tanks were filled with waste material by November 1, 1980. They were then allowed to stand undisturbed for one month to permit the establishment of equilibrium radon-222 flux conditions. The measurement program was thus begun on December 3, 1980.

Radon-222 fluxes were measured over an eight day period by the method described in Appendix A. A small (5 gallon) can was used to make measurements at three specific points on the material in each tank. These points were located equidistant from the center of the tank and the tank rim and positioned 120 degrees apart to obtain good surface coverage. Four measurements were made at each local site, yielding twelve measurements for each tank. Results are presented in Table 3.

Results show that a significant variation in flux occurs among the sampling points for the tailings material. Therefore the overall average flux (111 pCi/m^2-s) from that tank exhibits a standard deviation of about 65%. This represents a significant improvement over the standard deviation of 131% for field measurement.

Flux measurements from the tank containing sediments showed more uniformity than from the tailings tank, with little variation exhibited by site. The average flux (7.4 pCi/m^2-s) exhibited a standard deviation of about 49%, which is also significantly better than the standard deviation of 139% for measurements obtained from the outdoor pile.

3.3 Radiometric Analyses

Samples of tailings and sediment, collected from the outdoor waste piles during the initial site visit, were sent to a commercial laboratory for radiometric analyses. These analyses involved the measurement of the radium-226 content of the material and the radon emanation coefficient. The radon emanation coefficient is defined as the fraction of radon generated within a soil sample that is released to the interstitial spaces.

The methodologies employed in measuring the above two parameters are provided in Appendix B. Measurements were made on three replicates of single samples of each material. Results of analyses are presented in Table 4. Also presented are the radium-226 content determinations of six samples collected from the material deposited in the tanks.

Table 3

Experimental Program: Radon-222 Flux Measurements (pCi/m^2-s $\pm\sigma$)

Waste Pile	Site 1		Site 2		Site 3	
	date	flux	date	flux	date	flux
Tailings	12-3	178 ± 18	12-3	191 ± 30	12-4	18 ± 2
	12-3	216 ± 37	12-4	114 ± 7	12-4	13 ± 4
	12-7	133 ± 22	12-7	83 ± 4	12-8	158 ± 64
	12-7	147 ± 12	12-8	61 ± 4	12-8	16 ± 5
Overall Average:	111 ± 72					
Sediment	12-5	2.5 ± 0.2	12-5	12.1 ± 1.3	12-6	1.9 ± 0.8
	12-5	8.8 ± 3.8	12-6	3.6 ± 0.2	12-6	10.2 ± 2.3
	12-9	6.9 ± 0.4	12-9	10.0 ± 0.1	12-10	10.6 ± 0.0
	12-9	7.9 ± 1.4	12-10	3.7 ± 0.5	12-10	10.2 ± 1.7
Overall Average:		7.4 ± 3.6				

Table 4

Radiometric Analyses of Waste Material

Material	Sample	Ra-226 Content pCi/g	Radon Emanation Coefficient dimensionless
Outdoor Tailings	1	640	0.12
	2	660	0.22
	3	640	0.04
	$\bar{x} \pm$	647 ± 12	0.13 ± 0.09
Outdoor Sediment	1	660	0.20
	2	650	0.18
	3	660	0.04
	$\bar{x} \pm$	657 ± 6	0.14 ± 0.09
Indoor Tailings	1	590	*
	2	630	*
	3	610	*
	$\bar{x} \pm$	610 ± 20	
Indoor Sediments	1	85	*
	2	70	*
	3	77	*
	$\bar{x} \pm$	77 ± 7	

* Radon Emanation Coefficients for these samples were not available for inclusion in this report.

Results from the outdoor samples show that the radium-226 contents are consistent and essentially identical for both sediment and tailings piles. The radon emanation coefficients showed more variability among replicates, but sample means for each of the two materials were also essentially the same.

Additional samples were collected from the experimental tanks after flux measurements were completed. This was performed to assure the applicability of the outdoor concentrations in conjunction with the indoor flux determinations. However, the radium-226 content of the material from the indoor samples varied significantly between the sediment and tailings material. This is most likely due to the localized variability of the radium-226 concentrations. The second set of concentration measurements were utilized in conjunction with the indoor flux determinations.

3.4 Moisture Profiles

After completion of the radon flux measurements, core samples were collected at each flux point on each tank down to the bottom of the tanks. Samples were collected in one-foot increments. Each one-foot sub-sample was well mixed and an aliquot taken. The aliquots were double-bagged in zip-lock plastic bags and brought to a nearby Dames and Moore soils laboratory for measurement of moisture contents. These results are presented in Table 2 with the field depth-profile measurements.

Results show that moisture levels are very uniform within each tank, exhibiting little variation with depth and position of sample. Moisture levels are consistent with those measured in the outdoor waste piles. Both materials are very moist, with mean ($\pm$ one standard deviation) moisture levels of 51 $\pm$ 2 and 68 $\pm$ 2 percent by weight for tailings and sediments, respectively.

3.5 In-Situ Density

The bulk densities of the two materials were measured at each flux measurment point (before the cores were taken) using the standard sand-cone method (ASTM D-1556). Results are presented in Table 5. These results show that while both materials exhibit about the same wet bulk density (95 lbs/ft^3), the higher moisture content of the sediments results in a lower dry bulk density of 56 lb/ft^3 as compared to 64 lbs/ft^3 for tailings.

3.6 Soil Analyses

Bulk samples of tailings and sediments, collected during the initial Dames and Moore site visit, were sent to a Dames and Moore soils laboratory for testing. Two tests were performed on each material; a compaction test to determine moisture content vs. dry bulk density, and a particle size analysis to determine grain size distribution.

Results of compaction tests (ASTM D1557 Method A) are presented in Figures 2 and 3 for tailings and sediment, respectively. These figures show that the maximum dry densities attainable at optimum moisture content are 96.7 lbs/ft^3 for the tailings and 77.2 lbs/ft^3 for sediments. The dry density value determined for tailings is similiar to values expected for sand, but somewhat low for fine grained material such as these tailings (see Figure 4). The sediments are similarly fine-grained (see Figure 5), but the maximum dry density of 77.2 lbs/ft^3 is atypically low. The optimum moisture contents corresponding to maximum compaction are 29.5% for tailings and 53.2% for sediments.

The above values are compared in Table 5 to the conditions measured during the experimental program. The comparison shows that the tailings emplaced in the tank were compacted to 66.4% of the maximum and contained 167% of the optimum moisture, while sediments attained 72.9% of maximum dry density and 128% of the optimum moisture content.

SAMPLE NO. Bulk DEPTH ______ ELEVATION ______

SOIL Tailings

LOCATION ILL.

OPTIMUM MOISTURE CONTENT 29.5%

MAXIMUM DRY DENSITY 96.7 pcf

METHOD OF COMPACTION ASTM D1557 Method A

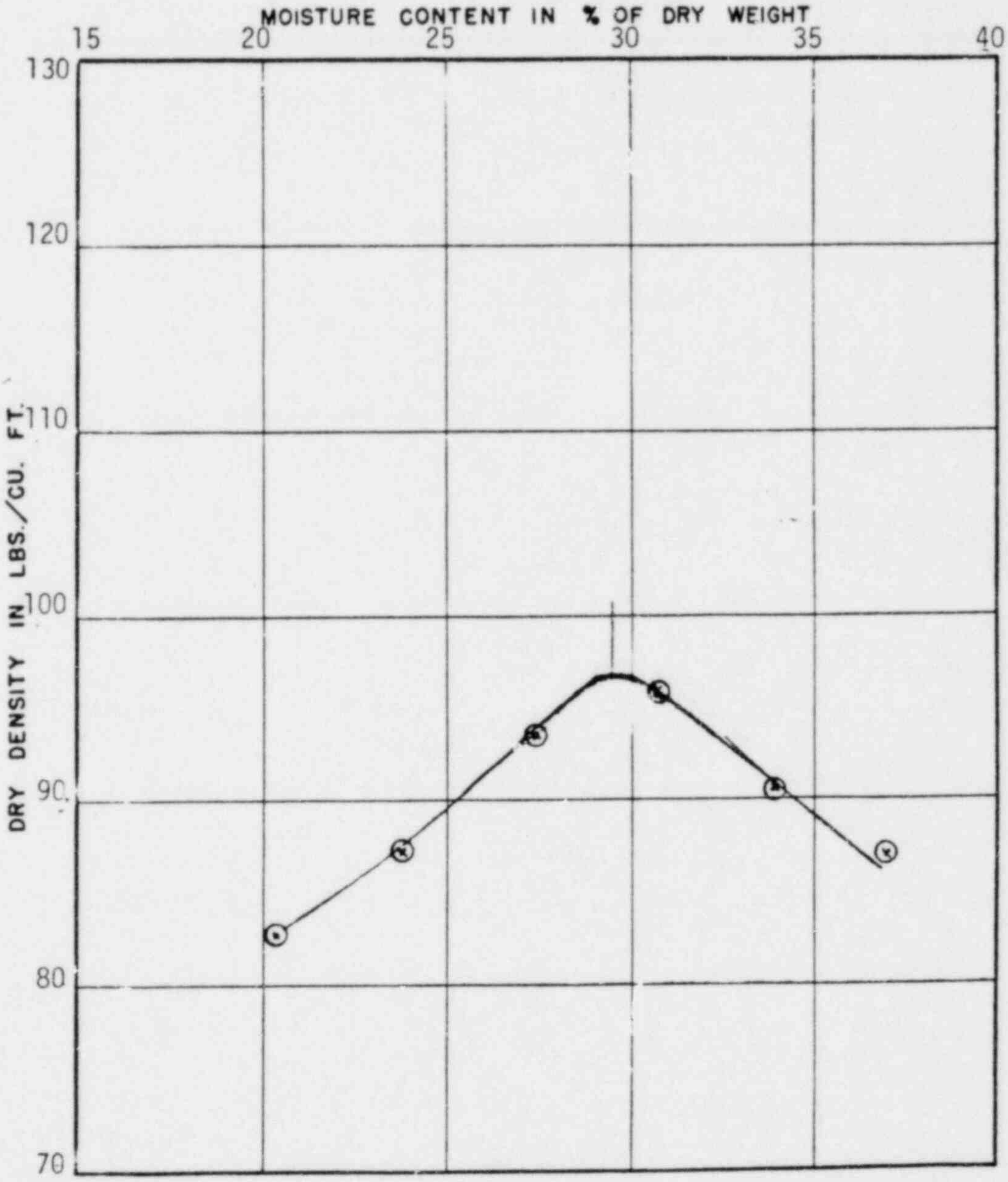


FIGURE 2. BULK SAMPLE: TAILINGS

COMPACTION TEST DATA

DAMES & MOORE

PLATE

DRAWN BY ______ DATE ______
CHECKED BY ______ DATE ______
REVISION 2 BY ______ DATE ______
REVISION 1 BY ______ DATE ______
FILE 09636-005-23

956.1 (REV. 4-57)

SAMPLE NO. Bulk DEPTH ______ ELEVATION ______
SOIL SEDIMENT
LOCATION ILL.
OPTIMUM MOISTURE CONTENT 53.2
MAXIMUM DRY DENSITY 77.2 pcf
METHOD OF COMPACTION ASTM D1557 Method A

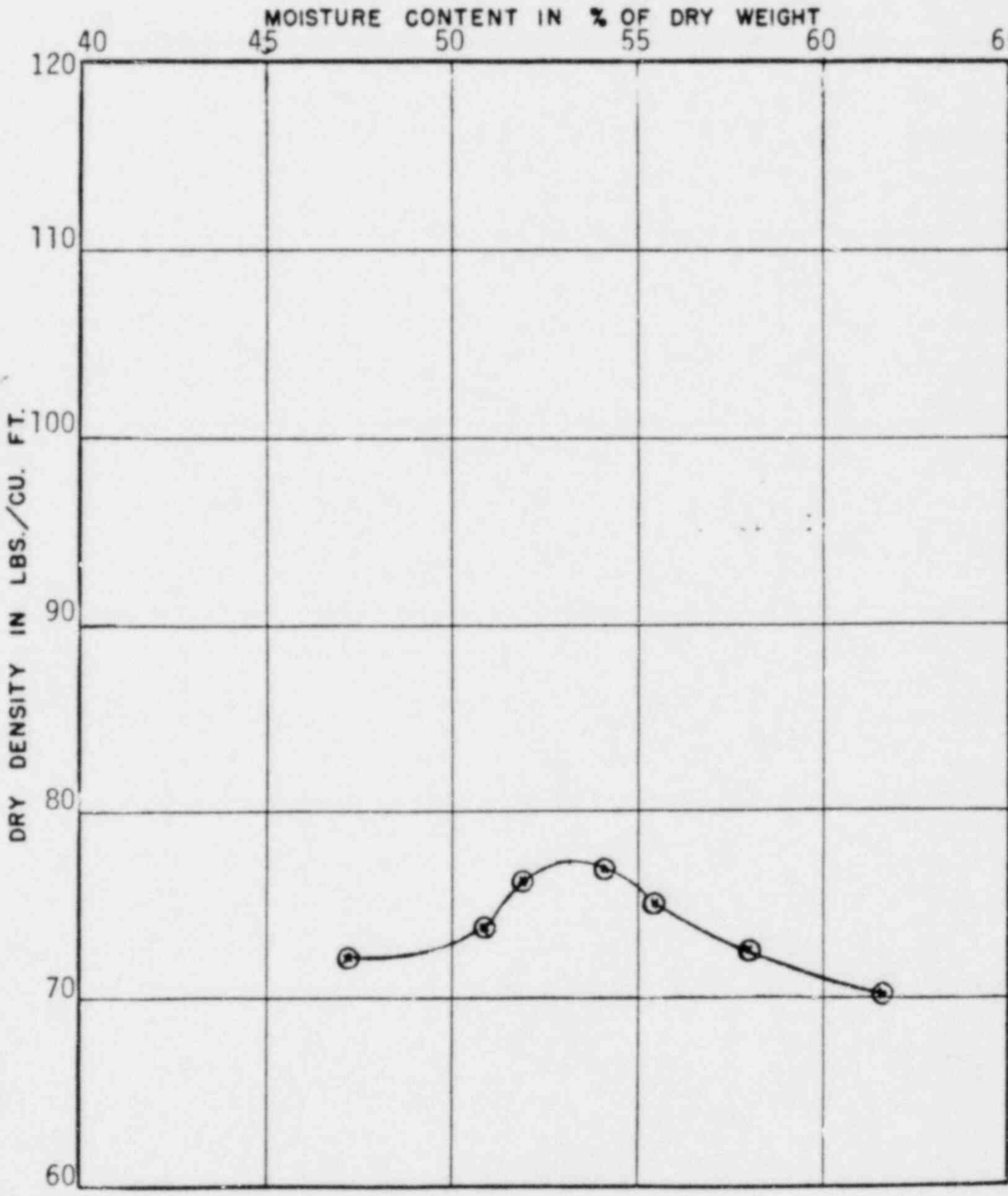


FIGURE 3. BULK SAMPLE: SEDIMENT

COMPACTION TEST DATA

DAMES & MOORE

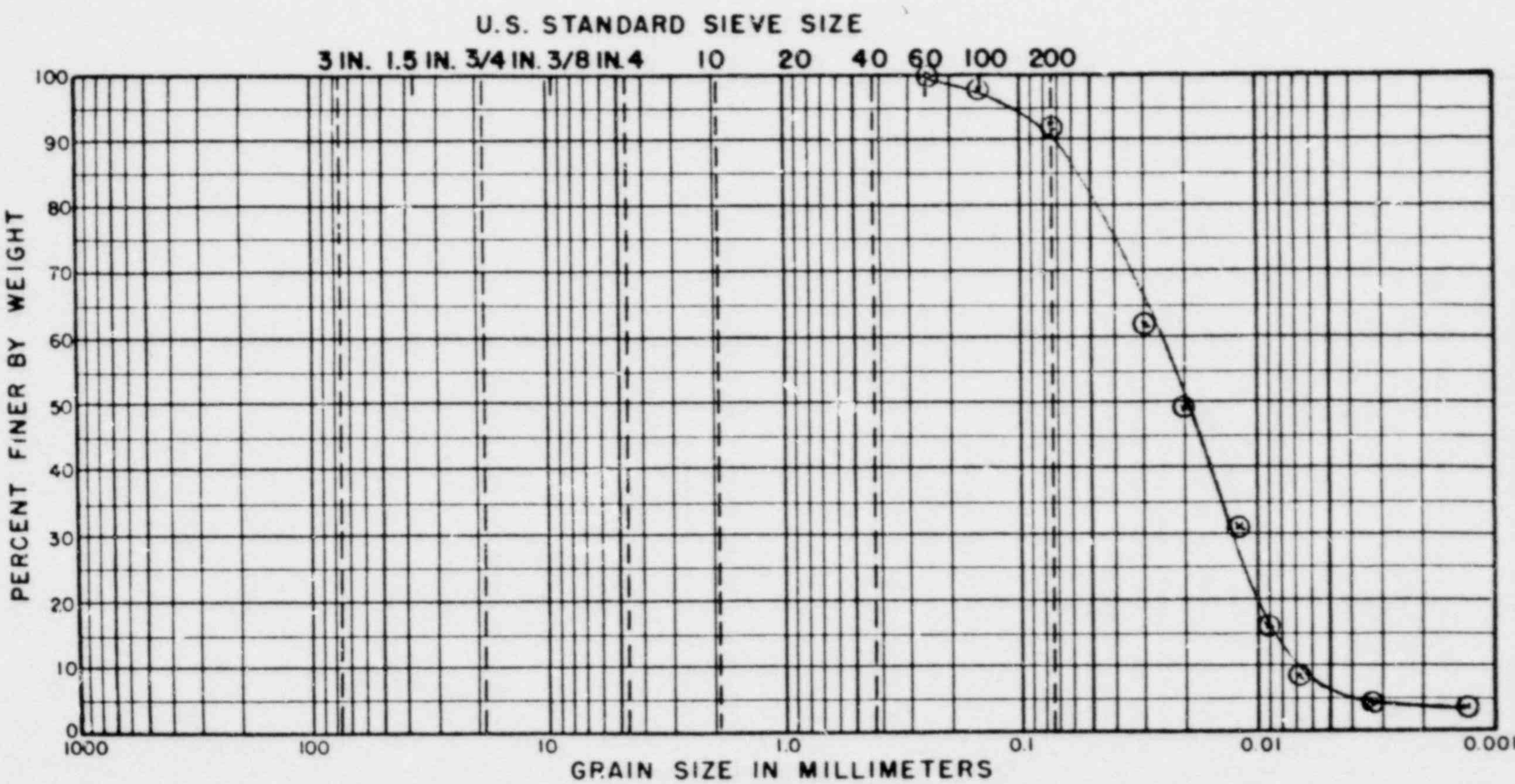
PLATE

DRAWN BY ______ DATE ______
CHECKED BY ______ DATE ______
REVISION 2 BY ______ DATE ______
REVISION 1 BY ______ DATE ______
FILE 09838-005-23

956.1 (REV. 4-57)

FILE 09E36-005-23
BY ______ DATE ______
CHECKED BY ______ DATE ______

RE ______
BY ______ DATE ______
BY ______ DATE ______
PLATE ______ OF ______



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT. WC	LL	PL.	PI	

Figure 4. BULK SAMPLE: TAILINGS

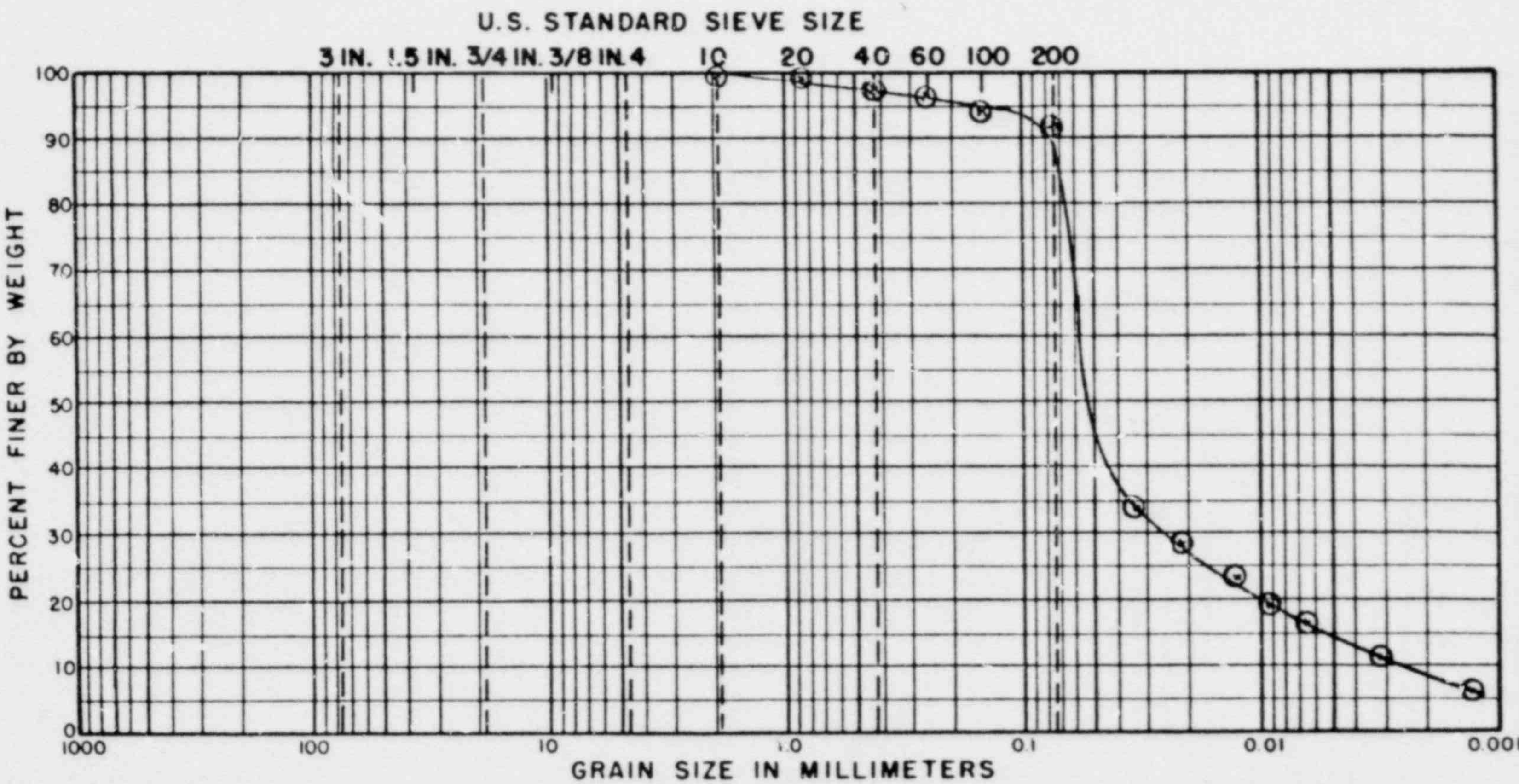
GRADATION CURVE

DAMES & MOORE

757 1 (REV. 4-62)

09838-005-23

FILE		REVISIONS	
BY	DATE	BY	DATE
CHECKED BY	DATE	BY	DATE
		PLATE	OF



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	

Figure [illegible]. BULK SAMPLE [illegible] SEDIMENT

GRADATION CURVE

DAMES & MOORE

797.2 (REV. 4-83)

Table 5

Experimental Program: Density and Moisture Data

Material	Wet Density lbs/ft³	Moisture Content Weight %	Dry Density lbs/ft³	% of Maximum Compaction	% of Optimum Moisture Content
Tailings					
Site 1	93.9	49.2	62.9		
Site 2	93.6	49.2	62.7		
Site 3	100.3	49.2	67.2		
Average	95.9	49.2	64.2	66.4	167
Sediment					
Site 1	93.5	68.2	68.5		
Site 2	98.3	68.2	58.4		
Site 3	92.5	68.2	55.0		
Average	94.8	68.2	56.3	72.9	128

Tailings Maximum dry density = 96.7 lbs/ft^3 at 29.5% moisture.
Sediment Maximum dry density = 77.2 lbs/ft^3 at 53.2% moisture.

The above analyses indicate that stabilized tailings and sediments, which currently contain approximately 50% and 60% moisture by weight, respectively (see Table 2), can be expected to lose some moisture when compacted. They should, however, also naturally retain moisture at levels of approaching 30% and 50% by weight for tailings and sludge, respectively.

3.7 Diffusion Coefficient

The release of radon from a finite layer of material can be calculated based on diffusion theory as follows:

$$J = E \rho C \sqrt{\lambda D} \left[\tanh \left(t \sqrt{\lambda / D} \right) \right] \times 10^4$$

where:

- J = radon flux from the material surface, pCi/m^2-s;
- E = radon emanation coefficient, dimensionless;
- ρ = dry solids density of the bulk material, g/cm^3;
- C = radium concentration in the solids, pCi/g;
- λ = radon decay constant, $2.1x10^{-6}s^{-1}$ for radon-222;
- D = radon diffusion coefficient, cm^2/s;
- tanh = hyperbolic tangent, dimensionless;
- t = thickness of the material, cm;
- 10^4 = factor to convert cm^2 to m^2, dimensionless.

The results of the experimental program have provided material-specific values for each of the above parameters except for D, the diffusion coefficient. Therefore, D can be obtained by substituting experimental values for all parameters except J and D into the above equation, and then substituting in various values for D and solving the equation in reiterative fashion until the calculated flux equals the measured flux. The D value that yields the correct flux is thus the diffusion coefficient of the tested material.

The above iterative calculational procedure was performed by computer and yielded diffusion coefficients of 9.9×10^{-3} cm^2/s for tailings and 2.2×10^{-3} cm^2/s for sediments. Individual parameter values used in determining D are summarized in Table 6.

Table 6

Summary of Experimental Radon Diffusion Parameters

Parameter Name	Symbol	Units	Values	
			Tailings	Sludge
Flux (Rn-222)	J	pCi/m^2-s	111	7.4
Emanation Coefficient	E	dimensionless	0.13	0.14
Dry bulk solids density		g/cm^3	1.00	0.88
Radium-226 Concentration in solids	C	pCi/g	610	77
Radon-222 Decay Constant		s^{-1}	2.1×10^{-6}	2.1×10^{-6}
Test material thickness	t	cm	145	140
Calculated Rn-222 Diffusion Coefficient	D	cm^2/s	9.9×10^{-3}	2.2×10^{-3}

APPENDIX A

A.0 Radon Flux Measurement Methodology

A.1 Sampling Methodology

Radon flux is measured using the accumulator can method described by Bernhardt and others (1975). In that method, a steel drum with one open end is placed on the ground with the open end down. The drum is sealed to the ground by piling soil around the rim and tamping down the soil. The drum is equipped with a sample port and a pressure equalization port so that the drum pressure remains at barometric pressure. The radon concentration within the drum increases linearly with time as radon emanating from the ground is trapped.

The buildup of radon inside the drum is monitored by sampling at approximately 30, 60, and 90 minutes after placement of the drum. More frequent intervals (e.g., 10, 20, and 30 minutes) are used if relatively high fluxes are anticipated. Air is withdrawn from the drum using a recirculating sampling system. The system is connected to the sampling and pressure equalization ports and consists of a small battery-powered air pump (MSA Monitair Sampler, Model S), a desiccator, a 47 mm glass fiber filter (Gelman, Type A/E), and an alpha scintillation cell. The desiccator and filter prevent introduction of moisture and particulate radon daughters into the cell.

The air pump is set at a flow rate of approximately 3.8 l/min and runs for about 3 minutes, thus resulting in 8 air changes in the 1.4 liter cell. This is sufficient to completely replace the nitrogen initially contained in the cell. Sampling data recorded on the Radon Sampling Data Sheet (Table A-1) include location, date, time of drum placement, time of sampling, sample pumping duration, and pump setting. Relevant meteorology conditions are also recorded.

TABLE A-1

Radon Sampling Data Sheet

Job Name________________________ Job No.________________________
Investigator________________________ Sample Type________________________
Site Location________________________ Sampler No.________________________

Run #	1	2	3
Field Data:			
Cell #			
Sampling: Start-Date			
-Time			
Stop-Date (Low-Vol. Radon Samplers Only)			
-Time (Low-Vol. Radon Samplers Only)			
Midpoint-Date (Low-Vol. Radon Samplers Only)			
-Time (1) (Low-Vol. Radon Samplers Only)			
MSA Pump: Setting			
Pump Start Time (1) (Flux Only)			
Pumping Duration (min)			
Ambient Conditions:			
Wind Speed (Est)			
Temperature			
Cloud Cover (Est)			
Barometric Pressure			
Counting Data:			
Start-Date			
-Time			
Duration (min)			
Mid Time (2)			
Sample:			
Gross Counts			
Count Rate ±σ (cpm)			
Background:			
Gross Counts			
Count Rate ±σ (cpm)			
Cell LLD (pCi/l)			
Radon Concentration Calculations:			
Net Sample Count Rate ±σ (cpm)			
Cell Factor ±σ (k)			
Radon Concentration ±σ (pCi/l)			
Decay Time (ΔT = 2-1)			
Corrected Radon Conc. ±σ (pCi/l)			
Cell Purge: Date			
Time			

Comments:

A.2 Counting Procedures

Exposed scintillation cells are held before counting to allow ingrowth of alpha-emitting radon daughters. The minimum holding time of 2.5 hours assures that daughter activities reach at least 95 percent of equilibrium. Equilibrated cells are counted using an Eberline SAC R-5 photomultiplier tube and Eberline MS-2 portable scaler/power supply. The time that counting begins, the counting time (duration), and the gross sample counts are recorded on the sheet in the field notebook.

Immediately after counting, the cell is purged with nitrogen. After at least four hours, the nitrogen-filled cell is counted to determine the background count rate for the next cell exposure. The date, time, counting time, and background counts are recorded in the field notebook. Background data are then transferred to the sample data sheet prior to the next cell exposure.

Calibration and performance testing are described in Section A.4.

A.3 Data Processing

Calculation of radon flux involves linear regression analysis of radon concentrations versus time. Radon concentrations and counting errors are calculated using Equations A-1 and A-2, respectively. The lower limit of detection (LLD) is also calculated using Equation A-3, although undetectable radon concentrations are rarely encountered in flux determinations.

$$\text{Radon Conc. (pCi/l)} = \frac{\left(C_s/t_s - C_b/t_b\right)}{K \times DF} \quad \text{(A-1)}$$

$$\text{Counting Error (pCi/l)} = \frac{\sqrt{C_s/t_s^{\,2} + C_b/t_b^{\,2}}}{K \times DF} = \sigma \quad \text{(A-2)}$$

$$LLD\ (pCi/l) = 4.66 \frac{\sqrt{C_b/t_b^2}}{K \times DF} = 4.66\sigma_b \quad (A-3)$$

where:

C_s = gross sample counts,

C_b = background counts,

t_s, t_b = sample and background counting times, respectively (min),

K = cell calibration factor (pCi/l/cpm), and

σ = standard deviation of the net sample concentration

σ_b = standard deviation of the net background concentration

DF = exp $(-\lambda t)$, radon decay factor

where:

λ = radon decay constant (4.535×10^{-4} min^{-1}), and

t = elapsed time betwen the midpoint of sample collection (pumping time) and the midpoint of counting.

Determination of the cell calibration factor is discussed in Section A.4.

Since all cells are held to allow alpha-emitting daughters to reach equilibrium before counting (including counting to determine efficiency), the correction for incomplete ingrowth discussed by Lucas and Woodward (1964) is not necessary.

The radon concentrations obtained increase linearly with time, as described by the equation:

$$y = mx + b \quad (A-4)$$

where:

y = radon concentration (pCi/l) at time, t,

m = slope (pCi/l-sec),

x = elapsed seconds between placement of drum and time, t, and

b = ambient air radon concentration (pCi/l).

The slope, m, is determined using standard linear regression methods (Natrella, 1966). The radon flux (pCi/m^2-sec) is then obtained by multiplying the slope by the drum factor (l/m^2). The drum factor is the ratio of the drum volume (in liters) to the surface area (in square meters) of the open end. The one sigma (standard deviation) error in the flux is estimated as the drum factor times the square of the variance of the slope.

A.4 Calibration and Performance Testing

Alpha Scintillation Cells

The zinc sulfide-coated alpha scintillation cells are calibrated every six months or each time the coating is replaced, whichever is more frequent. The cells to be calibrated are connected in series to the sampling system described in Section A.1 and placed inside the Environmental Radon Chamber at the Environmental Measurement Laboratory (EML) of the U.S. Department of Energy (located in New York City), whose cooperation is gratefully acknowledged. The air pump is allowed to run for 5-10 minutes. The cells are then sealed and the actual radon concentration in the chamber obtained from the EML staff. The cells are returned to the Dames & Moore offices and, after allowing four hours ingrowth, the cells are counted as described in Section A.2. The cell factors are then calculated using Equation A-1 after substitution of the chamber radon concentration.

Counting Equipment

Each time the counting equipment, described in Section A.2, is moved to a new location, the proper high voltage setting must be established. This is accomplished by placing a thor.um-230 source on a thin sheet of zinc sulfide in the center of the photomultiplier tube. Counts obtained in 2-minute periods are plotted versus high voltage to determine the optimum high voltage setting (about 100 volts upscale from the onset of the "plateau region"). After setting the high voltage to the optimum setting, the thorium-230 source is re-counted for 10 minutes. The counts obtained are then compared to the expected value, which is typically slightly less than 50 percent of the source alpha-emission rate since the counting geometry is 2 . If the source count rate differs from the expected count rate by more than 4-5 percent in a 10-minute count, instrument operation is considered to be improper and steps are taken to determine and correct the cause before any samples are analyzed.

Air Pump

The MSA air sampling pump is calibrated prior to each field program. Airflow rate versus rotometer setting is determined by measuring the time required for a soap bubble film to move a given number of graduations in a large-diameter volume-calibrated glass tube. Burets or graduated cylinders are normally used.

Recordkeeping

Records of all calibrations and tests are kept in a radon field notebook.

REFERENCES

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