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RADON AND RADON FLUX MEASUREMENTS AT THE FEED MATERIALS PRODUCTION CENTER FERNALD, OHIO AUGUST 6, 1985

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REPORT

MLM-MU-85-68-0001

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Phyllis J. Gephart, and Clifford R. Rudy

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SUMMARY

Results of time integrated measurements of radon in air in the environs of the K-65 residue storage tanks and radon flux from the concrete surfaces of the tanks at the Feed Materials Production Center, Fernald, Ohio are reported. Radon concentration measurements were made over the period from September 20, 1984 to February 5, 1985. Radon flux measurements were performed in October, 1984. Average radon concentrations at seventeen locations ranged from 0.24 to 5.1 pCi/liter. The highest radon concentration values were at the fenceline immediately surrounding the residue storage tanks. Levels within the site production area ranged from approximately 0.5 to approximately 1 pCi/liter which are below the DOE guideline value of 3.0 pCi/liter above background for uncontrolled areas and well below the 100 pCi/liter value for occupational exposures. The highest radon concentration found at the site boundary fence was 0.46 pCi/liter on the western perimeter. Radon flux measurements made utilizing charcoal canisters at 24 locations on each tank ranged from 13 pCi/m²/sec to 3 x 10^7 pCi/m²/sec on surfaces which contained obvious cracks. Recommendations are presented to continue radon monitoring and to apply a sealant to the surfaces of the tanks to inhibit the transport of radon.

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INTRODUCTION

In August, 1984, Oak Ridge National Laboratory and Monsanto-Mound were requested by the Department of Energy, Oak Ridge Operations Office, to assess the radon release in the environs of two K-65 residue storage tanks at the National Lead of Ohio, Incorporated site, Fernald, Ohio.

A proposal was subsequently prepared by Monsanto-Mound and submitted to Oak Ridge National Laboratory. The proposal outlined a monitoring effort which would involve: 1) the measurement of the concentrations of radon in air in the environs of the K-65 residue storage tanks and 2) the measurement of radon flux from the concrete surfaces of the tanks.

The results of radon monitoring over the period from September 20, 1984 to February 5, 1985 and of radon flux measurements performed in October, 1984 are presented in this report.

METHODS AND INSTRUMENTATION

A. Radon Measurement Methods

Time-integrated measurements of radon in air were made using Passive Environmental Radon Monitors (PERMs)[1]. These instruments were developed at the Environmental Measurements Laboratory (DOE), and are manufactured by EDA Instruments, Incorporated, Toronto, Canada.

In the Passive Environmental Radon Monitor, radon concentration is measured by exposure of a thermoluminescent dosimeter (TLD) chip of lithium fluoride. The subsequent readout of the chip permits the calculation of the radon concentration since the response of the TLD chip per unit concentration and per unit time is determined by prior calibration. The monitors are typically exposed for one-week time periods. A number of two-week exposures were made also with the monitors during the December, 1984 through February, 1985 time period.

The radon monitoring network at the Feed Materials Production Center, Fernald, Ohio consists of a series of monitors surrounding the K-65 residue storage tanks at the fenceline immediately around the tanks, and at successively increasing distances from the tanks. The greatest concentration of monitors was emplaced east of the tanks since the fenceline of the production area is just over 1000 feet from the tanks in the downwind direction.

Figure 1 shows the locations of monitors in the network at the Feed Materials Production Center, Fernald, Ohio. All monitors are located onsite with monitors #15, #17, and #18 being at site boundaries adjacent to nearby roads at sampling stations already used by National Lead of Ohio, Incorporated for other monitoring activities. The prevailing winds in the region are generally southwest to northeast.

Measurements of radon in air in the environs of the K-65 residue storage tanks were initiated by Monsanto-Mound on September 20, 1984. Six monitors were emplaced on this date. Subsequently, six additional monitors were installed on September 27, three on October 18, and two on December 5, 1984. Since December 5, these seventeen monitors have been operative in the network.

B. Radon Flux Measurements Methods

A number of methods have been used to measure the radon flux from surfaces. Accumulator methods[2][3] have been used extensively. These methods involve the collection of radon in a closed container placed on a surface followed by the measurement of radon in air taken from the container by such methods as the alpha scintillation flask. The charcoal canister method developed by Countess[4] is relatively easy to apply and gives essentially a time-integrated measurement of the radon flux. The Charcoal Canister method was used in this study.

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The Charcoal Canisters used were approximately 4" diameter by 1 1/2" high. The procedure for applying the canister method involved the placement of the canister on the emanating source for a time period depending upon the magnitude of the source. Specifically, the canister was inserted in a PVC adapter ring which placed the face of the canister at approximately 1/2" from the concrete surface to minimize contamination from this surface. Both the interface between ring and canister and between ring and concrete surface were sealed with a pliable caulking material. The canister was sealed at the termination of the exposure with a tight-fitting metal lid taped in place. The ^{222}Rn content of the canister was then analyzed using a calibrated 3" x 3" NaI(Tl) scintillation spectrometer system in the radon laboratory at Monsanto-Mound. The integration region on the multichannel analyzer was set to encompass the 0.242 MeV, 0.294 MeV, and 0.352 MeV photons from ^{214}Pb and the 0.609 MeV photon from ^{214}Bi.

Twenty-four locations were selected on both the north and south residue storage tanks for radon flux measurements. A layout drawing of the locations on each tank is shown in Figure 2. On the north tank, the locations were designated 1 through 24 as shown in the figure, and on the south tank, they were designated 25 through 48. On the north tank, the locations 1, 2, 3, 13, 14, and 15 were along the north/south line; whereas, locations 7, 8, 9, 19, 20, and 21 were along the east/west line. Essentially, all of these canisters were on intact concrete showing no serious cracks or fissures. The remaining twelve locations were chosen in areas which had obvious cracks or fissures. A similar choice of locations was used on the south tank, namely, those canisters along the north/south and east/west lines being essentially on intact concrete, the remaining canisters being placed in locations with obvious cracks or fissures.

On October 18 and 24, 1984 radon flux from the concrete surfaces of the two residue storage tanks was measured by the use of charcoal canisters. Canisters were placed at the 24 locations on each tank and subsequently analyzed at Monsanto-Mound for radon uptake.

RESULTS

A. Radon Monitoring Network

Table 1 is a summary of radon concentrations for the Fernald, Ohio radon monitoring network for the period from September 20, 1984 to February 5, 1985 ranked in order of decreasing concentrations. A total of 215 measurements of radon concentration integrated over one- or two-week periods was made. The number of samples at different locations varied because of differences in the dates of initiation of monitoring, as previously mentioned. In addition, several samples were found to be invalid due to anomalous readings of TLD chips, and thus those data do not appear in Table 1.

Average radon concentrations range from 5.1 pCi/liter to 0.24 pCi/liter. Maximum concentrations are observed at monitoring locations around the tanks, while minimum concentrations were found at the three monitors located the farthest downwind along the eastern site perimeter. These locations were within the range of background; whereas, all other locations were above the background range.

Figure 3 is a cumulative probability plot of the average radon concentration values summarized in Table 1. The break in the curve at approximately 0.3 pCi/liter differentiates those monitors within the range of background from those which are influenced by radon from another source or sources (K-65 residue storage tanks). Data from the three monitors within the range of background appear to follow a linear plot, whereas the concentrations from the remaining monitors, all of which are above background, follow a distribution of two differing slopes. This may be due to local versus more distant effects from an extended source.

To illustrate the influence of radon from the residue storage tanks on the near environs, the average radon concentration values from Table 1 are shown superimposed on a map of the Fernald Site in Figure 4. The effects of transport of radon toward the east and north are seen from this figure. All along the production fence east of the tanks, for example, the radon concentration ranges from slightly below to slightly above 1.0 pCi/liter. The concentration in much of the area between the storage tanks and production fence appears to be above 1.0 pCi/liter.

Figure 5 shows the contours of equal radon concentration derived from the plot in Figure 3. Again, the transport of radon toward the north and east is evident. The 1.0 pCi/liter contour falls approximately half-way into the production area. Essentially the entire production area is within the 0.5 pCi/liter contour. The 2.0 pCi/liter contour projects in an easterly direction to approximately half-way between the residue storage tanks and the production area fence. It appears that toward the west the 0.5 pCi/liter contour projects to the boundary fence at Paddy's Run Road.

B. Radon Flux Monitoring

Several weeks prior to the flux monitoring effort, personnel of Oak Ridge National Laboratory and Monsanto-Mound carried out limited flux measurements and ancillary measurements with portable survey meters. It was found that when alpha probes were held over some of the obvious cracks, the meters (Ludlum Model 12) were disabled even on the least sensitive scale. Likewise, substantial readings were found where metal rods and pipes protruded through the concrete surface.

From these preliminary studies, it was decided that it would be imperative to evaluate whether the rate of release of radon from some of the more serious cracks was sufficient to saturate charcoal canisters. Two locations on the north tank which appeared to have the most significant cracks, and the highest radon flux as determined by alpha survey meter readings, were thus selected for study. Charcoal canisters were placed on each location for several different periods of time and subsequently measured on the scintillation spectrometer.

Figure 6 shows the results of this study. Each canister was analyzed and the total uptake of radon in microcuries was calculated based on prior calibration of the scintillation spectrometer. This calculated value, corrected for decay back to the time of collection, was then plotted versus the length of time for each exposure. As may be seen from Figure 6, the uptake is linear from zero to 200 to 250 microcuries. Further uptake is markedly nonlinear, thus indicating partial saturation of the charcoal canister. For both of the locations investigated in this study, the 200 to 250 microcurie uptake required only 20 minutes of exposure, which translated into elevated radon flux values. Clearly, the exposure time for these flux measurements is considerably different from the measurements on mill tailings and soils which are usually carried out over a period of several days. Exposures of several days with the high flux values in certain locations on the residue storage tanks would be meaningless in view of the short-term saturation effect.

Building upon the findings of this study, it was decided to expose canisters on areas of obvious cracks and fissures for less than an hour; whereas, those on what appeared to be intact concrete would be exposed for approximately two hours. It was estimated that exposures for these time intervals should produce sufficient adsorbed radon activity to be capable of measurement on the scintillation spectrometer. Flux exposures on the K-65 residue storage tanks were thus made on October 24, 1984. Results of the flux measurements are compiled in Table 2.

In spite of the selection of the times of exposure as described above, certain canisters could not be measured immediately on the scintillation spectrometer. A number of canisters contained sufficient ^{222}Rn activity that the surface gamma-ray exposure rates were many tens of mR/hr. This resulted in a prohibitively high count rate on the spectrometer.

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To permit the measurement of canisters with elevated gamma-ray emission rates, two low-geometry counting conditions were established which could be readily related to the counting efficiency on the crystal surface. In the first condition, the canister was placed on the end of a PVC tube in a reproducible location, about 12" from the crystal surface. In the second condition, lead shielding with a hole of approximately 3/4" diameter was placed on the end of the PVC tube. Condition 1 resulted in an efficiency reduction of approximately a factor of 20; whereas, in condition 2 the efficiency reduction was approximately a factor of 386. All measured values were related to those on the crystal surface. The counting efficiency on the crystal surface in counts per minute per picocurie of ^{222}Rn was determined by cross calibration with the Environmental Measurements Laboratory through exposure of canisters on a source of known flux [5].

Even with reduced counting efficiency, it was necessary in a number of cases to wait as long as 8 days before analyzing certain canisters on the spectrometer. Most canisters were, however, analyzed during the first four days. Following the initial measurement, all canisters were analyzed at least a second time and in most cases, at least seven to ten times over a two to seven week time period. Each analysis was decay, geometry, and efficiency corrected to obtain the microcurie value at time of collection. Any leakage from canisters was determined by following the decrease in the corrected microcurie value at time of collection. Correction was made for leakage of radon in several cases by extrapolation of these data back to time of collection. In several instances, it was also necessary to correct for saturation effects. This was done by assuming that the uptake of radon actually followed the experimental curve shown in Figure 6 and adjusting to the linear extrapolation above 200 microcuries.

All data shown in Table 2 were corrected for leakage and for saturation effects. The flux values are in $pCi/m^2/sec$. This assumes that the accumulated radon is coming from a planar source which, in the case of cracks or fissures, is not true; although, it provides a basis of comparison.

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In another column of Table 2 the rate of radon release is expressed in pCi/cm/sec. The assumption made in this case is that the radon is coming through a single crack of undefined width whose length is equal to the diameter of the canister. Although this is not always true, it is again a basis for comparison. It might also serve to approximate the magnitude of the source along certain cracks.

Flux values on the north tank range from approximately 13 pCi/m²/sec to 3 x 10^7 pCi/m²/sec and on the south tank from approximately 30 pCi/m²/sec to 1.4 x 10^7 pCi/m²/sec. In general, the values found on intact concrete were lower than values obtained at nearby locations having obvious cracks and fissures; although, there is considerable overlap of the data. The magnitude of the flux values found on what appeared to be intact concrete suggest that small cracks and fissures not apparent to the eye may be present.

DISCUSSION

Results of time-integrated radon measurements in the environs of the K-65 residue storage tanks show that levels above background prevail throughout most of the Fernald site. A portion of the production area is above 1.0 pCi/liter, essentially the remaining portion being in the range of 0.5 to 1.0 pCi/liter. Levels between 1.0 and 2.0 pCi/liter prevail through much of the area between the tanks and production area fence to the east. The background range for three monitors was 0.24 to 0.29 pCi/liter which is in keeping with background from other locations in the northeastern United States of approximately 0.2 to 0.3 pCi/liter(6). Thus, the effect of radon released from the residue storage tanks is to cause an increase over background of roughly a factor of 5 to 8 through a portion of the production area (1 to 2 pCi/liter) and of approximately a factor of 2 to 5 throughout the remainder of this area (0.5 to 1 pCi/liter).

These on-site levels are below the DOE guideline value of 3.0 pCi/liter above background for uncontrolled areas and well below the 100 pCi/liter

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value for occupational exposures. They are thus well within regulatory guidelines, but may not be as low as reasonably achievable in view of the several-fold increase over background.

The results summarized in Table 1 and referred to above are the result of taking the average radon concentration at each location over the period from September 20, 1984 to February 5, 1985.

Seasonal variations will modify the levels somewhat and possibly also the direction of transport of radon if significant changes in direction of prevailing winds occur. In addition, integrated average values over a certain few days or weeks could increase markedly in summer or fall months if inversion conditions exist through the area.

Flux measurements which were made on 24 locations on each tank resulted in values ranging from approximately 13 $pCi/m^2/sec$ to 3×10^7 $pCi/m^2/sec$. These values are greater than the Environmental Protection Agency standard for uranium mill tailings disposal sites of 20 $pCi/m^2/sec$[(7)]. They are also greater than the release rate of radon from 23 inactive mill tailings sites which range from approximately 1 to 3000 $pCi/m^2/sec$[(8)]. All of the locations on tanks which appeared to be intact concrete were comparable in value or somewhat higher than this range of values for mill tailings sites. Many of the locations encompassing cracks produced flux values much higher than this range as Table 2 shows.

Although the measured flux values tend to be higher than those found on inactive mill tailings sites, the surface areas of the tanks are substantially less than those of the tailings sites, i.e., several thousand square feet versus many acres. Thus, the annual radon release from the tanks is probably less than from the inactive mill tailings sites (200 to 11,500 Ci/yr)[(8)]. The surfaces of the storage tanks represent a very discontinuous source. It is, therefore, virtually impossible to employ the

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measured flux values to infer a source term. The problem is compounded by the existence of severe radon release around most of the metal protrusions on top of the tanks which could not be measured by charcoal canister methods. The values obtained in this study serve to highlight the order of magnitude of the flux and can be used to evaluate the success of any future remedial action which might be undertaken.

The measurement of concentrations of radon in air throughout the Fernald network provides additional means for the assessment of any remedial action which would be performed on the tanks. A substantial reduction in the release rate of radon from the tanks should result in a change in the radon concentration contours shown in Figure 4. The contours shown in this figure thus serve as fingerprints for future assessment of radon release rates.

RECOMMENDATIONS

This project was initiated to document the extent of radon release from the K-65 residue storage tanks and its impact on the environs. The results summarized in the tabular data and discussed in previous sections of this report are the basis for the following recommendations.

1. Continue to maintain the fenced area immediately surrounding the K-65 residue storage tanks as a limited access area. The area should continue to be posted as a high radiation area.

2. Seal the cracks and interfaces between metal protrusions and concrete surfaces with an appropriate sealant to significantly inhibit the transport of radon. A plastic coating (such as Dow Corning silicone) which is adherant to these surfaces, withstands extremes of weather conditions, and some abuse from walking would be required. Personnel familiar with properties of such coatings

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should be consulted on a suitable material. This action would be in keeping with the ALARA philosophy of minimizing exposures to workers from a source of exposure for which there is no evident benefit for the risk involved.

3. Continue radon monitoring and expand the network to several off-site locations.

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1. George, A. C., A Passive Environmental Radon Monitor, HASL-325, p. 25, July, 1977.

2. Kramer, H. W., Schroeder, G. L., and Evans, R. D., "Measurements of the Effects of Atmospheric Variables on Radon-222 Flux and Soil-Gas Concentrations", The Natural Radiation Environment, edited by J. Adams and W. Louder (University of Chicago Press) (1964).

3. Wilkening, M. H., "Measurement of Radon Flux by the Accumulation Method", Procedures of Workshop on Methods for Measuring Radiation In and Around Uranium Mills, Albuquerque, New Mexico, May 23-26, 1977, p. 131.

4. Countess, R. J., "Measurement of ^{222}Rn Flux With Charcoal Canisters," ibid, p. 139.

5. George, A. C., private communication.

6. Gesell, T. F., "Background Atmospheric ^{222}Rn Concentrations Outdoors and Indoors: A Review", Health Physics 45, 289-302 (1983).

7. Draft - Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing (40 CFR 192), Appendix D, December 1980.

8. ibid, p. 3-2.

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Table 1

SUMMARY OF DATA FOR FERNALD RADON MONITORING NETWORK
FOR THE PERIOD OF SEPTEMBER 20, 1984 TO FEBRUARY 5, 1985

Locations Above Range of Background		Number of Samples	Radon Conc. pCi/liter Ave.	Radon Conc. pCi/liter Std. Error	Date Initiated
# 3	West perimeter K-65 fence	15	5.1	0.6	09/20/84
# 1	East perimeter K-65 fence	15	3.6	0.5	09/20/84
# 5	NE 30 meters	15	3.6	0.5	09/20/84
# 4	North perimeter K-65 fence	15	3.0	0.4	09/20/84
# 2	South perimeter K-65 fence	15	1.8	0.2	09/20/84
#12	Northwest 200 meters	13	1.7	0.2	09/27/84
# 6	East 75 meters	15	1.3	0.1	09/20/84
# 7	East production fence	14	1.2	0.1	09/27/84
# 8	Southeast production fence	13	1.0	0.1	09/27/84
#11	North 300 meters	14	0.97	0.14	09/27/84
# 9	Northeast production fence	14	0.82	0.11	09/27/84
#10	North northeast production fence	13	0.71	0.08	09/27/84
#13	South 150 meters	11	0.60	0.09	10/18/84
#15	West Paddy's Run Road	12	0.46	0.05	10/18/84
Locations in Background Range					
#14	East sewage treatment plant	11	0.29	0.03	10/18/84
#18	Northeast route 126	5	0.24	0.04	12/05/84
#17	Southeast Wiley Road	5	0.24	0.04	12/05/84

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Table 2

SUMMARY OF RADON FLUX MEASUREMENTS MADE ON OCTOBER 24, 1984 FROM K-65 RESIDUE STORAGE TANKS, FERNALD, OHIO

North Tank

Location	Distance From Center ft.	Quadrant	Sampling Period (min.)	Condition	JA[(2)]	JL[(3)]
1	30	N/S line, north	114	I	2.2 (3)	1.6 (0)
2	20	"	115	I	1.3 (2)	9.7 (-2)
3	10	"	177	I	5.8 (1)	4.4 (-2)
3	10	"	115	I	1.3 (1)	9.5 (-3)
4	21.7	Northeast	51	C	7.5 (2)	5.6 (-1)
5	22.6	"	50	C	6.2 (2)	4.7 (-1)
6	32.6	"	51	C	2.8 (2)	2.1 (-1)
7	30	E/W line, east	117	I	1.1 (2)	8.0 (-2)
8	20	"	117	I	9.8 (1)	7.4 (-2)
9	10	"	181	I	6.4 (1)	4.8 (-2)
9	10	"	116	I	3.4 (2)	2.6 (-1)
10	21.1	Southeast	53	C	3.9 (3)	2.9 (0)
11	20.9	"	52	C	3.7 (4)	2.8 (1)
12	33.8	"	52	C	1.9 (7)	1.4 (4)
13	30	N/S line, south	117	I	4.3 (3)	3.2 (0)
14	20	"	116	I	8.4 (2)	6.4 (-1)
15	10	"	180	I	6.3 (1)	4.7 (-2)
15	10	"	116	I	1.7 (3)	1.3 (0)

Table 2 (Cont'd)

Location	Distance From Center ft.	Quadrant	Sampling Period (min.)	Condition	JA(2)	JL(3)
North Tank						
16	21.6	Southeast	182	C	7.7 (1)	5.8 (-2)
16	21.6	"	52	C	1.1 (3)	8.0 (-1)
17	23.6	"	53	C	3.1 (4)	2.3 (1)
18	29.9	"	183	C	8.3 (6)	6.2 (3)
18	29.9	"	53	C	2.5 (7)	1.8 (4)
19	30	E/W line, west	114	I	2.1 (2)	1.6 (-1)
20	20	"	114	I	7.7 (1)	5.7 (-2)
21	10	"	115	I	8.2 (1)	6.1 (-2)
22	23.2	Northwest	50	C	5.0 (2)	3.7 (-1)
23	23.4	"	52	C	6.6 (2)	4.9 (-1)
24	36.4	"	181	C	1.6 (7)	1.2 (4)
24	36.4	"	52	C	2.8 (7)	2.1 (4)
South Tank						
25	30	N/S line, north	207	I	1.8 (2)	1.4 (-1)
25	30	"	81	I	1.6 (3)	1.2 (0)
26	20	"	84	I	1.3 (5)	9.5 (1)
27	10	"	84	I	3.1 (4)	2.4 (1)
28	23.4	Northeast	206	C	2.4 (1)	1.8 (-2)

Table 2 (Cont'd)

South Tank

Location	Distance From Center ft.	Quadrant	Sampling Period (min.)	Condition	JA[2]	JL[3]
28	23.4	Northeast	56	C	1.4 (2)	1.0 (-1)
29	28.3	"	56	C	1.1 (4)	7.9 (0)
30	34.9	"	55	C	7.1 (1)	5.3 (-2)
31	30	E/W line, east	212	I	6.2 (1)	4.6 (-2)
31	30	"	85	I	1.6 (2)	1.2 (-1)
32	20	"	84	I	9.3 (1)	6.9 (-2)
33	10	"	83	I	2.4 (3)	1.8 (0)
34	28.9	Southeast	50	C	9.0 (5)	6.7 (2)
35	34.0	"	50	C	2.1 (5)	1.6 (2)
36	34.5	"	212	C	6.9 (6)	5.2 (3)
36	34.5	"	51	C	1.4 (7)	1.0 (4)
37	30	N/S line, south	85	I	3.3 (2)	2.5 (-1)
38	20	"	85	I	5.3 (2)	3.9 (-1)
39	10	"	85	I	1.3 (2)	9.4 (-2)
40	27.6	Southwest	209	C	1.7 (4)	1.3 (1)
40	27.6	"	52	C	8.8 (4)	6.6 (1)
41	34.7	"	52	C	3.2 (3)	2.4 (0)
42	35.0	"	52	C	2.2 (2)	1.7 (-1)
43	30	E/W line, west	80	I	2.9 (1)	2.2 (-2)
44	20	"	81	I	9.6 (1)	7.2 (-2)

Table 2 (Cont'd)

South Tank

Location	Distance From Center ft.	Quadrant	Sampling Period (min.)	Condition	JA(2)	JL(3)
45	10	E/W line, west	208	I	3.3 (1)	2.5 (-2)
45	10	"	81	I	1.0 (2)	7.8 (-2)
46	23.2	Northwest	57	C	6.4 (3)	4.8 (0)
47	34.2	"	55	C	2.3 (4)	1.7 (1)
48	35.5	"	56	C	1.0 (2)	7.5 (-2)

North Tank

(1) I = Intact concrete, C = crack or fissures

(2) JA is Radon Flux in units of $pCi/m^2/sec$. 2.2 (3) = 2.2×10^3 $pCi/m^2/sec$

(3) JL is in units of pCi/cm/sec. 1.6 (0) = 1.6×10^0 pCi/cm/sec

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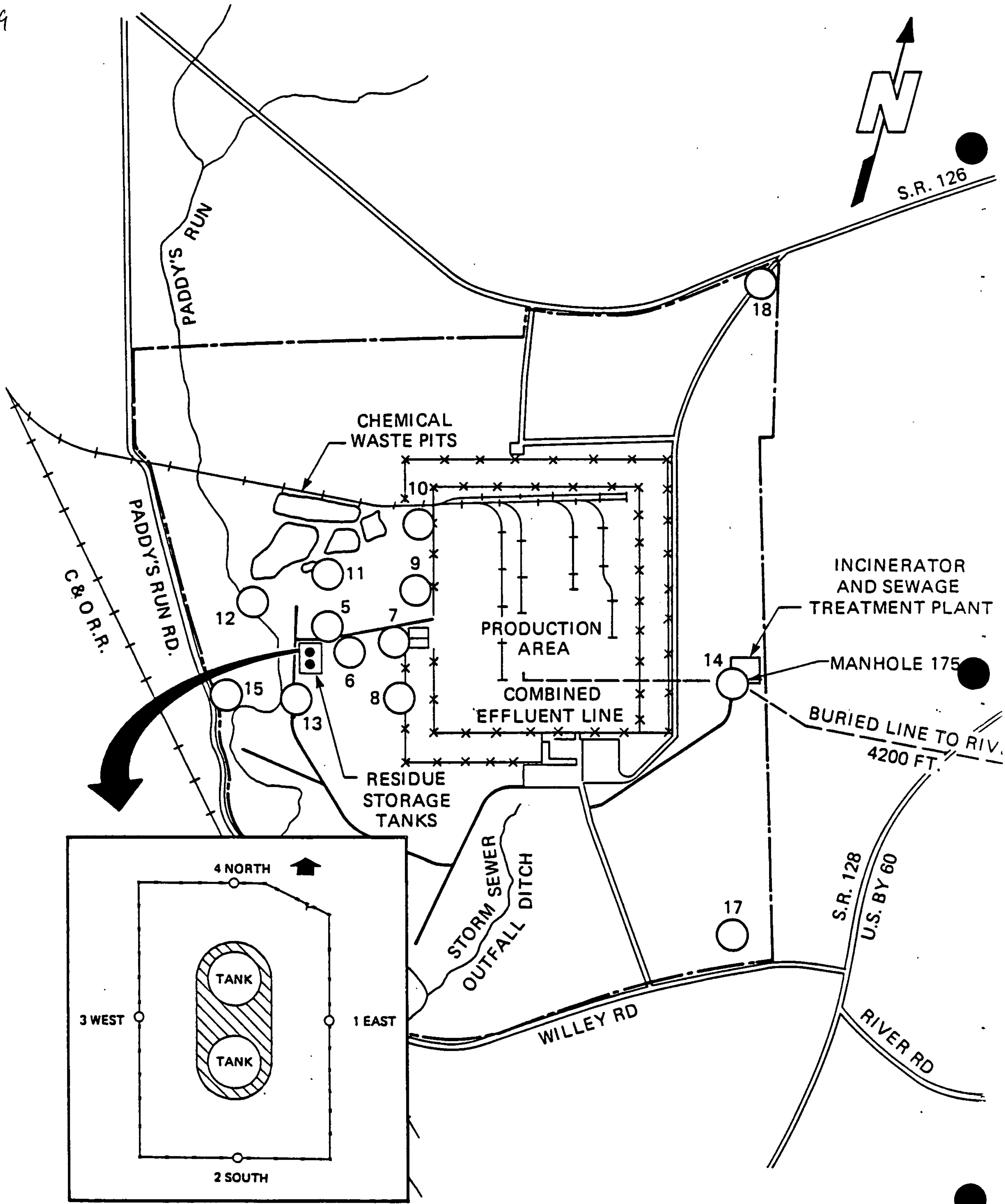

Figure 1.
Radon Monitoring Network, Fernald, Ohio

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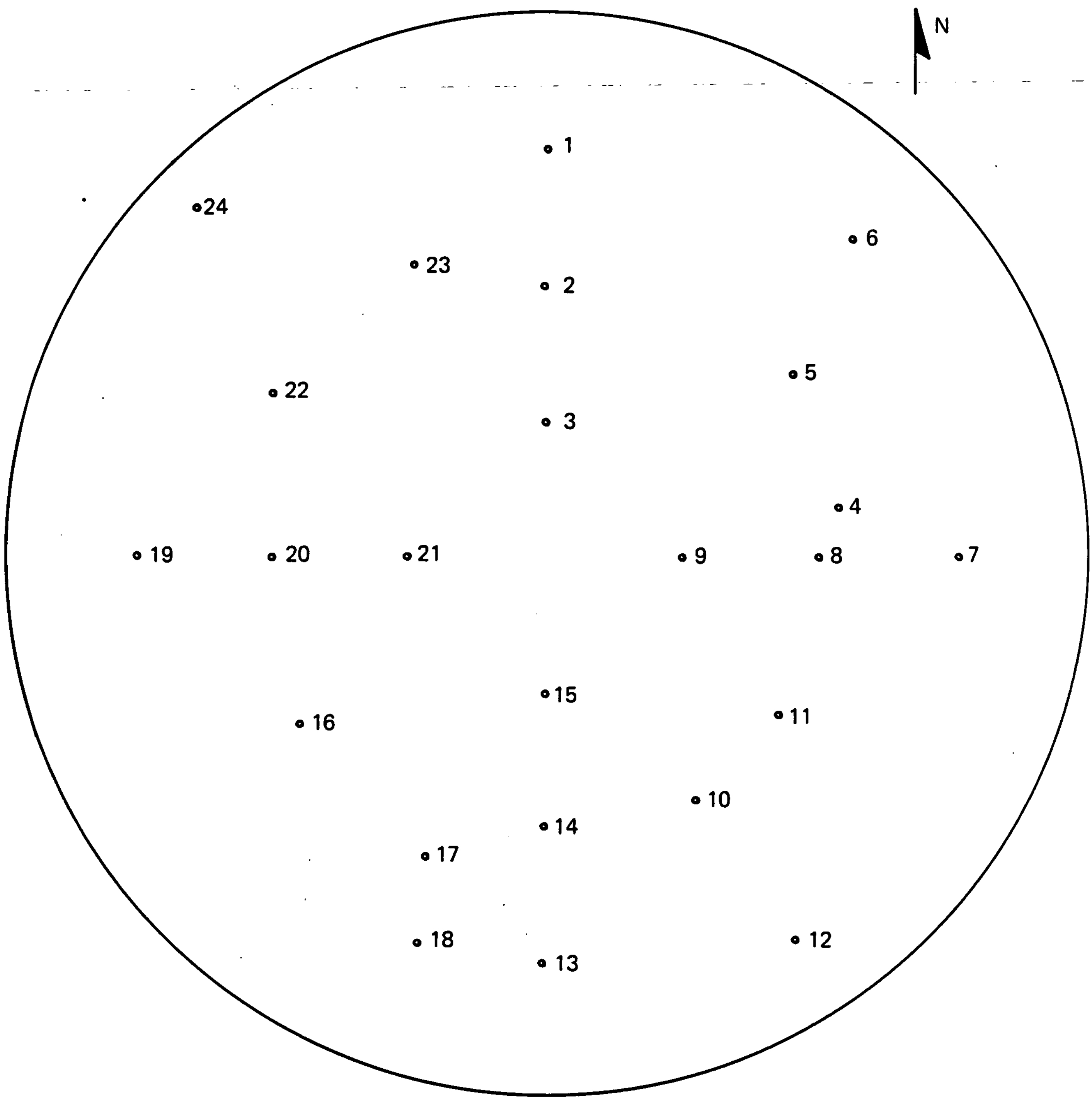

Figure 2A.
Charcoal Canister Locations - North K65 Tank

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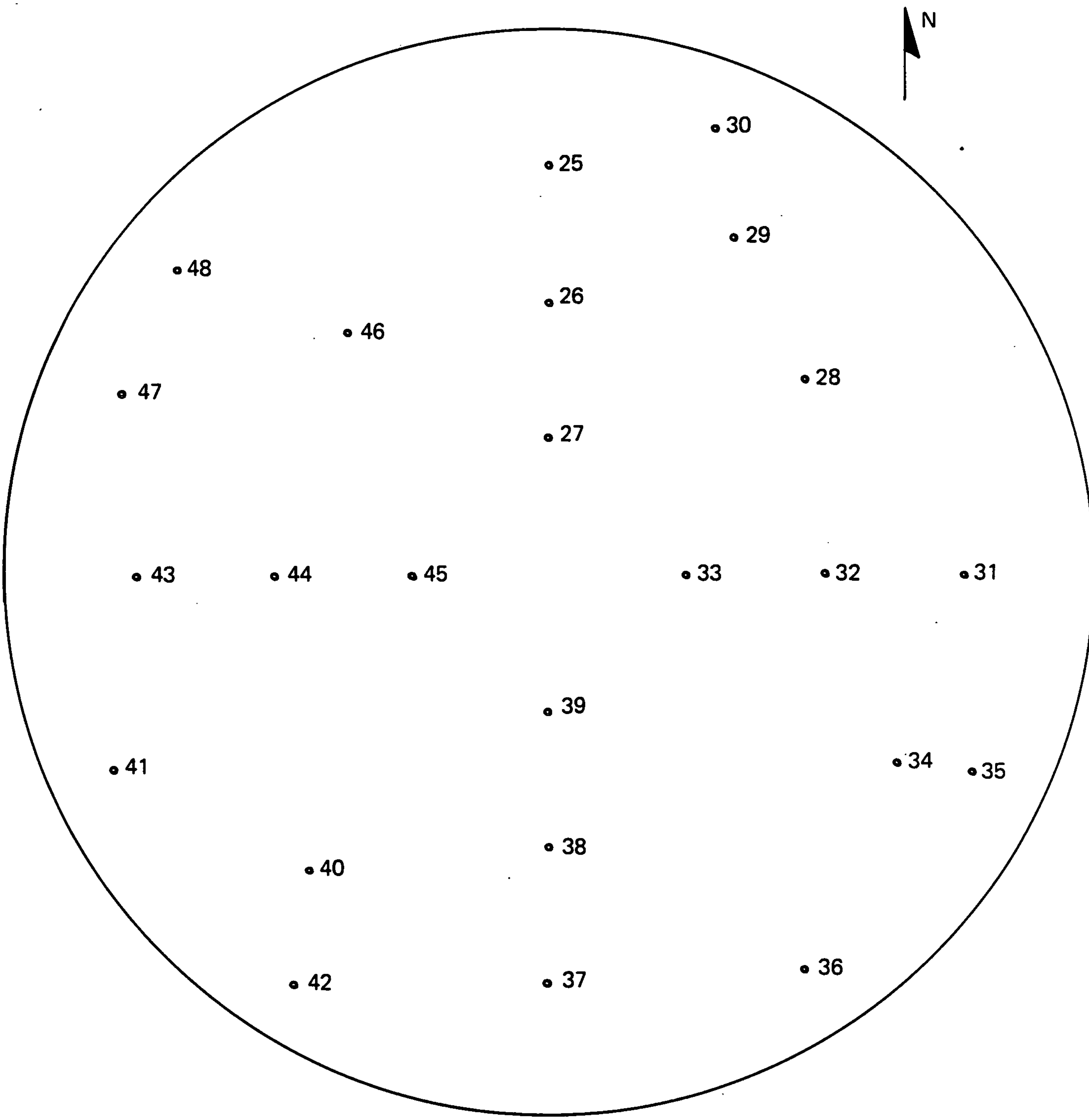

Figure 2B.
Charcoal Canister Locations - South K65 Tank

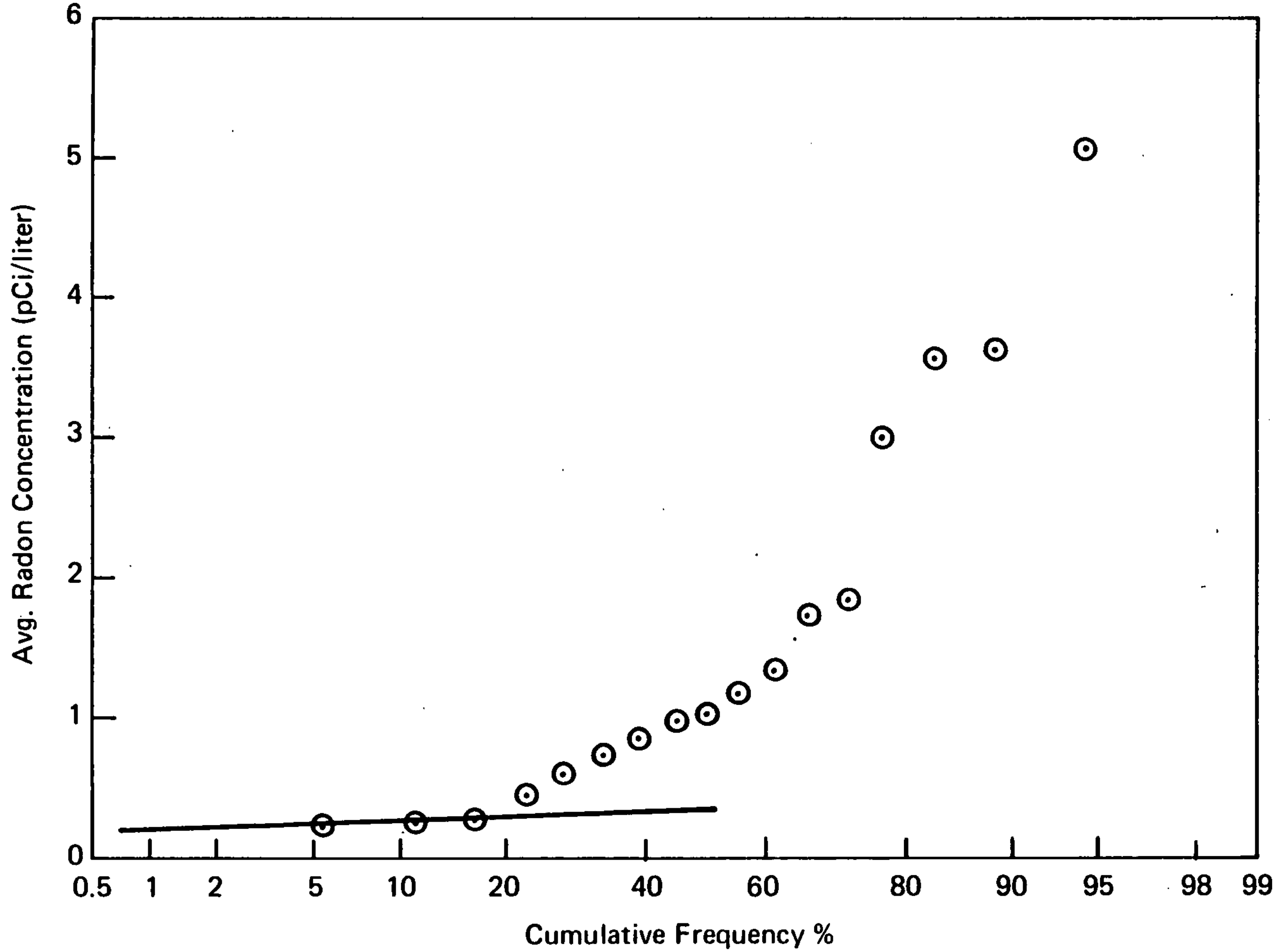

Figure 3.
Cumulative Frequency Plot of Average Radon Concentrations for Fernald Monitoring Stations for the Period From September 20, 1984 to February 5, 1985

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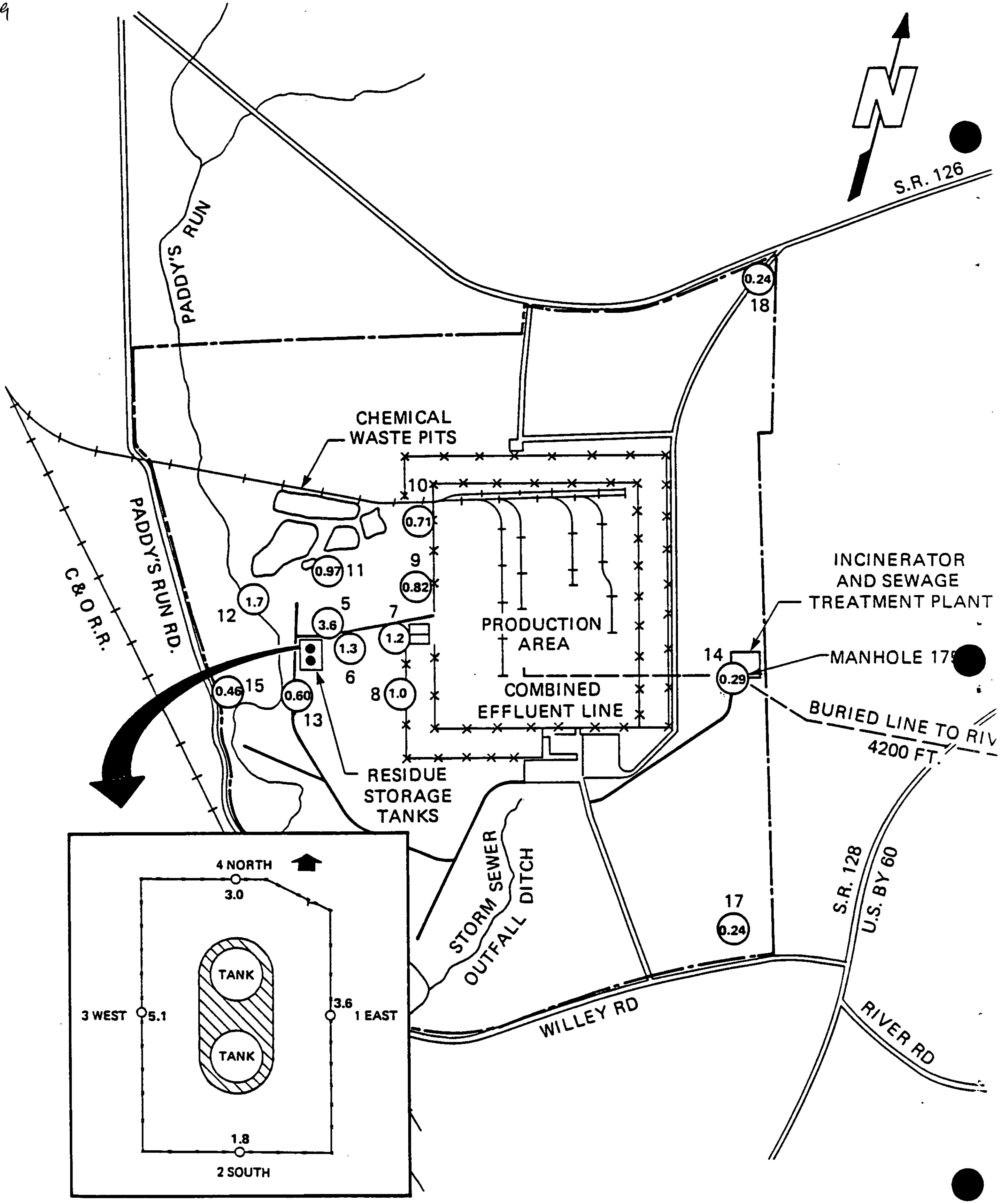

Figure 4.
Average Radon Concentrations in pCi/liter for Seventeen Locations in Fernald, Ohio,
Radon Monitoring Network for the Period from September 20, 1984 to February 5, 1985

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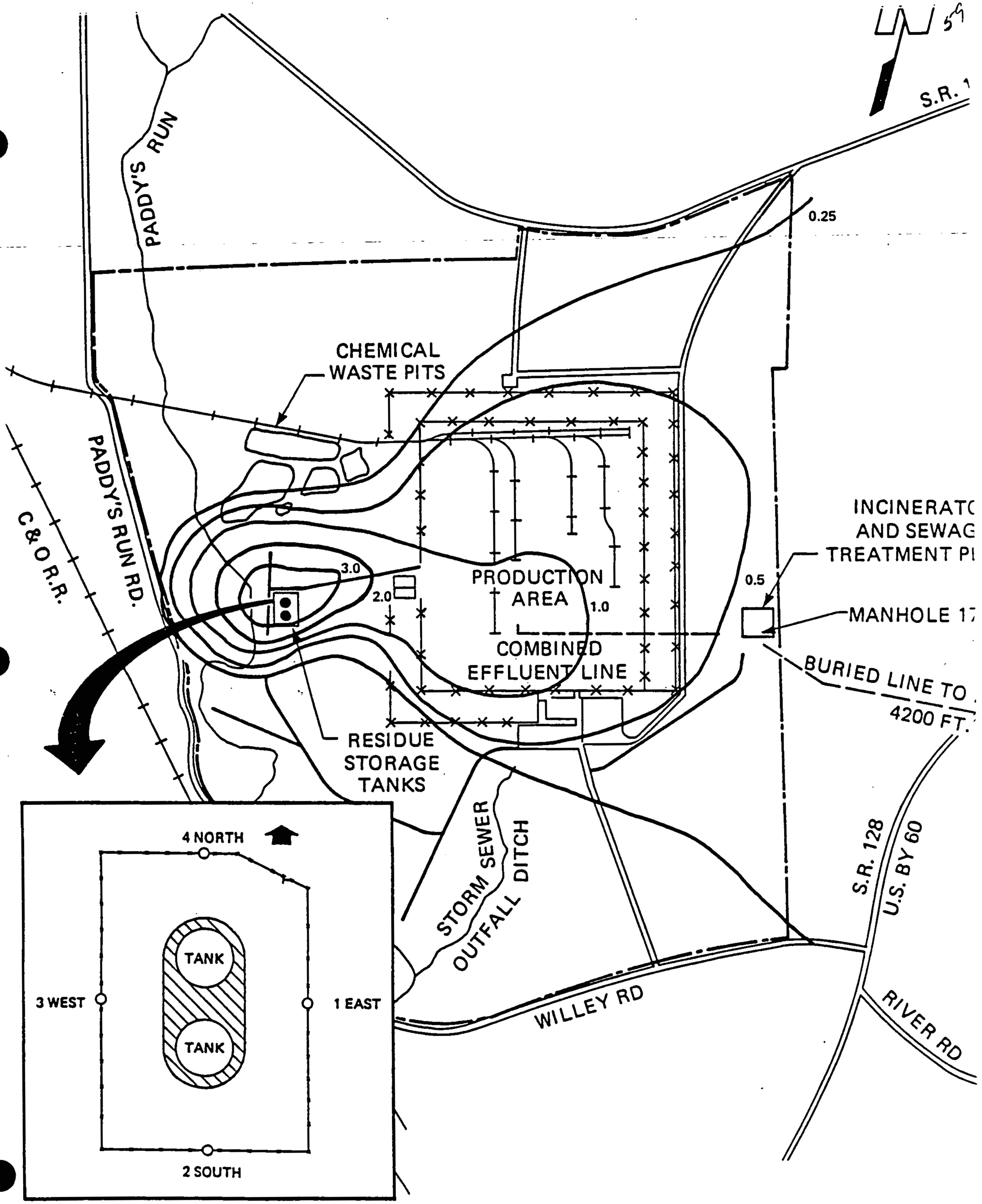

Figure 5.
Contours of Equal Radon Concentration (pCi/liter) Derived From Radon Concentration Measurements, Fernald, Ohio for the Period From September 20, 1984 to February 5, 1985

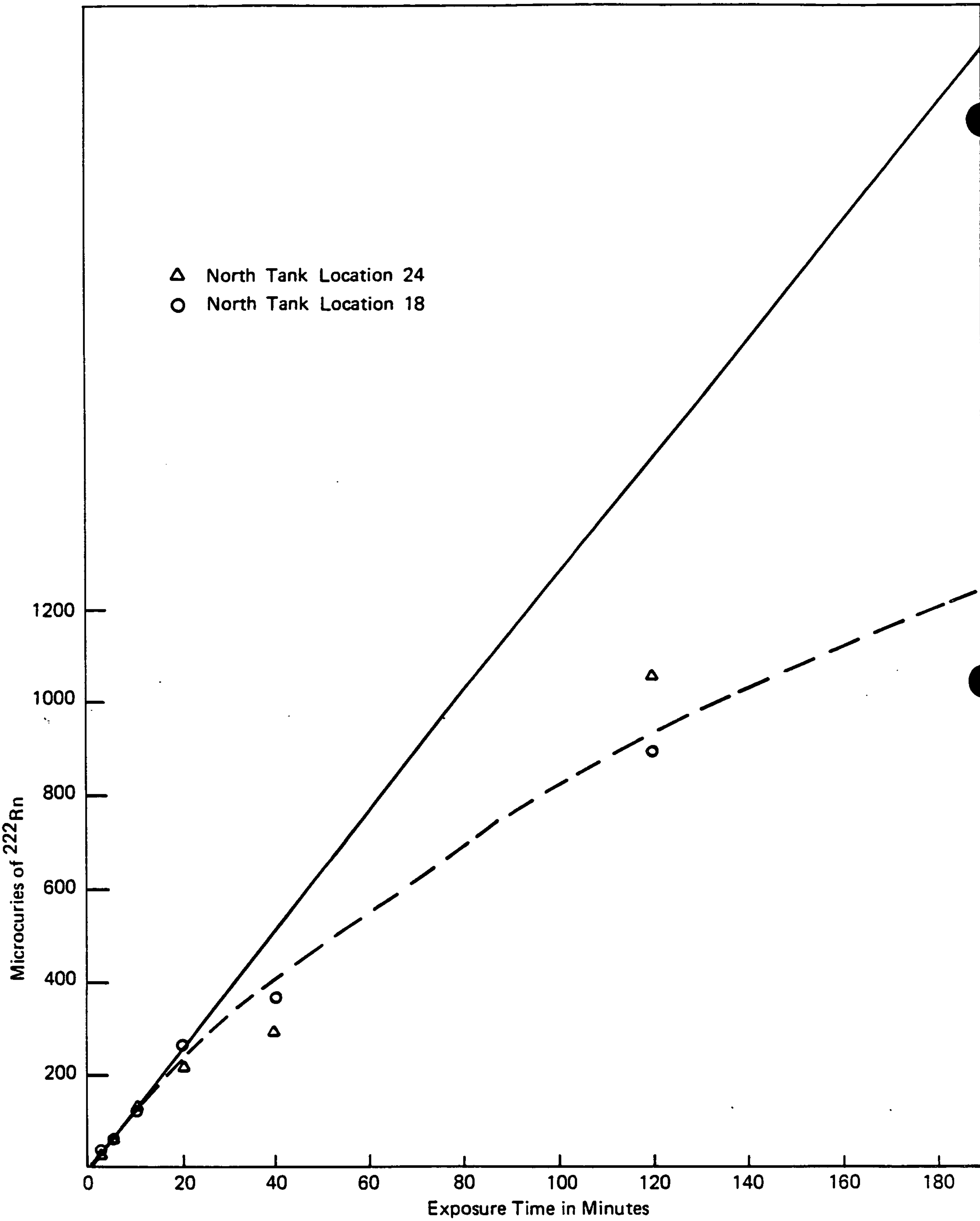

Figure 6.
Buildup of ^{222}Rn Activity in Charcoal Canisters Exposed for Increasing Periods of Exposure at Two Locations on K65 Residue Storage Tanks, Fernald, Ohio, on October 18, 1984

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