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G-000-106.53

REPORT ON RADON FLUX ESTIMATES

12/17/90

DOE-417-91
DOE-FMPC/USEPA
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LETTER

Department of Energy
FMPC Site Office
P.O. Box 398705
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DEC 17 1990
DOE-417-91

Mr. David Kee
U.S. Environmental Protection Agency
Region V, 5AR-26
Air and Radiation Division
230 S. Dearborn Street
Chicago, Illinois 60604

Dear Mr. Kee:

REPORT ON RADON FLUX ESTIMATES

Reference: Letter, DOE-157-91, Gerald W. Westerbeck to D. Kee, "Proposed Provisions to be Included in the Clean Air Act Compliance Agreement," dated November 6, 1990.

As part of the on-going negotiations of the FFCA/NESHAP, the DOE has agreed to submit a report on radon flux estimates from potential sources other than the K-65 silos at the Feed Materials Production Center (FMPC). The subject report is enclosed, with supporting documentation.

The estimated radon flux from Silo 3 currently exceeds 20 pCi/m^2-s. Based on this estimate and the fact that a measurement program is not practical, DOE agrees to initiate an evaluation of the need for a removal action under CERCLA for Silo 3, in accordance with our proposed language for the FFCA/NESHAP as referenced above. The results of this evaluation will be provided to U.S. EPA when completed.

The "RADON" model used to estimate flux from Waste Pits 1, 2 and 3 proved to be inappropriate. The model predicted a range of values for flux, from 0.03 to 197 Ci/m^2-s. This was because a wide range of radium was measured in the pits and cover thicknesses also varied considerably. The model was not able to evaluate sources covered with water, so values for Pit 5 and the Clearwell are not available.

To rectify the problems inherent in the model, DOE is developing a program for directly measuring radon flux from the pits.

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If you have any questions, please contact Behram Shroff at FTS 774-6003.

Sincerely,

Ray Hansen for

Gerald W. Westerbeck
FMPC Site Manager

DP-84: Shroff

Enclosure: As stated

cc w/encl.:

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ESTIMATES OF RADON FLUX FROM FMPC WASTE PITS 1, 2, 3, AND SILO #3

Estimates of radon flux from FMPC Waste Pits 1, 2, 3, have been made using the NRC-approved RADON computer code (see table). The RADON code was developed for use at uranium mill tailings sites where both the radium concentration and the pertinent geophysical parameters are relatively homogeneous. In attempting to apply the RADON code to the FMPC waste pits, it was found that the wide range of radium concentrations measured in the pits and the estimated variations in cover thicknesses resulted in a very wide range of possible radon flux value. A typical computer run for Pit 2 is attached as requested.

The RADON computer code is not able to account for water cover; hence radon flux estimates are not available for Pit 5 and the Clearwell, both of which have water covers. As previously discussed, Pits 4 and 6 are not sources per definition in 40 CFR 61.91; therefore, they are not included in this report.

Ranges of Radium Concentration, Cover Thickness and Radon Flux

	^{226}Ra (pCi/g)				Cover (cm)		Rn Flux (pCi/m^2 sec)	
Pit	Max	Min	AVG	+/- 2 SD	Max	Min	Max	Min
1	60.2	12.0	30.5	123%	30	15	47	5.6
2	412	12.2	117.7	283	60	15	197	1.7
3	369	3.1	124.2	218	240	22.5	159	.03

The large range of possible radon flux values illustrates the problems encountered in attempting to apply a computer model to a situation where assumed homogeneity does not exist. The range of flux values would decrease somewhat if, instead of maximum and minimum radium concentrations, the average ± 2-sigma standard deviation was used. However, the two-standard-deviation range goes from ± 123% to ± 283% for the waste pits. And if uncertainties in the other parameters (such as soil density and moisture) were included, the maximum and minimum flux values would be even further apart.

The estimate of the flux from Silo #3 is based on a number of assumptions, measurements and calculations listed below. A conservative, yet reasonable, approach was utilized in arriving at this estimate.

ASSUMPTIONS

1. The primary mechanism for release of radon from Silo #3 is the thermal expansion of the air in the headspace.

2. Silo #3 does not act as a pressure vessel to any significant degree, and is unable to contain the warming headspace air.

3. The area through which radon escapes is the area of the Silo #3 dome, 496 m^2.

4. Data on internal temperature of Silos #1 and #2 on May 8-11, 1987 after adjustment for percent sunshine during those days, represents average annual internal temperatures for Silo #3.

MEASUREMENTS:

1. The radon concentration in the Silo #3 headspace is 2.07×10^5 pCi/L ($\pm$ 12%).

2. The average internal maximum temperature fluctuation in Silos #1 and #2 measured on May 8-11, 1987 is 32.2 F (17.9 C).

3. The average internal maximum temperature fluctuation in Silo #3 for 7 days in December, 1990 was 10.5 C.

4. The daily temperature fluctuation at a point 2.5 ft. below the surface of the Silo #3 residues averaged approximately 0.1 C. There is no detectable pressurization of Silo #3.

CALCULATIONS:

1. The headspace volume was calculated to be 105 m^3 (see attachment). This was based on observations by at approximately 8 locations below the Silo #3 dome.

2. For the May 8-11, 1987 time period, the percent sunshine recorded at Greater Cincinnati Airport was 92.5%. The average for years 1984-1989 is 53%. Therefore, the sunshine factor for the May 8-11, 1987 time period is 1.745. When the observed temperature rise of 32.2 F is adjusted by this factor, the resulting average temperature fluctuation of 10.25 C is very close to the measured average for Silo #3 for 7 days in December, 1990 of 10.5 C.

THE ESTIMATE:

1. A temperature change each day of 18.45 F (10.25 C) will cause 105 m^3 of air to increase in volume to:
$$[(273 + 10.25)/(273)] \times [105] = 108.94\ m^3$$

2. The extra volume (3.94 m^3) will escape. This air will contain
$$3.94\ m^3 \times 2.07 \times 10^8\ pCi/m^3 = 8.161 \times 10^8\ pCi \text{ of } {}^{222}Rn$$

3. Averaged over the area of the Silo #3 dome,
$$[8.161 \times 10^8\ pCi] / [496\ m^2] = 1.645 \times 10^6\ pCi/m^2 \text{ each day}$$

4. And averaged over the 86,400 seconds per day,
$$[1.645 \times 10^6\ pCi/m^2 \cdot day] / [86{,}400\ sec/day] = 19.04\ pCi/m^2 \cdot sec$$

The uncertainty in the measurement of headspace radon concentration was $\pm$12%. Combined with the uncertainties inherent in the estimation of temperature fluctuation and headspace volume, as well as the potential contribution to flux due to diffusion through four inches of concrete, it can be concluded that radon flux from Silo #3 exceeds 20pCi/m^2 sec.

*****! RADON !*****

Version 1.2 - May 22, 1989 - G.F. Birchard tel.# (301)492-7000 [redacted]
U.S. Nuclear Regulatory Commission Office of Research

RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS
ARE CALCULATED FOR MULTIPLE LAYERS

Pit 2/18 12/9/90

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	2	
NO LIMIT ON RADON FLUX		
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 Pit 2 Waste

THICKNESS	400	cm
CALCULATED POROSITY	0.479	
MEASURED MASS DENSITY	1.38	g cm -3
MEASURED RADIUM ACTIVITY	412	pCi/g
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	8.720D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	12.747	%
MOISTURE SATURATION FRACTION	.367	
CALCULATED DIFFUSION COEFFICIENT	2.200D-02	cm^2 s^-1

LAYER 2 Pit 2 Cover

THICKNESS	15	cm
CALCULATED POROSITY	0.219	
MEASURED MASS DENSITY	2.07	g cm -3
MEASURED RADIUM ACTIVITY	0	pCi/g
DEFAULT LAYER EMANATION COEFFICIENT	.35	
CALCULATED SOURCE TERM CONCENTRATION	0.000D+00	pCi cm^-3 s^-1
WEIGHT % MOISTURE	5.6208	%
MOISTURE SATURATION FRACTION	.532	
CALCULATED DIFFUSION COEFFICIENT	7.800D-03	cm^2 s^-1

[redacted]

DATA SENT TO THE FILE RNDATA' ON DRIVE A:

N	FO1	CN1	ICOST	CRITJ	ACC
2	-1.000D+00	0.000D+00	0	0.000D+00	1.000D-03

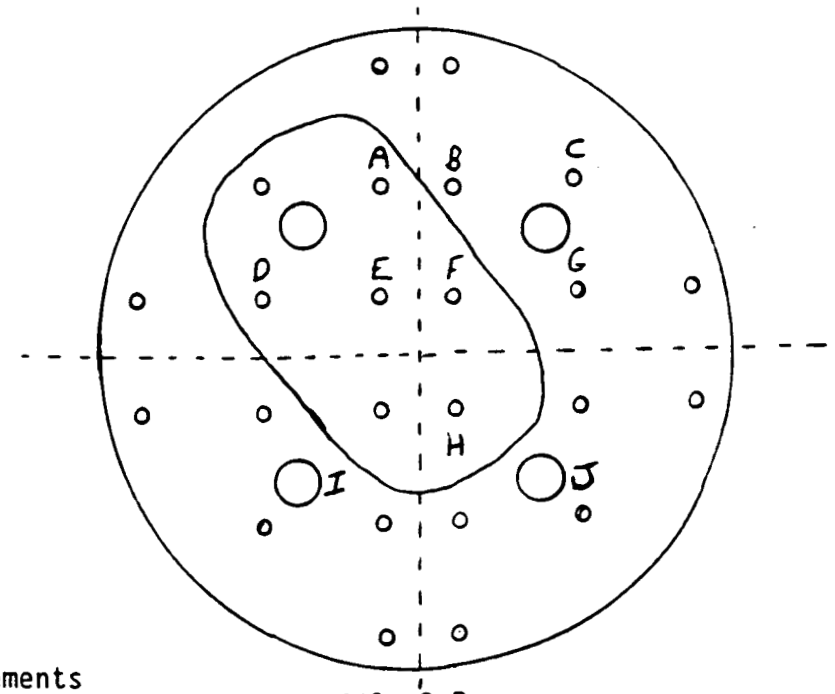
LAYER	DX	D	P	Q	XMS	RHO
1	4.000D+02	2.200D-02	4.792D-01	8.720D-04	3.671D-01	1.380
2	1.500D+01	7.800D-03	2.189D-01	0.000D+00	5.316D-01	2.070

BARE SOURCE FLUX FROM LAYER 1: 4.189D+02 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi L^-1)
1	4.000D+02	2.029D+02	2.099D+05
2	1.500D+01	1.969D+02	0.000D+00

Methodology for Calculating Headspace Volume in Silo 3



Silo 3 Dome
(Top View)

Actual Measurements
(underneath dome to
top of residue):

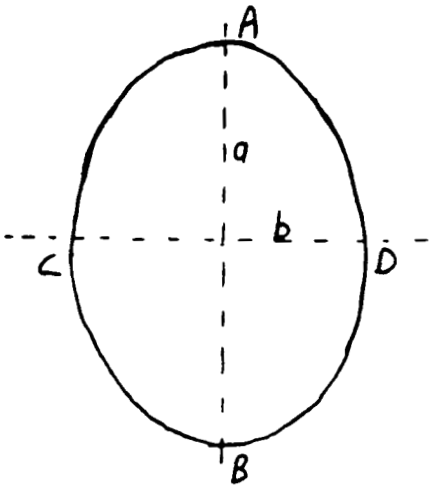
A=3′
B=1/2′
C=0′
D=3′
E=5 1/4′
F=2′
G=0′
H=3 1/4"
I=0′
J=0′

<u>Assumptions</u>

1) Location E is the center of the headspace.
2) The area of the headspace is elliptical in shape.
3) The dome surface used in the calculations is symmetrical.
4) The surface of the residues is level for calculations.
5) Radon is emitted from the silo as a result of thermal expansion of the air in the headspace.
6) The silo does not act as a pressure vessel.
7) Radon is being emitted through the entire dome. $496m^2$

[redacted]

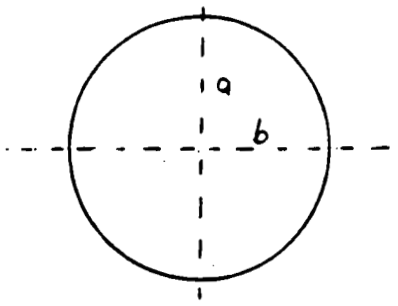
[redacted]



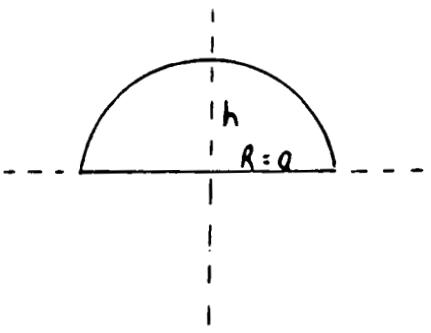
Scaled off engineering drawing
AB = 52 ft.
CD = 34 ft.

Area of an ellipse:

Area = π ab
= π(26)(17)
= 1388.6 ft.^{2}



a=b=R
πR^2 = 1388.6 ft.^{2}
R = 21 ft.



Volume of a Spherical Segment:

$V = 1/6\ \pi h(h^2+3a^2)$
$V = 1/6\ \pi(5.25)\ [(5.25)^2 + 3(21)^2]$
V = 3712.6 ft.^{3}

$3712.6\ \text{ft.}^3 \times \frac{1\text{m}^3}{35.3147\ \text{ft.}^3} = 105\text{m}^3$

[redacted]