7100 G-000-104.174

RENEWAL OF PERMITS TO OPERATE AT THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT OEPA ID NOS. 1431110128 P272, T111, AND T112

08/10/95

C:EC:95-104
FERMCO HAMILTON COUNTY
20
PTOS

Fernald Environmental
FERMCO
Restoration Management Corporation P.O. Box 398704 Cincinnati, Ohio 45239-8704 (513) 738-6200

7100

August 10, 1995

Fernald Environmental Management Project
Letter No. C:EC:95-0104

Mr. Peter Sturdevant, Compliance Specialist
Air Quality Management Division
Hamilton County Department
of Environmental Services
1632 Central Parkway
Cincinnati, Ohio 45210

Dear Mr. Sturdevant:

RENEWAL OF PERMITS TO OPERATE AT THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT OEPA ID. NOs. 1431110128 P272, T111, AND T112

Enclosed are three FEMP Permit to Operate renewal applications which are scheduled to expire in November 1995.

Please contact Kip Klee of my staff at 648-5289 if you have any questions about these applications.

Sincerely,

Terence D. Hagen
Director
Environmental Compliance

TDH:KOK:mhv
Enclosures

c: S. M. Beckman, FERMCO/MS65-2 - w/o enclosures
K. O. Klee, FERMCO/MS65-2 - w/o enclosures
P. R. Kraus, FERMCO/MS67 - w/enclosures T111, T112
P. B. Spotts, FERMCO/MS65-2 - w/o enclosures
W. J. Quaider, DOE-FN/MS45
AR Coordinator
File Record Storage Copy 108.6
RTS Files (PTOs P272, T111, T112)

1

OHIO ENVIRONMENTAL PROTECTION AGENCY
APPLICATION FOR A PERMIT TO OPERATE
AN AIR CONTAMINANT SOURCE

7100

D.O.E.-Fernald Environmental Management Project
Facility Name

Mr. Stephen M. Beckman
Person to Contact

7400 Willey Road
Facility Address

Post Office Box 538704
Mailing Address

Fernald Hamilton 45030
City County Zip

Cincinnati OH 45253-8704
City State Zip

513/ 648-3000
Telephone Area Number

513/ 648-5264
Telephone

#1431110128- T111
(Application no., if this is a renewal application)

4953
Std. Ind. Class. Code

1. Complete and attach any of the following appendices most appropriate to the air contaminant source. In addition, a compliance time schedule form is to be attached when applicable. Check as appropriate the following:

___Appendix A, Process
___Appendix B, Fuel-Burning Equipment
___Appendix C, Incinerator
___Appendix D, Surface Coating or Printing Operation
X Appendix E, Storage Tank
___Appendix H, Gasoline Dispensing Facility
___Appendix J, Loading Rack at Bulk Gasoline Plant or Terminal
___Appendix K, Surface Coating Line or Printing Line
___Appendix L, Solvent Metal Cleaning
___Appendix M, Fugitive Dust Emission Sources
___ Specify Appendix No.
___Appendix N, Rubber Tire Manufacturing
___Appendix O, Dry Cleaning Facility
___Appendix P, Landfills
___Other Appendix ___
___Compliance Time Schedule

2. Description of Source (same as used on appendix): K-65 Silo #1

3. Your identification for Source (same as used on appendix): 65-001

I, being the individual specified in Rule 3745-35-02(B) of the Ohio Administrative Code, hereby apply for a Permit to Operate the air contaminant source(s) described herein. As required, the following additional documents are submitted as part of this application (describe all attachments):

Authorized Signature*
Terence D. Hagen
Director Environmental Compliance
Title
8/1/95
Date

*Pursuant to OAC Rule 3745-35-02(B) (Permit to Operate).
Operation of an air contaminant source without an effective permit to operate is prohibited to 3704.05 Ohio Revised Code.

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FOR OFFICIAL USE ONLY

Premise No.___/___/___/___
Source No.___/___
Application No.___/___

7100

DOE - FEMP
(Facility Name)
OEPA NO 1431110128 T111
FEMP ID NO. 65-001

APPENDIX E-2

INORGANIC MATERIAL STORAGE TANK OR
STORAGE TANK WITH CAPACITY LESS THAN 40,000 GALLONS

1. Tank identification: Name or number K-65 Silo #1 Date Installed 1952 (month/year)

2. Tank capacity: 156,350 cubic feet

3. Tank shape: [X] Cylindrical [ ] Rectangular
[ ] Spherical [ ] Other, specify ___

4. Tank dimensions: Diameter 80 ft. Height 36 ft.* Length --- Width ---
*To the top of the dome is 36ft. The sidewall is 27 ft. High.

5. Tank shell material: [ ] Steel [ ] Aluminum [X] Other, specify Reinforced concrete

6. Type of tank:
[ ] External floating roof tank
[ ] Internal floating roof tank
[X] Fixed roof tank
[ ] Vertical cylindrical tank
[ ] Horizontal cylindrical tank
[ ] Pressure tank
[ ] Other, specify ___

7. Location of tank: [X] Outdoors [ ] Indoors [ ] Underground

8. Type of filling: [ ] Splash [ ] Submerged [ ] Other, specify See note @ 12

9. If this tank is located outdoors and above ground, provide the paint color of the tan

[ ] Aluminum (specular) [ ] Light gray [ ] White
[ ] Aluminum (diffuse) [ ] Medium gray [X] Other, specify N/A
The tank sidewall is coated with a tar sealent, enclosed in an earthen berm. The dom is coated with a polyurethane foam.
Condition of paint: [ ] Good [ ] Poor N/A

10. If this tank is equipped with or vented to a vapor control system, complete (a) throug (c) of this item.

a) Type of vapor control system Radon Treatment System
Manufacturer Custom made Make or model N/A
Date installed (month and year) 11/1987

b) Date tank was equipped with or vented to vapor control system (month & year) 11/198

c) Specify the rate of emission or percent control (by weight) for any pollutants beir controlled: Radon gas, 2.5 Ci/year See atached calculations
(Attach calculations and test data to support response, unless previously submittec

7100

DOE - FMPC
(Facility Name)
K-65 Silo #1 65-001
(tank identification)

11. Complete the table below for any pressure or vacuum relief vent valve.

Type of Vent Valve	Pressure Setting	Vacuum Setting	If pressure relief is discharged to a vapor control, identify the vapor control.
N/A			

12. Operational Data (complete (a) through (g) of this item for all materials stored or t be stored. Attach additional sheets if necessary.)

a) Material K-65 & Australian Radium cake Trade Name N/A
Density: `92 lbs/ft^3 or _____° API Producer N/A

b) Temperature of stored material: Average AMB±8 °F and Maximum _____ ° F
(If temperature is approximately outdoor ambient temperature, write "AMB".)

c) Vapor pressure of stored material (Complete i, ii, iii of this item. If vapo pressure is not known, write "unknown"):

i.) Actual vapor pressure: None psia at average storage temperatur
None psia at maximum storage temperatur
The stored material is a solid.

ii.) Reid vapor pressure: Average unk psi and minimum-maximum _____-_____ ps

iii.) If material stored is a gas or liquified gas, provide the pressure a which it is stored: _____ psi gage at _____ °F

d) Type of liquid organic material (If the material is an organic liquid other tha a gasoline, fuel oil, kerosene, crude oil, lubricant or other petroleum liquid answer the question below.)

Is it a photochemically reactive material? [ ] Yes [ ] No

e) Type of waste material (If the material is a waste, answer the question below.)

Is it a hazardous waste? [ ] yes [ ] No
If yes, identify type (EPA hazardous waste number) _____

f) Indicate the year (or 12-month period) for item (g): See note below

g) Annual throughput of material: N/A - See note below gallons.

NOTE: Radon containing material was last placed in the tank in 1966. Bentonite cla was placed in the silo in 1991 to minimize radon emissions.

Completed by Kip Klee Date 08/03/95

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7100

From: Randy C. Janke WMCO:CP:OU4:91-005

Date: January 21, 1991

Subject: Gamma Dose Calculations At The K-65 Silo Domes After The Addition Of Bentonite

To: D. A. Nixon

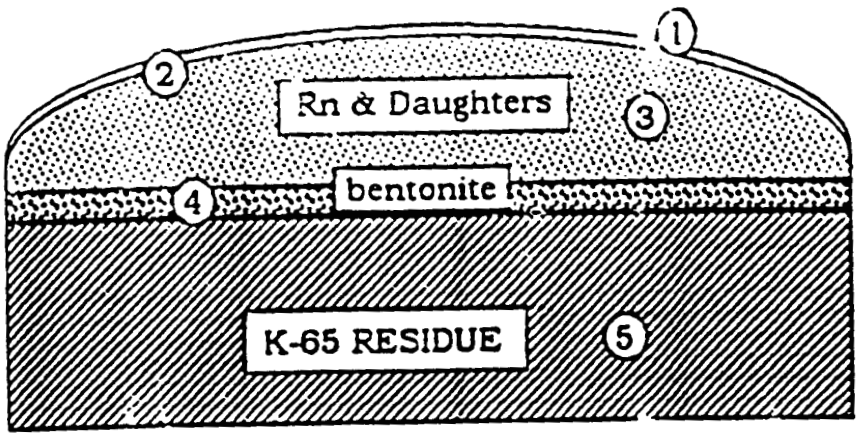
This memo serves to illustrate both the nature and a reasonable approximation to the problem of gamma dose at the top of the K-65 Silo dome. The following information presents the background and the calculations used to make an estimate of the dose after bentonite has been added.

The K-65 Silos (Silos 1 and 2) contain radium bearing residues. The radium concentration in the residue is on the order of 100 - 400 nCi/g with a total inventory estimated to be approximately 1600 Curies per silo. The radium and the associated decay products (radon, polonium, bismuth, and lead) emit gamma rays (g) as part of the radioactive decay process. These g's are not emitted in every disintegration process nor is the energy of the g the same in each case. The number of g's and the corresponding energies is dependent on the decay scheme of the associated radionuclide. The energy of these g's ranges from 46 Kev to 1.76 Mev. These g's are the principal contributor to the external dose measured at the top of the silo dome. To calculate specifically the dose rate that will result from the residues covered by bentonite detailed knowledge of the source its configuration and the characteristics of the shield material is required.

The shield material is considered to be both the bentonite, the air inside the dome head space, and the dome surface. Figure 1 illustrates the various facets of the g flux problem. These are described as follows: 1) the silo dome acts as a shield which is taken to be approximately 3 inches thick at the center. 2) the inside portion of the dome can serve to collect radon daughter products and thereby serve as a secondary source of g's. 3) radon and the associated daughter products reside in the open head space of the silo and therefore serve as a secondary source of g's. 4) the bentonite acts as both a shield and a secondary source due to the diffusion of radon, and 5) the principal source of gamma ray energy is the K-65 radium bearing residues.

For the purposes of the estimate of the dose at the top of the dome the K-65 residues are taken to be uniformly distributed with radium. This assumption reduces the complexity of the gamma source by using an infinite and homogeneous planar source to approximate the K-65 residues. By using this approximation the gamma flux can be represented by a simple equation representing both the collided and uncollided flux. This equation is given below:

Figure 1: K-65 Silo Gamma Source And Shielding Diagram



1) - Silo dome acts as a shield.

2) - Rn & daughters build up on the inside dome surface.

3) - Rn & daughters build up in head space.

4) - Bentonite acts as a shield to Ra gammas and as a reservoir for radon and daughters

5) - K-65 Residue is the primary source of gammas and is the only source of radium

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$$\phi_b = \frac{S}{2} \sum A_n E_i(1 + \alpha)\mu aj \quad (1)$$

where:

f_b = uncollided and collided gamma flux.
S = source strength.
E_1 = a function used to approximate the gamma interaction inside the shield material.
A_n and a - are coefficients of the point buildup correlation.
a = the perpendicular distance from the source to the point of exposure.
m = mass absorption and/or attenuation coefficient of the shield material.

This equation is used to estimate the gamma flux at any point from the surface of the residue to the dome surface and the associated buildup of gammas as a result of scattering reactions. Using the flux calculations the dose rate then can be represented by Equation 2:

$$\dot{D} = 0.0576 \; o_t E_0 \; (\mu a) \quad \text{mrad/hr} \qquad (2)$$

where:
$\dot{D}$ = dose rate (mrad/hr).
f_t = the total gamma flux (g's/cm²-sec).
E_0 = the energy of the gamma ray (Mev).
ma = mass absorption coefficient (cm²/g).

The calculation of buildup flux results in a source term multiplication factor of 0.4825. This factor incorporates the uncollided and collided gamma flux through the bentonite. The reduction factor resulting from the silo dome structure was found to be approximately 0.73. The overall reduction of gamma flux is then the product of these two factors which is 0.35. This factor multiplied by the source term will provide a final gamma flux in order to determine the external dose rate.

The next essential requirement is an estimate of the source term. The source term is the total number of g's emitted per cm² per second. The source term estimate as well as the final flux calculations is made by less complex by making several simplifying assumptions. The first is the averaging of the gamma ray energies. The second relates to an estimate of the fraction of g's emitted per disintegration of radium and the associated daughter products. The third assumption is related to the total activity of radium and the daughters and to the depth of residue material which contributes to the surface flux. The total gamma ray flux is estimated to be in the range of 5×10^4 to 2×10^5 g/cm2-sec. This results due to contributions from the

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residues down to a depth of 150 cm as well as from radon and its associated daughters. This range of gamma flux also correlates with measured dose rates at the top of the dome. The measured dose rate values were in the range of 125 to 209 mrad/hr. The final estimate of the dose rate is then made by calculating the emerging flux at the top of the silo dome. Using the above calculated buildup factor the final gamma flux was found to be 3.5 x 10^4 g's/cm^2-sec. Using the dose equation presented the dose rate was found to be approximately 19 mrem/hr.

The estimate of the dose rate at the dome top was also made by incorporating external dose conversion factors as referenced in "A Manual For Implementing Residual Radioactive Material Soil Guidelines" also referred to as RESRAD (DOE/CH/8901). The dose conversion factors (DCF) and the associated methodology provided in the above document was used to both supplement and check the estimation of flux and dose rate by means of Equations 1 and 2 above. In addition to the RESRAD methodology an estimate of the reduction in gamma flux is made by calculating the flux attenuation due to bentonite, the air, and the dome itself. The equations the flux attenuation is given below.

$$I = I_0 \, e^{-(\mu/\rho)\rho x} \qquad (3)$$

where:

I = attenuated gamma flux,
I_0 = incident gamma flux,
m/r = mass attenuation coefficient (cm^2/g),
r = density,
x = thickness of shield.

The RESRAD method incorporates a DCF and an environmental transport factor (ETF). The depth of the K-65 residue material reduces the ETF to unity. The DCF for radium-226 and the associated daughters is given as 9.63 mrem/yr per pCi/cm^3. The range of activity of radium per gram of residue was discussed previously and is assumed to be 600 nCi/cm^3 for the purposes of this calculation. The dose rate would then be calculated to be approximately 659 mrem per hour. This estimate is taken to be at a height of 1 meter above the surface. The estimate of the dose at the dome top must also take into account the gamma attenuation due to the air in the head space and the concrete in the dome itself. After these factors are accounted for the dose rate was found to be approximately 19 mrem/hr. The attenuation factor of bentonite was found to be 88% and the silo dome structure was 73%.

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Both of the methods used result in estimates of the dose rate at the top of the silo dome to be approximately the same. The use of several different methods to check results provides additional confidence in the results. The dose rate at the top of the silo after installation of bentonite was estimated to be approximately 20 mrem/hr.

Randy C. Janke

R. C. Janke
Operable Unit 1

RCJ:rcj

c: J. R. Craig, DOE/FMPC
H.H. Glassey
L. A. Heckendorn
S. A. Radabaugh
W. G. Tope
R. A. Vogel

AR Files

DATA SHEET

Calculated By: R. C. Janke

Date: 22 January 1991

The purpose of this calculation is to relate the addition of bentonite to Silos 1 and 2 to the amount of radon that will be released. The basic assumption is that the added bentonite will not reduce the radon concentration to zero. The problem is then to estimate the quantity that will be available for release. This calculation references the Data Sheet attached to Appendix E2 of the Air Permit to Operate and NUREG-CR/5 33. The method used to determine the radon release is simply a comparison of the radon flux from the bare and covered residues.

The basic bare flux equation is:

$$J_t = 10^4 R\rho E\sqrt{\lambda D_t}\tanh\sqrt{\frac{\lambda}{D_t}}X_t \qquad (1)$$

where:

J_t = Radon flux from bare residue pCi/m² - s

R = Specific activity of radium

ρ = Residue density

E = Radon emanation coefficient

λ = Radon decay constant

D_t =Radon diffusion coefficient through the residue

X_t = Depth of residues

The flux from covered residues is then:

$$J_c = \frac{2J_t e^{-b_c x_c}}{\left[1+\sqrt{\frac{a_t}{a}}\tanh(b_t x_t)\right] + \left[1 - \sqrt{\frac{a_t}{a_c}}\tanh(b_t x_t)\right] e^{-2b_c x_c}} \qquad (2)$$

J_c = flux from covered residues pCi/m² - s

$$b_c = \sqrt{\frac{\lambda}{D_c}}$$

$$a_c = p_c^2 D_c [1 - (1-k) m_c]^2$$

$$b_t = \sqrt{\frac{\lambda}{D_t}}$$

$$a_t = p_t^2 D_t [1 - (1-k) m_t]^2$$

p = porosity

k = water to air radon retention factor

$m_{c,t}$ = moisture content

x_c = thickness of bentonite

See attached sheet for results of equations (1) and (2).

These flux calculations were based on using one (1) foot of bentonite.

$J_t = 3.775 \times 10^4$ pCi/m² - s

$J_c = 2.877 \times 10^2$ pCi/m² - s

$$\frac{J_t}{J_c} = 7.62 \times 10^{-3} \text{ or a } 99.24\% \text{ reduction}$$

The currently estimated release of radon is essentially 150 Ci/year per silo. The quantity of radon released after the bentonite has been added is estimated to be:

2.287 Ci/year for both Silos 1 and 2

Based on the inherent uncertainties associated with calculations of this nature. it would be prudent to estimate a total inventory of radon released to the atmosphere to be 2.5 Ci/year for each silo with the total being 5.0 Ci/year.

//

The following is a printout of the specific calculations made using the above referenced equations. The intermediate values and the final flux values are included. It is important to note that the printout uses variable names and symbols wherever possible and there are two distinct calculation sets one for the residues and one for the cover.

RAECOM solution of radon flux from bentonite covered tailings inside the K-65 silos. The calculated flux levels are assumed to represent the radon condition inside the silos.

	bare residue	cover
D	1.72487E-03	1.25948E-04
D'	0.00000E+00	0.00000E+00
D	1.72487E-03	1.25948E-04
λ	2.10000E-06	2.10000E-06
R	1.12000E+05	
ρ	1.60000E-00	8.80000E-01
E	3.50000E-01	
p	4.48300E-01	6.48000E-01
x	2.40000E+01	1.20000E+01
constant	1.00000E+04	

	bare residue	cover
sqrt(lDt)	6.01850E-05	1.62632E-05
sqrt(l. Dt)	3.48924E-02	1.29126E-01
at	6.08472E-05	
ac	3.57509E-06	
bt	3.48924E-02	
bc	1.29126E-01	
xt	7.31520E+02	
xc	3.04800E+01	
k	2.60000E-01	1.01345E+00
m	7.85188E-01	1.00000E+00
M	2.20000E+01	7.46270E+01
sqrt(at/ac)	4.12550E+00	
tanh(btxt)	1.00000E+00	
at/ac	1.70198E+01	

FLUX FROM BARE TAILINGS

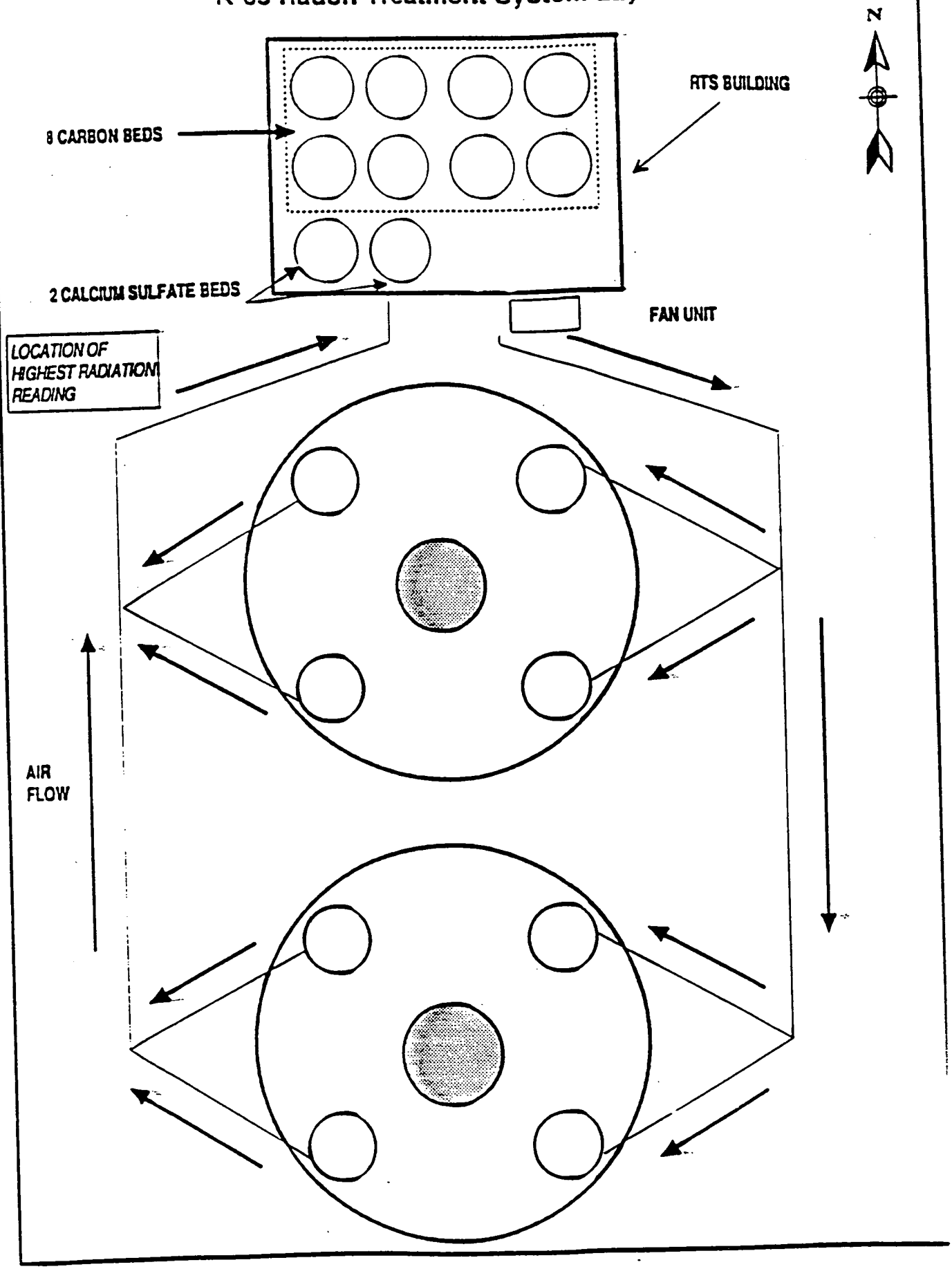
Jt
3.77480E+04

FLUX FROM COVERED TAILINGS

Jc
2.87744E+02

Jc - s
1.47449E+03

∧-65 Radon Treatment System Layout



Radon Treatment System

The RTS was installed in 1987. It is currently being used as a means to temporarily reduce the radiation dose at the silo dome surface. This radiation is produced by the radioactive decay of the residues in the silos.

To operate the RTS, PVC piping is attached to the four peripheral manholes on one of the silos, and a designated set of valves are opened to establish a flow path for the air from the silo through the RTS and back into the silo (see Figure 3). The flow path from the silo first passes through two calcium sulfate beds which remove the moisture from the air. The air then passes through a minimum of two and up to eight activated-carbon beds which remove the radon from the air through an adsorption process. The filtered air is then returned to the silo. The process will reduce the surface dose rates at the silo domes from a nominal 150 mrem/hr to less than 60 mrem/hr in approximately 4 hours.

The RTS operates as a closed, recirculating system so that the radon from the silo air is continuously absorbed in the activated-carbon beds. The time estimated to exchange one volume of the silo dome head space is 48 and 38 minutes for K-65 Silos 1 and 2, respectively. This figure is based on a head space volume of 48,000 and 38,000 ft^3 for K-65 Silos 1 and 2, respectively.

The RTS design assumed a 1,000ft^3/min. flow with an initial radon content in the silo dome head space of 37 Ci and a one time 10 volume turnover for each silo. It was estimated that at least 0.4 Ci remains in the silo domes following operation of the RTS because of the continual generation of radon gas from within the residues (Grumski 1988).

The radon treatment building (located immediately north of Silo 2) contains two calcium sulfate beds, eight activated-carbon beds, and two fan units. The building is surrounded by 32-inch thick concrete radiation shielding walls made of stacked solid unmortared blocks. Other equipment includes the valves and piping used to transport the radon-laden air from and back to the silos. The shielding reduces the gamma radiation dose rates from the radioactive decay of the materials collected within the activated-carbon canisters. Manual valve actuation rods extend through the concrete walls.

Operation of the RTS will be required prior to any activities on either of the K-65 silos, immediately after a visual inspection of the system piping to and from the silo to assure continuity of the gas movement system.

Due to the amount of radon trapped on freshly used carbon filters and the inherent direct gamma radiation rate (several rads/hr), entry to the RTS equipment shed is carefully controlled by Radiological Safety to minimize personnel exposure.

7100

OHIO ENVIRONMENTAL PROTECTION AGENCY
APPLICATION FOR A PERMIT TO OPERATE
AN AIR CONTAMINANT SOURCE

D.O.E.-Fernald Environmental Management Project
Facility Name

Mr. Stephen M. Beckman
Person to Contact

7400 Willey Road
Facility Address

Post Office Box 538704
Mailing Address

Fernald Hamilton 45030
City County Zip

Cincinnati OH 45253-8704
City State Zip

513/ 648-3000
Telephone Area Number

513/ 648-5264
Telephone

#1431110128- T112
(Application no., if this is a renewal application)

4953
Std. Ind. Class. Code

1. Complete and attach any of the following appendices most appropriate to the air contaminant source. In addition, a compliance time schedule form is to be attached when applicable. Check as appropriate the following:

___Appendix A, Process
___Appendix B, Fuel-Burning Equipment
___Appendix C, Incinerator
___Appendix D, Surface Coating or Printing Operation
_X_Appendix E, Storage Tank
___Appendix H, Gasoline Dispensing Facility
___Appendix J, Loading Rack at Bulk Gasoline Plant or Terminal
___Appendix K, Surface Coating Line or Printing Line
___Appendix L, Solvent Metal Cleaning
___Appendix M, Fugitive Dust Emission Sources
_____ Specify Appendix No.
___Appendix N, Rubber Tire Manufacturing
___Appendix O, Dry Cleaning Facility
___Appendix P, Landfills
___Other Appendix _____
___Compliance Time Schedule

2. Description of Source (same as used on appendix): K-65 Silo #2

3. Your identification for Source (same as used on appendix): 65-002

I, being the individual specified in Rule 3745-35-02(B) of the Ohio Administrative Code, hereby apply for a Permit to Operate the air contaminant source(s) described herein. As required, the following additional documents are submitted as part of this application (describe all attachments):

Authorized Signature*
Terence D. Hagen
Director Environmental Compliance
Title
8/9/95
Date

*Pursuant to OAC Rule 3745-35-02(B) (Permit to Operate).
Operation of an air contaminant source without an effective permit to operate is prohibited to 3704.05 Ohio Revised Code.

FOR OFFICIAL USE ONLY

Premise No.___/___/___/____
Source No.___/____
Application No.____/____

7100

DOE - FEMP
(Facility Name)
OEPA NO 1431110128 T112
FEMP ID NO. 65-002

APPENDIX E-2

INORGANIC MATERIAL STORAGE TANK OR
STORAGE TANK WITH CAPACITY LESS THAN 40,000 GALLONS

1. Tank identification: Name or number K-65 Silo #2 Date Installed 1952 (month/year)

2. Tank capacity: `156,350 cubic feet

3. Tank shape: [X] Cylindrical [ ] Rectangular
[ ] Spherical [ ] Other, specify

4. Tank dimensions: Diameter 80 ft. Height 36 ft.* Length --- Width ---
*To the top of the dome is 36ft. The sidewall is 27 ft. High.

5. Tank shell material: [ ] Steel [ ] Aluminum [X] Other, specify Reinforced concrete

6. Type of tank:
[ ] External floating roof tank
[ ] Internal floating roof tank
[X] Fixed roof tank
[ ] Vertical cylindrical tank
[ ] Horizontal cylindrical tank
[ ] Pressure tank
[ ] Other, specify

7. Location of tank: [X] Outdoors [ ] Indoors [ ] Underground

8. Type of filling: [ ] Splash [ ] Submerged [ ] Other, specify See note @ 12c

9. If this tank is located outdoors and above ground, provide the paint color of the tan

[ ] Aluminum (specular) [ ] Light gray [ ] White
[ ] Aluminum (diffuse) [ ] Medium gray [X] Other, specify N/A
The tank sidewall is coated with a tar sealent, enclosed in an earthen berm. The dom is coated with a polyurethane foam.
Condition of paint: [ ] Good [ ] Poor N/A

10. If this tank is equipped with or vented to a vapor control system, complete (a) throug (c) of this item.

a) Type of vapor control system Radon Treatment System
Manufacturer Custom made Make or model N/A
Date installed (month and year) 11/1987

b) Date tank was equipped with or vented to vapor control system (month & year) 11/198

c) Specify the rate of emission or percent control (by weight) for any pollutants bein controlled: Radon gas, 2.5 Ci/year See atached calculations
(Attach calculations and test data to support response, unless previously submitted

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DOE - FMPC
(Facility Name)
K-65 Silo #2 65-002
(tank identification)

11. Complete the table below for any pressure or vacuum relief vent valve.

Type of Vent Valve	Pressure Setting	Vacuum Setting	If pressure relief is discharged to a vapor control, identify the vapor control.
N/A			

12. Operational Data (complete (a) through (g) of this item for all materials stored or t be stored. Attach additional sheets if necessary.)

a) Material K-65 & Australian Radium cake Trade Name N/A
Density: `92 lbs/ft^3 or _____° API Producer N/A

b) Temperature of stored material: Average AMB±8 °F and Maximum _____ ° F
(If temperature is approximately outdoor ambient temperature, write "AMB".)

c) Vapor pressure of stored material (Complete i, ii, iii of this item. If vapor pressure is not known, write "unknown"):

i.) Actual vapor pressure: None psia at average storage temperature
None psia at maximum storage temperature
The stored material is a solid.

ii.) Reid vapor pressure: Average unk psi and minimum-maximum _____-_____ psi

iii.) If material stored is a gas or liquified gas, provide the pressure at which it is stored: _____ psi gage at _____ °F

d) Type of liquid organic material (If the material is an organic liquid other than a gasoline, fuel oil, kerosene, crude oil, lubricant or other petroleum liquid, answer the question below.)

Is it a photochemically reactive material? [ ] Yes [ ] No

e) Type of waste material (If the material is a waste, answer the question below.)

Is it a hazardous waste? [ ] yes [ ] No
If yes, identify type (EPA hazardous waste number) _____

f) Indicate the year (or 12-month period) for item (g): See note below

g) Annual throughput of material: N/A - See note below gallons.

NOTE: Radon containing material was last placed in the tank in 1966. Bentonite cla was placed in the silo in 1991 to minimize radon emissions.

Completed by Kip Klee Date 08/03/95

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From: Randy C. Janke WMCO:CP:OU4:91-005

Date: January 21, 1991

Subject: Gamma Dose Calculations At The K-65 Silo Domes After The Addition Of Bentonite

To: D. A. Nixon

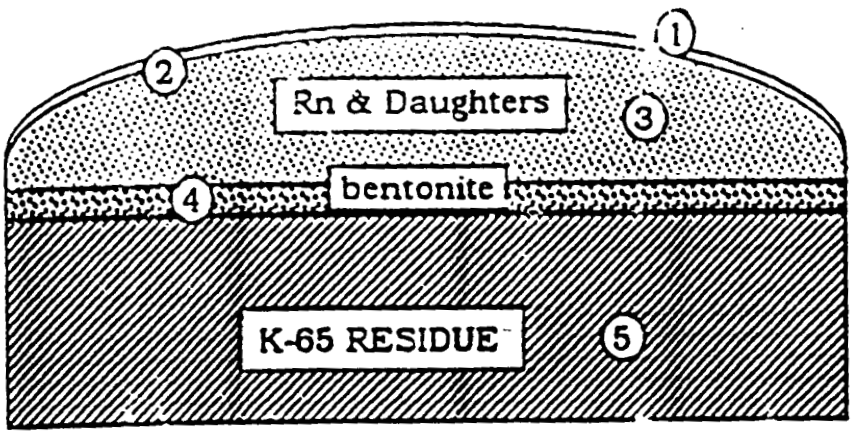
This memo serves to illustrate both the nature and a reasonable approximation to the problem of gamma dose at the top of the K-65 Silo dome. The following information presents the background and the calculations used to make an estimate of the dose after bentonite has been added.

The K-65 Silos (Silos 1 and 2) contain radium bearing residues. The radium concentration in the residue is on the order of 100 - 400 nCi/g with a total inventory estimated to be approximately 1600 Curies per silo. The radium and the associated decay products (radon, polonium, bismuth, and lead) emit gamma rays (g) as part of the radioactive decay process. These g's are not emitted in every disintegration process nor is the energy of the g the same in each case. The number of g's and the corresponding energies is dependent on the decay scheme of the associated radionuclide. The energy of these g's ranges from 46 Kev to 1.76 Mev. These g's are the principal contributor to the external dose measured at the top of the silo dome. To calculate specifically the dose rate that will result from the residues covered by bentonite detailed knowledge of the source its configuration and the characteristics of the shield material is required.

The shield material is considered to be both the bentonite, the air inside the dome head space, and the dome surface. Figure 1 illustrates the various facets of the g flux problem. These are described as follows: 1) the silo dome acts as a shield which is taken to be approximately 3 inches thick at the center. 2) the inside portion of the dome can serve to collect radon daughter products and thereby serve as a secondary source of g's. 3) radon and the associated daughter products reside in the open head space of the silo and therefore serve as a secondary source of g's. 4) the bentonite acts as both a shield and a secondary source due to the diffusion of radon, and 5) the principal source of gamma ray energy is the K-65 radium bearing residues.

For the purposes of the estimate of the dose at the top of the dome the K-65 residues are taken to be uniformly distributed with radium. This assumption reduces the complexity of the gamma source by using an infinite and homogeneous planar source to approximate the K-65 residues. By using this approximation the gamma flux can be represented by a simple equation representing both the collided and uncollided flux. This equation is given below:

Figure 1: K-65 Silo Gamma Source And Shielding Diagram



1) - Silo dome acts as a shield.

2) - Rn & daughters build up on the inside dome surface.

3) - Rn & daughters build up in head space.

4) - Bentonite acts as a shield to Ra gammas and as a reservoir for radon and daughters

5) - K-65 Residue is the primary source of gammas and is the only source of radium

$$\phi_b = \frac{S}{2} \sum A_n E_1[(1 + \alpha)\mu a] \quad (1)$$

where:

f_b = uncollided and collided gamma flux.
S = source strength,
E_1 = a function used to approximate the gamma interaction inside the shield material,
A_n and a - are coefficients of the point buildup correlation,
a = the perpendicular distance from the source to the point of exposure,
m = mass absorption and/or attenuation coefficient of the shield material.

This equation is used to estimate the gamma flux at any point from the surface of the residue to the dome surface and the associated buildup of gammas as a result of scattering reactions. Using the flux calculations the dose rate then can be represented by Equation 2:

$$\dot{D} = 0.0576 \; o_t E_0 \; (\mu a) \quad \text{mrad/hr} \qquad (2)$$

where:
$\dot{D}$ = dose rate (mrad/hr),
f_t = the total gamma flux (g's/cm^2-sec),
E_0 = the energy of the gamma ray (Mev),
ma = mass absorption coefficient (cm^2/g).

The calculation of buildup flux results in a source term multiplication factor of 0.4825. This factor incorporates the uncollided and collided gamma flux through the bentonite. The reduction factor resulting from the silo dome structure was found to be approximately 0.73. The overall reduction of gamma flux is then the product of these two factors which is 0.35. This factor multiplied by the source term will provide a final gamma flux in order to determine the external dose rate.

The next essential requirement is an estimate of the source term. The source term is the total number of g's emitted per cm^2 per second. The source term estimate as well as the final flux calculations is made by less complex by making several simplifying assumptions. The first is the averaging of the gamma ray energies. The second relates to an estimate of the fraction of g's emitted per disintegration of radium and the associated daughter products. The third assumption is related to the total activity of radium and the daughters and to the depth of residue material which contributes to the surface flux. The total gamma ray flux is estimated to be in the range of 5 x 10^4 to 2 x 10^5 g/cm2-sec. This results due to contributions from the

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residues down to a depth of 150 cm as well as from radon and its associated daughters. This range of gamma flux also correlates with measured dose rates at the top of the dome. The measured dose rate values were in the range of 125 to 209 mrad/hr. The final estimate of the dose rate is then made by calculating the emerging flux at the top of the silo dome. Using the above calculated buildup factor the final gamma flux was found to be 3.5 x 10^4 g's/cm^2-sec. Using the dose equation presented the dose rate was found to be approximately 19 mrem/hr.

The estimate of the dose rate at the dome top was also made by incorporating external dose conversion factors as referenced in "A Manual For Implementing Residual Radioactive Material Soil Guidelines" also referred to as RESRAD (DOE/CH/8901). The dose conversion factors (DCF) and the associated methodology provided in the above document was used to both supplement and check the estimation of flux and dose rate by means of Equations 1 and 2 above. In addition to the RESRAD methodology an estimate of the reduction in gamma flux is made by calculating the flux attenuation due to bentonite, the air, and the dome itself. The equations the flux attenuation is given below.

$$I = I_0 \, e^{-(\mu/\rho)\rho x} \qquad (3)$$

where:

I = attenuated gamma flux,
I_0 = incident gamma flux,
m/r = mass attenuation coefficient (cm^2/g),
r = density,
x = thickness of shield.

The RESRAD method incorporates a DCF and an environmental transport factor (ETF). The depth of the K-65 residue material reduces the ETF to unity. The DCF for radium-226 and the associated daughters is given as 9.63 mrem/yr per pCi/cm^3. The range of activity of radium per gram of residue was discussed previously and is assumed to be 600 nCi/cm^3 for the purposes of this calculation. The dose rate would then be calculated to be approximately 659 mrem per hour. This estimate is taken to be at a height of 1 meter above the surface. The estimate of the dose at the dome top must also take into account the gamma attenuation due to the air in the head space and the concrete in the dome itself. After these factors are accounted for the dose rate was found to be approximately 19 mrem/hr. The attenuation factor of bentonite was found to be 88% and the silo dome structure was 73%.

Both of the methods used result in estimates of the dose rate at the top of the silo dome to be approximately the same. The use of several different methods to check results provides additional confidence in the results. The dose rate at the top of the silo after installation of bentonite was estimated to be approximately 20 mrem/hr.

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DATA SHEET

Calculated By: R. C. Janke

Date: 22 January 1991

The purpose of this calculation is to relate the addition of bentonite to Silos 1 and 2 to the amount of radon that will be released. The basic assumption is that the added bentonite will not reduce the radon concentration to zero. The problem is then to estimate the quantity that will be available for release. This calculation references the Data Sheet attached to Appendix E2 of the Air Permit to Operate and NUREG-CR/5-83. The method used to determine the radon release is simply a comparison of the radon flux from the bare and covered residues.

The basic bare flux equation is:

$$J_t = 10^4 R\rho E\sqrt{\lambda D_t}\tanh\sqrt{\frac{\lambda}{D_t}}X_t \qquad (1)$$

where:

J_t = Radon flux from bare residue pCi/m^2 - s

R = Specific activity of radium

ρ = Residue density

E = Radon emanation coefficient

λ = Radon decay constant

D_t =Radon diffusion coefficient through the residue

X_t = Depth of residues

The flux from covered residues is then:

$$J_c = \frac{2J_t e^{-b_c x_c}}{\left[1+\sqrt{\frac{a_t}{a}}\tanh(b_t x_t)\right] + \left[1 - \sqrt{\frac{a_t}{a_c}}\tanh(b_t x_t)\right] e^{-2b_c x_c}} \qquad (2)$$

J_c = flux from covered residues pCi/m² - s

$$b_c = \sqrt{\frac{\lambda}{D_c}}$$

$$a_c = p_c^2 D_c [1 - (1-k) m_c]^2$$

$$b_t = \sqrt{\frac{\lambda}{D_t}}$$

$$a_t = p_t^2 D_t [1 - (1-k) m_t]^2$$

p = porosity

k = water to air radon retention factor

$m_{c,t}$ = moisture content

x_c = thickness of bentonite

See attached sheet for results of equations (1) and (2).

These flux calculations were based on using one (1) foot of bentonite.

$J_t = 3.775 \times 10^4$ pCi/m² - s

$J_c = 2.877 \times 10^2$ pCi/m² - s

$$\frac{J_t}{J_c} = 7.62 \times 10^{-3} \text{ or a } 99.24\% \text{ reduction}$$

The currently estimated release of radon is essentially 150 Ci/year per silo. The quantity of radon released after the bentonite has been added is estimated to be:

2.287 Ci/year for both Silos 1 and 2

Based on the inherent uncertainties associated with calculations of this nature, it would be prudent to estimate a total inventory of radon released to the atmosphere to be 2.5 Ci/year for each silo with the total being 5.0 Ci/year.

The following is a printout of the specific calculations made using the above referenced equations. The intermediate values and the final flux values are included. It is important to note that the printout uses variable names and symbols wherever possible and there are two distinct calculation sets one for the residues and one for the cover.

RAECOM solution of radon flux from bentonite covered tailings inside the K-65 silos. The calculated flux levels are assumed to represent the radon condition inside the silos.

	bare residue	cover
D	1.72487E-03	1.25948E-04
D'	0.00000E+00	0.00000E+00
D	1.72487E-03	1.25948E-04
λ	2.10000E-06	2.10000E-06
R	1.12000E+05	
ρ	1.60000E+00	8.80000E-01
E	3.50000E-01	
p	4.48300E-01	6.48000E-01
x	2.40000E+01	1.20000E+01
constant	1.00000E+04	

	bare residue	cover
sqrt(λD't)	6.01850E-05	1.62632E-05
sqrt(λ Dt)	3.48924E-02	1.29126E-01
at	6.08472E-05	
ac	3.57509E-06	
bt	3.48924E-02	
bc	1.29126E-01	
xt	7.31520E+02	
xc	3.04800E+01	
k	2.60000E-01	1.01345E+00
m	7.85188E-01	1.00000E+00
M	2.20000E+01	7.46270E+01
sqrt(at/ac)	4.12550E+00	
tanh(btxt)	1.00000E+00	
at/ac	1.70198E+01	

FLUX FROM BARE TAILINGS

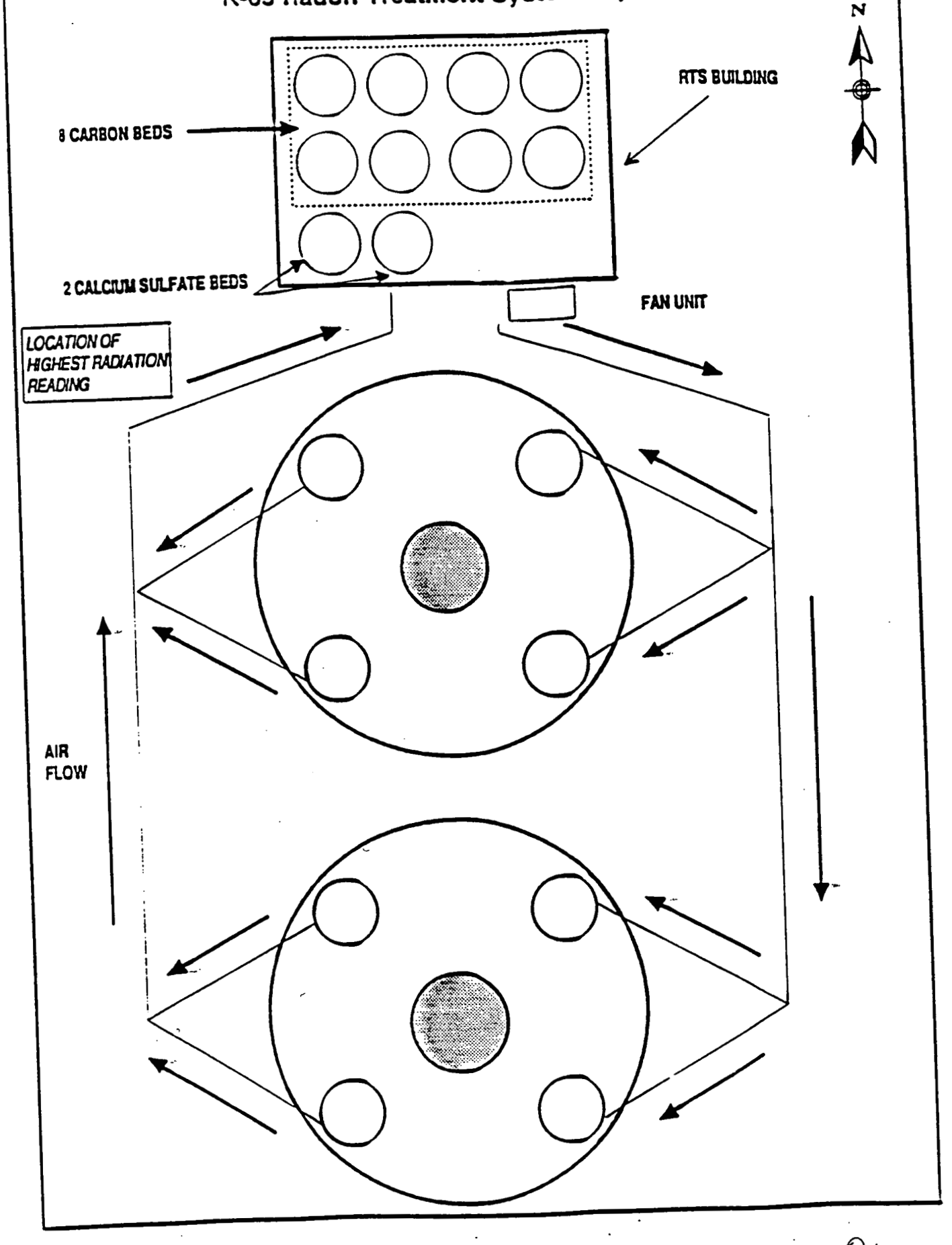
Jt
3.77480E+04

FLUX FROM COVERED TAILINGS

Jc
2.87744E+02

Jc - s
1.47449E+03

∩-65 Radon Treatment System Layout



Radon Treatment System

The RTS was installed in 1987. It is currently being used as a means to temporarily reduce the radiation dose at the silo dome surface. This radiation is produced by the radioactive decay of the residues in the silos.

To operate the RTS, PVC piping is attached to the four peripheral manholes on one of the silos, and a designated set of valves are opened to establish a flow path for the air from the silo through the RTS and back into the silo (see Figure 3). The flow path from the silo first passes through two calcium sulfate beds which remove the moisture from the air. The air then passes through a minimum of two and up to eight activated-carbon beds which remove the radon from the air through an adsorption process. The filtered air is then returned to the silo. The process will reduce the surface dose rates at the silo domes from a nominal 150 mrem/hr to less than 60 mrem/hr in approximately 4 hours.

The RTS operates as a closed, recirculating system so that the radon from the silo air is continuously absorbed in the activated-carbon beds. The time estimated to exchange one volume of the silo dome head space is 48 and 38 minutes for K-65 Silos 1 and 2, respectively. This figure is based on a head space volume of 48,000 and 38,000 ft^3 for K-65 Silos 1 and 2, respectively.

The RTS design assumed a 1,000ft^3/min. flow with an initial radon content in the silo dome head space of 37 Ci and a one time 10 volume turnover for each silo. It was estimated that at least 0.4 Ci remains in the silo domes following operation of the RTS because of the continual generation of radon gas from within the residues (Grumski 1988).

The radon treatment building (located immediately north of Silo 2) contains two calcium sulfate beds, eight activated-carbon beds, and two fan units. The building is surrounded by 32-inch thick concrete radiation shielding walls made of stacked solid unmortared blocks. Other equipment includes the valves and piping used to transport the radon-laden air from and back to the silos. The shielding reduces the gamma radiation dose rates from the radioactive decay of the materials collected within the activated-carbon canisters. Manual valve actuation rods extend through the concrete walls.

Operation of the RTS will be required prior to any activities on either of the K-65 silos, immediately after a visual inspection of the system piping to and from the silo to assure continuity of the gas movement system.

Due to the amount of radon trapped on freshly used carbon filters and the inherent direct gamma radiation rate (several rads/hr), entry to the RTS equipment shed is carefully controlled by Radiological Safety to minimize personnel exposure.