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BENTONITE EFFECTIVENESS MODEL RESULT FOR JANUARY THROUGH APRIL, 1992

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LETTER

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MAY 2 2 1992

DOE-1742-92

Mr. James A. Saric, Remedial Project Director
U. S. Environmental Protection Agency
Region V - 5HRE-8J
77 W. Jackson Boulevard
Chicago, Illinois 60604-3590

Mr. Graham E. Mitchell, Project Manager
Ohio Environmental Protection Agency
40 South Main Street
Dayton, Ohio 45402-2086

Dear Mr. Saric and Mr. Mitchell:

BENTONITE EFFECTIVENESS MODEL RESULTS FOR JANUARY THROUGH APRIL, 1992

Enclosed are the Bentonite Effectiveness Model Results for the January through April, 1992 time period. As discussed in the May 12, 1992 Program Managers' Meeting held in Chicago, due to the software and hardware problems encountered during the installation and checkout of the Data Logging System, the actual data for a majority of this time frame was thought to be suspect. To accommodate the fluctuations experienced in the radon concentrations in the headspace, a very conservative upper value of 500,000 pCi/l was selected and used as input to the Model. Also, hourly internal pressure and temperature readings were available for January 1-6, 1992 and February 1-14, 1992. Therefore, this data was used to support the January and February Model runs to evaluate the increase in radon concentration to the nearest resident. The results of these runs, utilizing the valid pressure and temperature data and the conservative radon concentration of 500,000 pCi/l, were both 0.0003 pCi/l radon concentration increases, above background, at the nearest resident. The results are significantly lower than the target concentration of 0.015 pCi/l above background. The internal pressure and temperature readings for March and April used to support the Model runs were daily averages, rather than hourly. However, we do not believe that this has significantly affected the outcome of the Model.

A re-run of the Model for these four months, after installation and check-out of the Data Logging System, as requested, is not possible because we are unable to recreate actual data. In addition, after analysis of the raw data, we feel the results are defendable and that they depict, if anything, a conservative estimate of the contribution to the radon concentration, above

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background, at the nearest resident resulting from the K-65 Silos after the installation of the Bentonite.

Substantial efforts are underway to correct the Data Logging System problems. We estimate that the system will be fully operational by July 1992.

If you or your staff have any questions, please contact Randi Allen at FTS/Commercial 513-738-6158.

Sincerely,

Jack R. Craig
Fernald Remedial Action
Project Manager

FN:Allen

Enclosure: As Stated

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BENTONITE EFFECTIVENESS ENVIRONMENTAL MONITORING REPORT

[redacted]

1.0 INTRODUCTION

As presented in the Silos 1 and 2 Removal Action - Bentonite Effectiveness Environmental Monitoring Plan, the Gaussian plume dispersion model, U.S. EPA's Industrial Source Complex Dispersion Model - Long Term, ISCLT version 3.4, was used to calculate the contribution of ^{222}Rn emitted from the K-65 silos to the off-site background radon concentration. Site-specific meteorological parameters and the calculated ^{222}Rn release rates were used as inputs to the ISCLT dispersion model to predict the ^{222}Rn concentration at the location of the nearest residence.

The exposure concentrations at the nearest residence were calculated for the following time periods:

Run 1A: Calculations for January 1-6, 1992 (with hourly averaged temperature and pressure parameters)

Run 1B: Calculations for the entire month of January, 1992 (with hourly averaged temperature and pressure parameters using data from January 1-6, 1992 and meteorological inputs using data for the entire month)

Run 2A: Calculations for February 1-14, 1992 (with hourly averaged temperature and pressure parameters)

Run 2B: Calculations for the entire month of February, 1992 (with hourly averaged temperature and pressure parameters using data from February 1-14, 1992 and meteorological inputs using data for the entire month)

Run 3: March, 1992 (with daily averaged temperature and pressure parameters, as opposed to hourly averages)

Run 4: April, 1992 (with daily averaged temperature and pressure parameters, as opposed to hourly averages)

The data for each of these runs will be discussed within this report. A Monte Carlo simulation was also conducted on the range of specific ^{222}Rn flux due to diffusion parameter values as indicated in the Bentonite Effectiveness Environmental Monitoring Plan; concrete thickness of the silo dome, porosity of concrete, and diffusion length of concrete.

2.0 METHODOLOGY

Two pathways for emissions of ^{222}Rn from the silos were considered: (1) diffusion of ^{222}Rn in the K-65 silo air through the concrete dome and polyurethane foam and (2) free air exchange between the silo air and the surrounding air (ventilation).

2.1 Diffusion Releases

2.1.1 Theory

From the concentration of ^{222}Rn in the silo air, the flux of ^{222}Rn diffusion through the concrete dome was calculated by:

$$J_c = \frac{E_c \lambda_{Rn} l_c C_a}{\sinh\left(\frac{L}{l_c}\right)}$$

[redacted]

Where:

J_c = ^{222}Rn flux from the concrete dome surfaces to the foam (pCi/M^2/sec, or similar units),
E_c = total porosity of the dome concrete,
l_c = diffusion length of ^{222}Rn in the dome concrete,
L = thickness of the dome concrete,
λ_{Rn} = decay constant of ^{222}Rn - (2.1×10^{-6} s^{-1})[1],
C_a = concentration of ^{222}Rn in the silo air,

There is also a foam and polyurethane coating over the surface of the concrete dome on each silo. This foam layer will further attenuate the radon flux before the radon is emitted to the atmosphere. This attenuation is determined as follows:

$$J = J_c \exp\left(\frac{-L_f}{\sqrt{D_f/\lambda_{Rn}}}\right)$$

Where:

J = ^{222}Rn flux emitted to the surrounding air (pCi/m^2-s)

J_c = ^{222}Rn flux from the concrete dome surfaces to the foam (pCi/M^2/sec, or similar units),

L_f = thickness of the foam (10 cm)

D_f = diffusion coefficient for the foam (4×10^{-6} cm^2/s)

The ^{222} Rn flux due to diffusion is then the value of **J**.

2.1.2 Calculations

Uncertainty associated with the modeling of release estimates have been performed for releases due to diffusion. The method used is a Monte Carlo simulation using a computer program to make many random samples from the parameter distributions and using these samples to develop a probability distribution of the forecasted release.

Uncertainty analysis is the process by which uncertainty in the parameters used in the development of a model is propagated through the model. The analysis process determines statistically defendable and quantitative impact on the final results, enabling the user of the information to fully understand the likely implications a project may have. Uncertainty analysis requires that a

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[1]The decay constant of radon is assumed to have no uncertainty.

[redacted]

distribution be assigned to a parameter instead of the use of a point estimate for the parameter. A Monte Carlo method was applied to the model through the use of a computer program for Monte Carlo simulation.

The Monte Carlo simulation used a simple random number sampling of the distribution of parameters. In simple random sampling, the distributions of parameters are assumed to be independent. For this assessment it was determined that 5,000 simulations were needed to obtain significant results.

The diffusion flux was estimated through a Monte Carlo simulation. This essentially means that each parameter, that had a range of values as indicated in the Bentonite Effectiveness Environmental Monitoring Plan, was varied considered in calculating the final flux. The radon flux due to diffusion at the interface of the silo domes and the atmosphere is 95 percent certain to be less than 0.078 pCi/M^2-s. The confidence level was established through the use of a Monte Carlo Simulation Mode used to address the uncertainty in the parameters. This information is included in appendix A.

The following are the parameter values which were input as ranges in the Monte Carlo model that were used in calculating the diffusion radon flux:

Concrete Thickness of the Silo Dome

The concrete thickness of the Silo Dome had a range of 7.62 centimeters to 10.16 centimeters (3 to 4 inches).

Porosity of Concrete

The porosity of concrete had a range of 0.05 to 0.27.

Diffusion Length of Concrete

The diffusion length of concrete had a range of 6 centimeters to 23 centimeters.

Silo Headspace ^{222}Rn Concentration

As originally presented in the plan, each silo headspace ^{222}Rn concentration would be included as a varied parameter in the Monte Carlo simulation based on the mean and the standard deviation of the collected data. This methodology was not performed because upon close examination of the data it was discovered to be extremely erratic and at times suspect. In February, 1992 this data began fluctuating. Since this data fluctuated so greatly it was deemed important to use a conservative upper value for the radon concentration. Hence, a ^{222}Rn concentration of 500,000 pCi/l was selected and used as a concentration input into the model.

2.2 Free Air Exchange (Ventilation)

2.2.1 Theory

Ventilation of radon from the silo is governed by the physics associated with the ideal gas law and, as such, is dependent upon the temperature and pressure

changes of the gases in the silo headspace as a result in the changes in the ambient atmosphere. The calculation of emissions of ^{222}Rn due to ventilation from the silos is based on the expansion of the silo gases due to changes in atmospheric conditions. The ventilation of silo gases is determined from the ideal gas law using temperature and pressure data collected.

$$PV = nRT$$

Where:

P = pressure of the gases within the silo,
V = volume of the silo headspace,
n = number of moles of the gases,
R = ideal gas constant, with appropriate units, and
T = temperature, in units of an absolute scale (K or °R).

For air exchange emissions, the assumption is made that the ^{222}Rn concentration in outside air is negligible compared to the silo concentration so that outside air does not provide a source of ^{222}Rn to the silo air. The ventilation of radon to the atmosphere is assumed to be small compared to the production of radon gases, thus the concentration of radon in the silos is assumed to be a constant which does not deviate from equilibrium. With these assumptions, the basic equation describing the rate of change in the silo air ^{222}Rn concentration can be written:

$$\frac{dC_a}{dt} = \frac{P_{Rn}}{V_0} - C_a \lambda_{eff}$$

C_a = concentration of $_{222}Rn$ in the silo air,
P_{Rn} = the constrained (by the presence of the silo) rate of release of $_{222}Rn$ into the silo air (production term) from the K-65 source material (activity per time),
V_o = volume of the air space in the silo above the K-65 material,
λ_{eff} = the effective removal rate of $_{222}Rn$ = $\lambda_{Eff} = \lambda_{Rn} + \lambda_v$,
λ_{Rn} = decay constant of ^{222}Rn - (2.1×10^{-6} s^{-1}),
λ_v = The ventilation rate due to the daily temperature changes λ_v is the fraction of the silo air exhaled due to the temperature changes per some unit of time period, with the units of air changes per time. Therefore:

$$\lambda_v = \Delta n / n_0$$

Where:

Δn = the change of number of moles of gas in silo headspace,
n_0 = the initial number of moles of gas in silo headspace

Based on the assumption of equilibrium of the radon in the headspace the following relationship is obtained:

$$P_{Rn} = C_a \lambda_{eff} V_0$$

[redacted]

Because the silo air space is a single compartment volume, it is assumed that the contained air will be well mixed. Thus, the air exchange release rate is simply the activity in the silo air space times the silo ventilation rate:

$$Q_{exch} = C_a \lambda_v V_0$$

where Q_{exch} is the rate of release of ^{222}Rn from the silo through air exchange. The release rate is the product of the ^{222}Rn flux (J) and the surface area of the dome (A):

$$Q_{exch} = JA$$

Therefore the ^{222}Rn flux from the silo through air exchange is:

$$J = Q_{exch}/A$$

Where:

J = ^{222}Rn flux from the silo through air exchange
A = Area of the silo dome

2.2.2 Calculations

Calculation of PV = nRT

The data collected at the K-65 silos is stored in the following format

Pressure

Ambient	= measured in inches of mercury
differential	= internal - external, inches of water
internal (inches Hg)	= differential * 0.07368 + ambient
internal (atm)	= internal Hg * (25.4MM/in) / (760MM/atm)

Volume

Silo 1 Volume	= 27,935 cubic feet
	= cu ft * ((12)^3 cu in/cu ft.)* ((2.54)^3 cu cm/cu in) / 1/1000 cu cm
Silo 2 Volume	= 44,820 cubic feet
	= cu ft * ((12)^3 cu in/cu ft.)* ((2.54)^3 cu cm/cu in) / 1/1000 cu cm

Temperature

Temp. deg. K.	=(internal temp. deg. f. + 32.2) * (5/9) + 273

R

Constant	= 0.082057 atm-L/deg. K-mole

which can be rewritten as

$$n = PV / RT$$

The positive change in the number of moles summed for the entire monitoring period is then divided by the original number of moles. This value is then divided by the number of seconds in the monitoring period to determine the

[redacted]

ventilation rate λ_v. The release rate (Q_{exch}) was then calculated by multiplying the concentration x ventilation rate x Volume. The ^{222}Rn flux from the silo through air exchange is then calculated by dividing Q_{exch} by the area of the dome.

3.0 Contribution to Background Concentration Calculation - ISCLT model

The ISCLT model is a climatological gaussian dispersion model used to predict concentration at discrete receptors. The model, as employed in this case, produced impacts based upon elevated releases from two area sources and sector averaged meteorological data collected on-site.

The diffusion radon flux value together with the ventilation radon flux value results in the total radon flux which is the value that is used as an input into the ISCLT model. The diffusion flux was estimated through a Monte Carlo simulation. The ^{222}Rn flux from the silo through air exchange value is calculated from Q_{exch} by dividing the release rate value by the area of the dome.

Runs 1A and 1B

Hourly data for the first six days of January 1992 were used in calculating the change in moles as a result of changes in temperature and pressure. For each hour of data, a corresponding quantity of moles were calculated in the head space. If the number of moles decreased between each comparison then that quantity was assumed to be lost to the atmosphere (i.e. if the number of moles was positive after the subtraction of hour 1 - hour 2 etc.). The change in the number of moles was not calculated if the pressure was negative. The total number of moles that were lost over the monitoring period were summed and divided by the original quantity of moles in the head space producing a scaler value. This scaler value is representative of the percent of moles lost over the entire monitoring period.

Run 1A was calculated using silo pressure and temperature date from the time period of January 1-6, 1992 in relation to the site meteorological data also from the time period of January 1-6, 1992. Run 1B was calculated using silo pressure and temperature data from the time period of January 1-6, 1992 in relation to the site meteorological data for the entire month of January. This methodology was used to enhance the input to the ISCLT model for the monthly estimate.

Runs 2A and 2B

Hourly data for the time period of February 1 -14, 1992 were used in calculating the change in moles as a result of changes in temperature and pressure. For each hour of data, a corresponding quantity of moles were calculated in the head space. If the number of moles decreased between each comparison then that quantity was assumed to be lost to the atmosphere (i.e. if the number of moles was positive after the subtraction of hour 1 - hour 2 etc.). The change in the number of moles was not calculated if the pressure was negative. The total number of moles that were lost over the monitoring period were summed and divided by the original quantity of moles in the head space producing a scaler value. This scaler value is representative of the percent of moles lost over the entire monitoring period.

Run 2A was calculated using silo pressure and temperature date from the time period of February 1-14, 1992 in relation to the site meteorological data also

from the time period of February 1-14, 1992. Run 2B was calculated using silo pressure and temperature data from the time period of February 1-14, 1992 in relation to the site meteorological data for the entire month of February. This methodology was used to enhance the input to the ISCLT model for the monthly estimate.

Runs 3 and 4

Since hourly data were not available for the months of March and April, a comparison of hourly averages versus daily averages was performed from the January and February data. The data logger was programmed to write data to disk using only a daily average rather than an hourly average, hence only daily averaged parameter values were available. Run 3 was calculated using 16 days of daily averaged pressure and temperature data in relation to the site meteorological data for the entire month of March. Run 4 was calculated using 27 days of daily averaged pressure and temperature data in relation to the site meteorological data for the entire month of April.

A flux value was calculated for the same time periods in January and February that hourly averaged data were available but this time the daily averaged values for pressure and temperature were used. The flux values obtained from this method were then compared to the flux values obtained using the hourly averaged values.

From this comparison, it appears that the daily averaged parameter data which includes the negative pressure values, underestimates the data that are obtained when data are recorded hourly and negative pressure values are deleted. The limited comparison data from January and February seems to suggest that the number of moles is underestimated by a factor of 2 - 2.5. This correction factor was applied to the radon flux data, using the daily averages, from March and April to estimate a flux. Thus, the flux data that is reported in Section 4.0 represents the calculated flux using daily averaged temperature and pressure data multiplied by 2.5 This data is included in the following files: JAN5AVE.WK1 and FEBAVE.WK1.

For each of the Runs 1A, 1B, 2A, 2B, 3 and 4, the calculated diffusion radon flux value was much smaller (three orders of magnitude) than the ventilation radon flux value, therefore, only the ventilation radon flux values were be used in calculating the radon flux to the atmosphere for each silo.

The data used to calculate the flux is contained in the following files: Run 1: JAN5AVE.WK1, JAN5HR.WK1; Run 2: HRFEB.WK1, FEBAVE.WK1; Run 3: MARAVE.WK1; and Run 4: APRAVE.WK1.

Meteorological and physical input parameters to the ISCLT model are as follows.

3.1 Meteorological Parameters

The meteorological parameters in the ISCLT model are input as a Stability Array (STAR) data base. The STAR data are a joint frequency distribution of wind speed and wind direction by atmospheric stability category: each record of STAR meteorological data consists of six values corresponding to the six wind speed classes for a particular wind direction sector and atmospheric stability category.

[redacted]

The STAR data for each of the runs are presented as files on the accompanying disk. The filenames are: Run 1A: JAN6.DAT; Run 1B: JAN6M.DAT; Run 2A: FEB14.DAT; Run 2B: FEB14M.DAT; Run 3: MAR92.DAT; and Run 4:APR92.DAT.

Average Ambient Temperature - 293 K (20°C)

Average Mixing height (meters) -	A	1254	
	B	836	
	C	836	
	D	836	
	E	10,000	
	F	10,000	(Data for Dayton, OH source Holsworth; for each stability class)

3.1 Physical Parameters

Physical parameters are a description of the site. The K-65 site is characterized by two area sources. They have an orientation and a physical size, as well as a flux rate. These data are used as a source term in the ISCLT model. The following parameters were used in the model.

Nearest Resident: The grid location for the nearest residence is (-330 m X, -360 m Y)

Radon flux for each silo: Calculated for each run.

Area of the source (area of the silo dome): 466.56 M^2

4.0 RESULTS

4.1 Run 1A

Silo 1 Flux ($pCi/M^2/sec$)	Silo 2 Flux ($pCi/M^2/sec$)	Resident Concentration (pCi/M^3)	(pCi/l)
76.8	99.7	1.06	0.0011

The time period selected for this run was based on the availability of data that was considered to be valid data. Included in this data was hourly pressure and temperature observations. The data are contained in the following file: JAN6.OUT

4.2 Run 1B

Silo 1 Flux ($pCi/M^2/sec$)	Silo 2 Flux ($pCi/M^2/sec$)	Resident Concentration (pCi/M^3)	(pCi/l)
76.8	99.7	0.28	0.0003

This run was conducted using the flux values calculated from January 1-6 where hourly averaged parameter data was available combined with meteorological data from the entire month. The data are contained in the following file: JAN6M.OUT

[redacted]

4.3 Run 2A

Silo 1 Flux ($pCi/M^2/sec$)	Silo 2 Flux ($pCi/M^2/sec$)	Resident Concentration (pCi/M^3)	(pCi/l)
61.1	95.0	0.27	0.0003

The time period selected for this run was based on the availability of data that was considered to be valid data. Included in this data was hourly pressure and temperature parameter observations. The data are contained in the following file: FEB14.OUT

4.4 Run 2B

Silo 1 Flux ($pCi/M^2/sec$)	Silo 2 Flux ($pCi/M^2/sec$)	Resident Concentration (pCi/M^3)	(pCi/l)
61.1	95.0	0.33	0.0003

This run was conducted using the flux values calculated from February 1-14 where hourly averaged parameter data was available combined with meteorological data from the entire month. The data are contained in the following file: FEB14M.OUT

4.5 Run 3

Silo 1 Flux ($pCi/M^2/sec$)	Silo 2 Flux ($pCi/M^2/sec$)	Resident Concentration (pCi/M^3)	(pCi/l)
64.1*	99.4*	0.088	0.0001

Data for these runs was in the form of daily averaged pressure and temperature parameter observations. (The wind blew from the Northeast less than 12% of the time). The data are contained in the following file: MAR92.OUT.

*The radon flux values presented in this section are estimated values using daily averaged parameter data and a 2.5 multiplication factor.

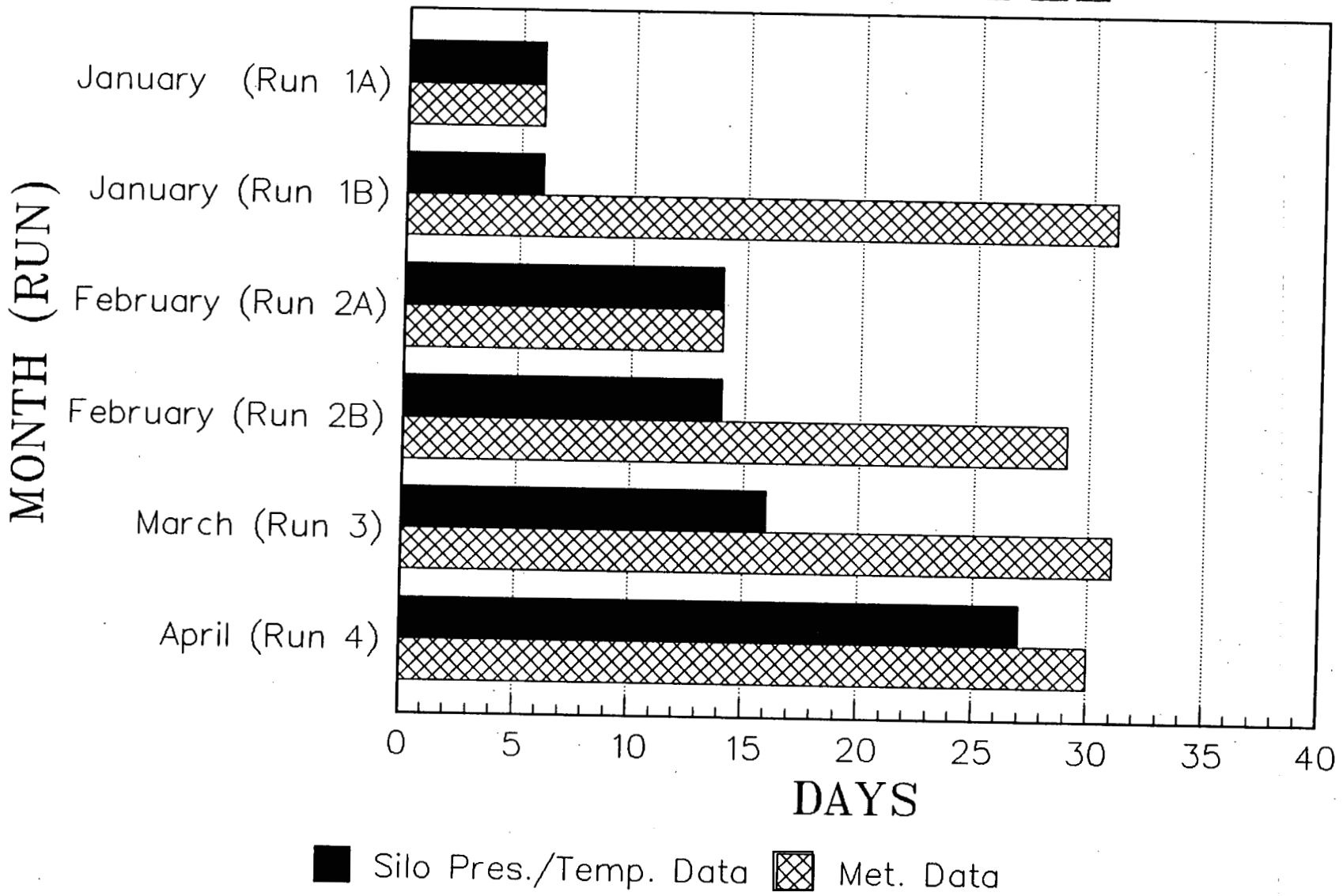
4.6 Run 4

Silo 1 Flux ($pCi/M^2/sec$)	Silo 2 Flux ($pCi/M^2/sec$)	Resident Concentration (pCi/M^3)	(pCi/l)
50.4*	77.6*	0.22	0.0002

Data for these runs was in the form of daily averaged pressure and temperature parameter observations. The data are contained in the following file: APR92.OUT

*The radon flux values presented in this section are estimated values using daily averaged parameter data and a 2.5 multiplication factor.

5.0 DISCUSSION/SUMMARY

The radon concentration data obtained from each of the runs indicates that the radon concentration at the nearest residence is less than the U.S. EPA and DOE established goal for the Silos 1 and 2 Removal Action of 0.015 pCi/l.

TIME PERIOD OF MODEL