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A Summary of EPA Radon Chamber Tests and Results for Rounds 3 and 4 of the National Radon Measurement Proficiency Program

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A Summary of EPA Radon Chamber Tests and Results for Rounds 3 and 4 of the National Radon Measurement Proficiency Program

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Glossary

AT	-	alpha track detector
Bi-214	-	the radioisotope bismuth-214
BOM	-	US Bureau of Mines, Denver Research Center
CC	-	charcoal adsorber
cfm	-	cubic feet per minute
CN	-	condensation nuclei
CR or CRM	-	continuous radon monitor
CW	-	continuous working-level monitor
EML	-	USDOE Environmental Measurements Laboratory
EP	-	electret-PERM detector
EPA	-	U.S. Environmental Protection Agency
ER	-	radon decay products/radon equilibrium ratio
GR	-	grab radon sampling
GW	-	grab working-level sampling
L	-	liter
Lpm	-	liters per minute
NAREL	-	National Air and Radiation Environmental Laboratory, USEPA
ORIA	-	EPA's Office of Radiation and Indoor Air
Pb-214	-	the radioisotope lead-214
Po-214	-	the radioisotope polonium-214
Po-218	-	the radioisotope polonium-218
PR	-	performance ratio
Ra-226	-	the radioisotope radium-226
radon	-	the radioisotope radon-222

Rn-222	-	the radioisotope radon-222
RDP	-	radon decay products
RMP	-	National Radon Measurements Proficiency Program
RMP3	-	general reference to Round 3 of RMP Program
RMP3FU	-	the followup test for RMP Program Round 3
RMP3P	-	the performance test for RMP Program Round 3
RMP4	-	general reference to Round 4 of RMP Program
RMP4FU	-	the followup test for RMP Program Round 4
RMP4P	-	the performance test for RMP Program Round 4
Rn	-	radon
RP	-	Radon Progeny Integrated Sampling Unit
RTI	-	Research Triangle Institute
TMC	-	USDOE Technical Measurements Center
WL	-	Working-Level
ZnS	-	zinc sulfide
μCi	-	microcurie

1.0 Introduction

The U.S. Environmental Protection Agency's Office of Radiation and Indoor Air (ORIA) established the National Radon Measurement Proficiency (RMP) Program in 1986. Through this voluntary program, participants can demonstrate their ability to measure radon and/or radon decay products by submitting their detection devices to a blind test in a designated radon chamber*. The first three test rounds were conducted using the radon chamber located at the U.S. Department of Energy Environmental Measurements Laboratory (EML) in New York, NY. Starting with round 4, EPA chambers have been used for these tests. The National Air and Radiation Environmental Laboratory (NAREL)** has had a small radon chamber (chamber C) since 1979. When the NAREL became involved in testing RMP participants, it was necessary to construct a new chamber (chamber A, completed in 1987) which was suitable for handling the large number of participants involved in the testing.***

In this report, radon chambers A and C will be described as will the associated chamber monitoring systems used to establish the official target values for radon and radon decay products concentrations during RMP Round 4. A summary of the test results for RMP rounds 3 and 4 will be presented and discussed. The results of several tests run in chamber A to address the reasons for the general overresponse of charcoal adsorbers (CC's) in round 4 will be discussed and the most probable reasons for the overresponse will be identified.

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*All EPA test chambers have the ability to furnish a test environment for both radon and radon decay products monitoring equipment. For simplicity, these chambers will be referred to as "radon chambers" throughout this report.

**Prior to March of 1990, the National Air and Radiation Environmental Laboratory was known as the Eastern Environmental Radiation Facility.

***In 1990, a third chamber (Chamber B) was constructed which was of the same basic design as Chamber A.

2.0 Background Information

Evaluation and calibration of measurement instruments for radon (Rn-222) or radon decay products (RDP) require a stable source of radon and RDP in some form that allows exposure over a designated measurement period. Most radiation measurement instruments are tested and calibrated with fixed (physically contained) sources of radioisotopes of known activities, e.g., electroplated alpha sources or sealed gamma sources. Generally, these sources are constructed to reproduce the geometry of the actual samples. However, radon is a gaseous radioactive material that is chemically non-reactive and consequently cannot be produced as a fixed source. Its short half-life (3.82 days) limits the usefulness of a given amount of radon as a calibration source. Radon gas in secular equilibrium with its long-lived parent, radium-226, is often encapsulated for use as a gamma radiation source, but this configuration is not useful for radon gas or radon decay products standardization.

Radon decay products include, among others, polonium-218 (Po-218), lead-214 (Pb-214), bismuth-214 (Bi-214), and polonium-214 (Po-214), which are short-lived particulates formed when radon undergoes radioactive decay. In the radioactive decay of each atom of polonium-218 and polonium-214, an alpha particle is emitted. In about 0.01 percent of the decays of bismuth-214 atoms, an alpha particle is emitted. Lead-214 atoms do not emit alpha particles during radioactive decay. These decay products are electrically charged when formed and tend to attach to or plateout on other particles in the air (condensation nuclei) or on nearby surfaces such as walls, clothes, hair and lung tissue. The half-lives of all these decay products are much shorter than radon, which effectively limits their use as standardized calibration sources.

A more practical approach to producing stable sources of radon and RDP is to construct an exposure chamber where Rn-222 can be constantly removed from a radium-226 (Ra-226) source of known

activity and mixed with measured quantities of air to create known concentrations of radon and RDP in an enclosed volume. Although this is more feasible than the fixed sources, it is still restricted in practice by the inability to extract completely the radon from the radium. Several techniques have been used for this purpose including bubbling air through aqueous radium solutions and passing air over very thin solid sources, but there is always some question about the completeness of the radon extraction (de-emanation).

A solution to all of these problems has not been found to date; however, the use of exposure chambers fed by Rn-222 from Ra-226 sources has been the most practical method for calibration. The lack of quantitative knowledge about the de-emanation of Rn-222 from the source is generally overcome by making measurements of the resulting radon or RDP concentrations. As long as the radium source produces a constant flow of radon that, when diluted, provides a range of concentrations of radon similar to those that are to be measured in the field, then the actual strength of the source is relatively unimportant. Consequently, the measurements of the radon and RDP concentrations in an exposure chamber become the principal determinant in the accuracy of the calibration and testing of instruments in the chamber.

3.0 EPA Radon Exposure Chambers

The NAREL radon chambers in Montgomery, Alabama utilize several solid Ra-226 sources to produce Rn-222 that is diluted with measured quantities of air. The combination of source strength (based on the manufacturer's measurements) and the dilution with measured quantities of air allows reasonable estimation of the radon concentration in these chambers. Selection of source strength and air flow rates allows maintenance of a stable radon concentration in these chambers up to about 500 pCi/L. This maximum could be extended by adding more Ra-226 sources. The practical minimum is limited to approximately 5 pCi/L by

fluctuations in environmental radon concentrations and measurement precision.

Radon decay products concentrations in the chambers are a function of radon concentration, air exchange rate and plateout. The latter two factors are not as easily controlled as the radon concentration. The air exchange rate can be varied by adding more or less dilution air; however, some air exchange due to leakage occurs. This leakage reduces the maximum concentrations of radon and RDP that can be obtained in a chamber with a given source strength.

The radon concentration in air sets an effective upper limit for the RDP concentration, but that maximum theoretical RDP concentration is rarely achieved in practice because the RDP's are constantly removed from the air by both plateout and radioactive decay. The degree of ingrowth of the RDP with respect to the radon is given by the equilibrium ratio* (ER). The larger the ER, the more RDP remain in the air for a given radon concentration. One way to produce a high ER in an exposure chamber is to use a low dilution air flow rate and a high concentration of condensation nuclei (CN). Condensation nuclei are small, airborne particles to which the RDP become attached and neutralized, thus remaining

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*$ER = \frac{WL \times 100}{[Rn]}$

where

WL = RDP concentration in units of working-levels. One working-level (WL) is any combination of the short-lived decay products of radon (Po-218, Pb-214, Bi-214, and Po-214) in one liter of air that will result in the ultimate emission by the bismuth and two polonium isotopes of 130,000 MeV of alpha energy.

[Rn] = Radon concentration in pCi/L.

The ER is a fraction less than unity that may also be expressed as a percent.

suspended in the air and not plating out. For the same radon concentration a lower ER can be obtained by increasing the dilution air flow rate and decreasing the CN concentration.

The three NAREL chambers include one small chamber (Chamber C) that is approximately 10 years old and two large chambers, Chamber A which was built in 1987 and Chamber B which was built in 1990. Chamber C (see Figure 1) has an approximate volume of 3.6 m^3 (127.1 ft^3) and is designed for radon flow in one end and out the other in a single pass. Three Ra-226 sources of approximately 50, 7, and 6 microcuries (μCi) are used, either individually or together to produce the desired radon concentrations (up to ~500 pCi/L). The radon is purged from the sources with air at a flow rate of ~1 Lpm (per source) and mixed with environmentally conditioned air at selectable flow rates over a range of about 10 to 200 Lpm. Air velocity in Chamber C is very low, essentially less than 0.50 fpm for all operating conditions. Environmental condition ranges include temperature (32 to 100° F), relative humidity (10 to 95 percent), and condensation nuclei (CN) concentration (1,000 to 1,000,000/mL). Condensation nuclei are generated by electrically heating a small diameter nichrome wire located in the chamber air inlet duct. Changes in CN concentration are induced by varying the voltage across this wire. The equilibrium ratio (ER) in this chamber is limited to a maximum of about 35 to 40 percent due to its small size and high air exchange rates. Therefore, RDP concentrations in units of working-levels (WL) are obtainable over a range of approximately 0.01 to 2 WL. Access to this chamber is through a small door that allows instruments to be placed inside or through a pass box with glove ports.

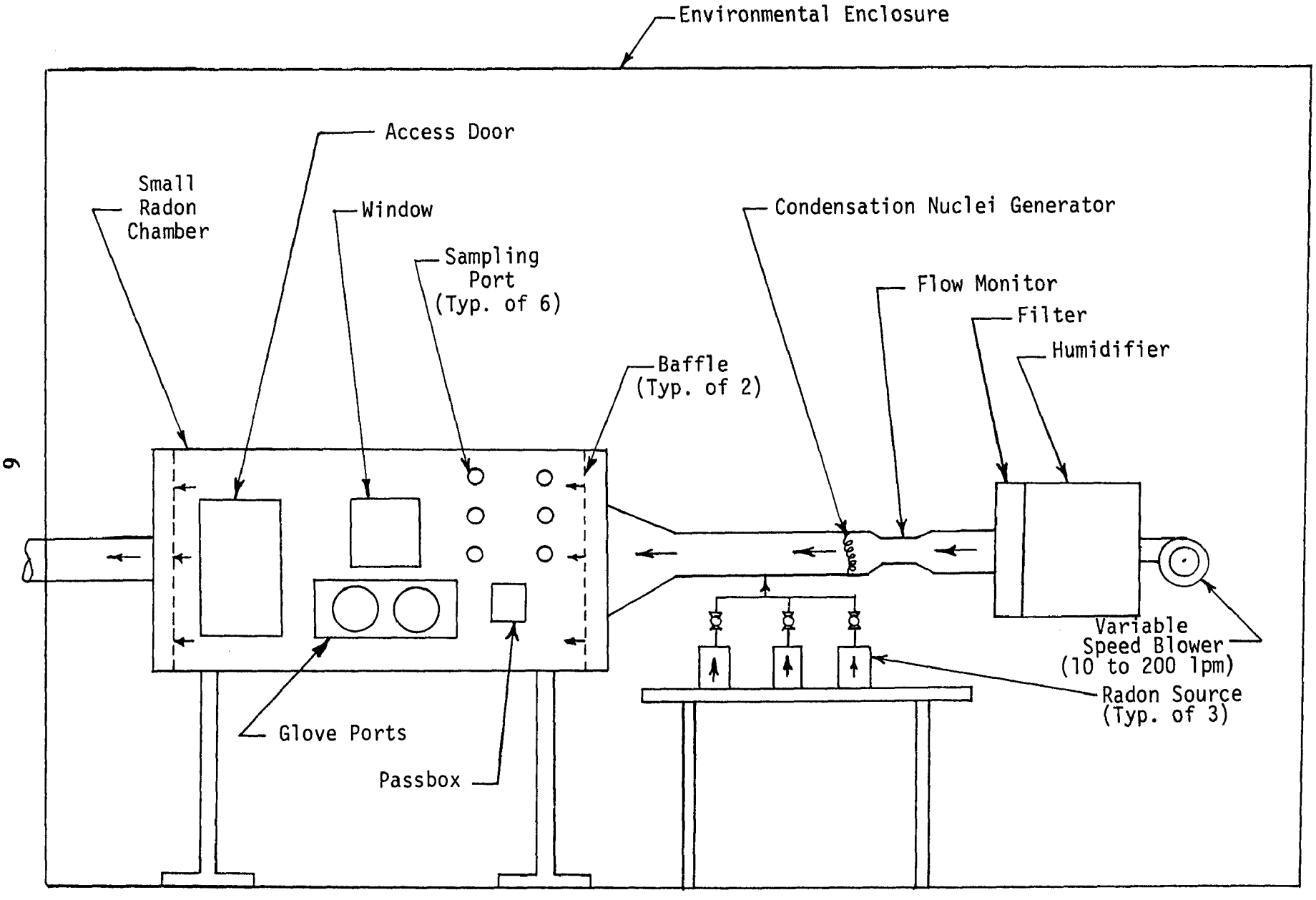

Figure 1: Schematic Diagram of NAREL Radon/RDP Chamber C (Side View)

Chamber A (see Figure 2) has a volume of approximately 44 m^3 (1550 ft^3) and is designed for recycling of most of the radon to reduce the source strengths required and to provide uniform mixing of the radon and decay products throughout the volume. Three Ra-226 sources of approximately 88, 85, and 28 μCi can be used, either individually or jointly, to produce radon that is mixed with air in the recycling system, which has a flow rate ranging from 50 to 200 cfm. The recycled air can be diluted with outside air at a flow rate ranging from 0 to 35 cfm to produce the desired concentrations. The larger size of the chamber and lower air exchange rates allow higher equilibrium ratios. ER's in excess of 60 percent are attainable. The Chamber A control systems allow environmental conditions to be varied over the following ranges: temperature, 32-100° F; relative humidity 20-90%; and CN concentration, 3,000-500,000/mL. Access to the chamber includes walk-in capability through a double-door entry room and a small door for passing objects in and out. Several 3-inch diameter access ports are provided on both chambers for collection of samples (by the operator from outside the chambers) with minimal effect on the radon or RDP concentrations inside. Condensation nuclei are generated in chamber A by vaporizing carnauba wax using a heating system which consists of a Pyrex heating tube located within a tube furnace (Tu81). The heating tube contains a Pyrex wax container. The furnace temperature can be varied to alter the production of condensation nuclei. A low air flow through both the wax container and the heating tube carries the CN from the generator into the chamber. Chamber B is very similar in design and construction to Chamber A.

Only chambers A and C were used in the National Radon Measurements Proficiency Program round 4 (RMP4). RMP3 performance tests were conducted in the USDOE Environmental Measurements Laboratory (EML) chamber in New York, NY. The designs of NAREL chambers A and B are similar to the EML chamber. All chambers were constructed using insulated metal-clad panels. All have a double-

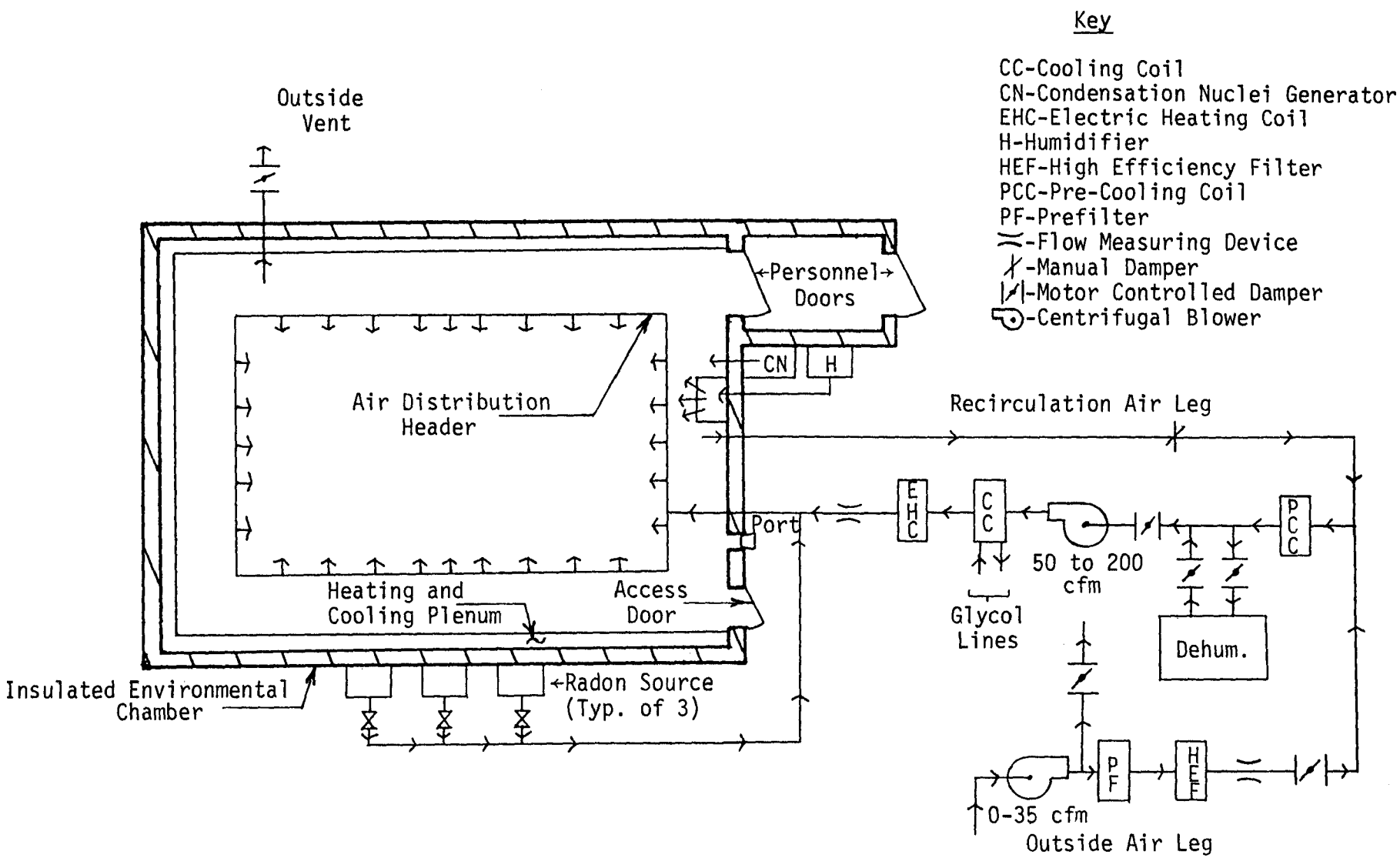

Figure 2: Schematic Diagram of NAREL Radon/RDP Chamber A (Top View)

door, air-lock entry and all recirculate chamber air to conserve radon and radon decay products. In the EML chamber, recirculated air enters the chamber through a header located near the floor and travels upward. In the NAREL chambers A and B, recirculated air enters the chambers through a header located near the ceiling and travels downward. All chambers use a condensation nuclei generator based on vaporizing carnauba wax.

4.0 Radon and Radon Decay Products Monitoring*

Although the radon concentration in the chamber can be estimated from the radium source strength and the flow rate, the exact concentration will vary with fluctuations in the flow rate and with small changes in emanation from the source. Consequently, it is necessary to measure the concentration of radon and decay products to have an accurate knowledge of the exposure to instruments and detectors in the chamber. Continuous monitors, calibrated by periodic grab samples, are used to document the radon and RDP concentrations during each test period.

Grab samples (short-term samples) for radon are collected using scintillation cells. These cells are cylindrical with a volume of 0.125 liters and are coated inside with zinc sulfide (ZnS) on all surfaces except the clear window on one end which sits directly on the photomultiplier tube during counting. The scintillation cell counting equipment is checked at regular intervals using a sealed standard containing a known amount of radium-226 with radon and the decay products in secular equilibrium. The standard has the same counting geometry as the scintillation cells. Periodically, the efficiency of each scintillation cell is determined using a known concentration of

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*This description of the radon and radon decay products monitoring systems and their calibrations represents the equipment and methodology used in RMP round 4. Since that time, improvements have been made in both the equipment and calibration procedures. The current equipment and calibration methodology will be described in a future EPA report.

radon in air derived from an NIST radium-226 standard reference solution.

For grab sampling radon decay products, a pump is used to pull air through a filter which traps the RDP's during a five-minute sampling period. The alpha activity on the filter is determined by placing it face down on a ZnS disk placed directly on top of the photomultiplier tube, which gives "two pi" counting geometry. The Thomas-Modified Tsivoglou technique (Th72) is used to determine radon decay products concentrations and working levels. The alpha scintillation counters are calibrated using a NIST-traceable electroplated americium-241 (Am-241) alpha source in the same geometry used for filter counting.

Both of these grab sample measurement techniques are calibrated independently in a NAREL laboratory, and they are routinely verified through intercomparisons with other laboratories (Fi88a, Fi88b, Fi87, Fi85a, Fi85b, Fi83, Fi81, Ge87, Pe87, Pe86, USBOM82). NAREL results for these intercomparisons through 1988 are shown in Tables 1 and 2. For the radon intercomparisons (Table 1), NAREL was biased low in the first two tests (April and June 1981). A change was made in the scintillation cell analysis procedures before the August 1981 intercomparison. The mean ratio of NAREL results/reference value for the period 8/28/81 to 8/8/88 is 0.98 +/-3.6% (1 standard deviation, s.d.). For the radon decay products intercomparisons (Table 2), the mean ratio of NAREL results/reference value for the period 5/25/82 to 3/26/87 is 1.00 +/-4.3% (1 s.d.). A review of these data in Tables 1 and 2 shows that the NAREL has performed well in the intercomparisons over a considerable period of time. For this reason, grab samples are used to calibrate the chambers continuous radon and RDP monitors.

Table 1: NAREL Performance in Grab Radon Intercomparisons[a]

Date	Facility Conducting Test	Test Category[b]	Reference Value[c] (pCi/L)	Ratio-NAREL/ Reference Value
08/08/88	EML[d]	F	6.0 ± 0.1	1.02 ± 0.13
02/08/88	EML	F	12.5 ± 0.2	0.94 ± 0.05
07/20/87	EML	F	12.2 ± 0.4	0.98 ± 0.05
02/23/87	EML	F	67.1 ± 0.7	0.93 ± 0.03
11/07/86	EML	RMP3	21.8	1.00 ± 0.05
09/02/86	NAREL	I	22.1 ± 0.06	0.98 ± 0.03
07/21/86	EML	RMP2	61.2	0.97 ± 0.02
04/03/86	EML	RMP1	45.0	1.06 ± 0.03
03/03/86	EML	F	70.2 ± 0.8	0.97 ± 0.03
07/15/85	EML	F	70.4 ± 1.5	1.00 ± 0.07
02/25/85	EML	F	34.9 ± 0.8	0.97 ± 0.03
07/16/84	EML	F	35.2 ± 0.6	1.03 ± 0.08
02/06/84	EML	F	82.2 ± 1.3	0.96 ± 0.04
01/24/83	EML	F	46.5 ± 1.2	0.98 ± 0.06
07/12/82	EML	F	31.3 ± 0.4	0.92 ± 0.05
01/27/82	EML	F	36.4 ± 0.8	0.99 ± 0.03
08/28/81	NAREL	I	41.0 ± 6.0	1.00
06/15/81	EML	F	44.6 ± 1.1	0.82 ± 0.05
04/20/81	EML	F	50.5 ± 0.9	0.88 ± 0.02

(a) all errors are 1 sigma.
(b) I=informal intercomparison; F=formal intercomparison; RMP=National Radon Measurement Proficiency Program; F and RMP are blind tests where the reference value is not known before the EPA results are submitted.
(c) Reference value for radon is always the EML value, regardless of the chamber used for the test.
(d) EML-US DOE Environmental Measurements Laboratory, New York, NY. NAREL-US EPA National Air and Radiation Environmental Laboratory, Montgomery, AL.

Table 2: NAREL Performance in Grab Working-Level Intercomparisons[a,b]

Date	Facility Conducting Test	Reference Value[c] (WL)	Ratio-NAREL/ Reference Value
3/25/87 (Test 1)	EML[d]	0.112 ± 0.005	0.98 ± 0.06
3/26/87 (Test 2)	EML	0.061 ± 0.004	0.90 ± 0.06
3/25-26/87 (Avg., 2 Tests)	EML		0.94 ± 0.06
4/16/86 (Test 1)	TMC	0.317 ± 0.067	1.08
4/16/86 (Test 2)	TMC	0.343 ± 0.022	1.00
4/16/86 (Test 3)	TMC	0.201 ± 0.013	0.97
4/16/86 (Test 4)	TMC	0.155 ± 0.010	1.02
4/17/86 (Test 5)	TMC	0.093 ± 0.007	1.04
4/17/86 (Test 6)	TMC	0.092 ± 0.007	0.99
4/16-17/86 (Avg., 6 Tests)	TMC		1.02 ± 0.04
9/11/85 (Test 1)	TMC	0.304 ± 0.011	0.94
9/11/85 (Test 2)	TMC	0.305 ± 0.008	1.02
9/11/85 (Test 3)	TMC	0.182 ± 0.006	0.99
9/11/85 (Test 4)	TMC	0.175 ± 0.006	1.02
9/12/85 (Test 5)	TMC	0.093 ± 0.005	0.92
9/12/85 (Test 6)	TMC	0.092 ± 0.006	1.06
9/12/85 (Test 7)	TMC	0.087 ± 0.003	1.01
9/11-12/85 (Avg., 7 Tests)	TMC		0.99 ± 0.05
5/25-26/82 (Test 1)	BOM	2.14 ± 0.08	1.02
5/25-26/82 (Test 2)	BOM	2.20 ± 0.08	1.00
5/25-26/82 (Test 3)	BOM	2.24 ± 0.10	0.99
5/25-26/82 (Test 4)	BOM	2.24 ± 0.07	1.01
5/25-26/82 (Test 5)	BOM	0.59 ± 0.09	1.00
5/25-26/82 (Avg., 5 Tests)	BOM		1.00 ± 0.01

(a) All errors are 1 sigma.
(b) All data in the table are for formal intercomparisons where the reference value is not known before the EPA results are submitted.
(c) Reference value for WL is the mean of all participants.
(d) EML-US DOE Environmental Measurements Laboratory, New York, NY. TMC-US DOE Technical Measurements Center, Grand Junction, CO. BOM-US Bureau of Mines, Denver Research Center, Denver, CO. Each continuous flow radon detector used in the NAREL chambers

is comprised of a 0.5 liter flow-through scintillation cell* and a 5-inch (12.7-cm) photomultiplier tube in a light-tight housing. Chamber C employs one continuous radon monitor and Chamber A uses two. To monitor the RDP concentration in the chambers continuously, a surface barrier semi-conductor detector is mounted directly adjacent to a filter through which air is drawn. The detector measures the alpha radioactivity deposited on the filter. The RDP detector is located inside the chamber and is connected through a small tube to an air pump with controlled flow set at 1 Lpm. Chamber C has one continuous WL monitor and Chamber A has two.

The radon and the RDP detectors are connected to computer-based multichannel analyzers that accumulate data and periodically print the total number of alpha counts accumulated by each detector. In addition to the continuous monitors which are part of each chamber monitoring system, additional self-contained continuous radon and RDP monitors are operated in each chamber as backup equipment during an RMP exposure round. For each monitor, the periodic counts are converted to radon or RDP concentrations with calibration factors. A calibration factor is the ratio of the concentration as measured by a grab sample over a short time to the periodic count generated by the continuous monitor during the period in which the grab sample was collected. Two calibration factors are normally computed during each weekday of a test period and one during each weekend day. An arithmetic mean calibration factor for each monitor is then computed. The final step is to multiply each periodic count from a continuous radon or radon decay products monitor by the arithmetic mean calibration factor for that

*During RMP round 4, the 0.5 L scintillation cells were used. These 0.5L cells have been replaced with larger cells (some 1.0 L and some 1.4 L) which has increased the sensitivity for the radon continuous monitoring systems.

monitor to form a time series of periodic concentrations for the entire test period.

In judging the quality of the data produced by each continuous monitor during Round 4, EPA computed the standard deviation of the mean calibration factor for each monitor. The standard deviation for a monitor was divided by the mean calibration factor and the result was multiplied by 100 to convert the fraction to percent. This procedure yielded a percentage standard deviation of the mean calibration factor. A low percent standard deviation indicated that the calibration factors used to generate the mean calibration factor for an instrument were consistently near the mean value. For RMP round 4, the percent standard deviations for all continuous monitors used to establish the official target values (against which participants results were compared) were less than eight percent.

For the performance and the followup tests in round 4, the official target values for alpha track detectors (AT), charcoal canisters (CC), continuous radon monitors (CR), and electret-perms (EP) were established using data from the continuous radon monitor record. The target values for continuous working-level monitors (CW) and radon progeny integrated sampling units (RP) were established using data from the continuous working-level record. For the grab radon (GR) detectors, NAREL scintillation cells were filled as participants sampled. If the sampling time for a participant's cells (or other devices) was short (generally 20 minutes or less) the mean of the NAREL scintillation cell results was used to establish the official target value. Generally, if the participant's sampling time extended more than 20 minutes, the mean of the NAREL scintillation cell results and the continuous monitoring record for the sampling period were used to establish the official target values. For the grab working-level (GW) participants, NAREL grab-sampled with the participants to obtain the official target values.

5.0 Summary of RMP Round 3 and Round 4 Results

Participant statistics for each detection method tested in Rounds 3 and 4 are listed in Table 3. EPA categorizes AT, CC, some GR, EP and RP as passive (or mail-in) methods and CR, some GR, GW and CW as active (or walk-in) methods. During RMP4P, there were 56 test periods where walk-in participants tested. For test periods with multiple walk-in participants, all participants failed during 2 periods (3.6 percent of the test periods). There were 5 test periods when a participant failed and he was the only one testing that method.

Referring to Table 3, the failure rates for AT, CC, GR, RP and CW were higher for RMP4P than for RMP3P. An explanation may be that as the RMP progresses, the new participants entering the program are generally less experienced in radon and RDP detection when they enter than the participants who joined in the early rounds. This may cause a higher failure rate from new entries than would have been the case for earlier rounds. Failure rates were lower in RMP4P for CR and GW methods. EP tested for the first time in RMP4P and all entries passed the performance round.

The method performance ratios (PR) (Table 3) are a measure of the degree of agreement between the participants for each method and the NAREL measurements*. In RMP4P, the method PR's for CR, GR, EP, GW, and CW were all close to 1.0 which indicates generally good agreement between the participants using these methods and NAREL. The low bias (15 percent) of RP can be explained by plugging of the filters on these devices with wax from the chamber A condensation nuclei (CN) generator, leading to a progressive

*Histograms for all methods tested in RMP4P are included in Appendix A.

Table 3: Methods Completed, Failure Rates and Method Performance Ratios for RMP Round 3 and RMP Round 4

Method	Methods Completed[a] Round 3P	4P	4FU	Failure Rate (Percent) Round 3P	4P	4FU	Method Performance Ratio[b] Round 3P	4P	4FU
AT	36	75	9	5.6	13.2	22.2	0.92	0.93	1.06
CC	120	253	73	4.2	30.3[e]	20.5[e]	0.93	1.16	1.06
CR	4	15	0	25.0	6.7	–	0.91	1.01	–
GR	21	40	9	10.0	25.0	33.3	0.96	0.97	1.02
EP	0	5	0	–	0	–	–	1.01	–
GW	35	46	5	34.3	28.3	0.0	0.93	0.98	1.08
RP	4	5	1	0	20.0	0.0	0.95	0.85[c]	1.10
CW	17	40	5	5.9	13.2	0.0	0.98	1.04	0.97
Total	237	479	102	9.7	24.4	19.6[d]	~0.93	~1.07	~1.05

(a) A method is complete when a participant returns his results reporting form to RTI and is evaluated against the official target value.

(b) A detector performance ratio (PR) is the quotient of a participant's detector reading divided by the official target value. A participant performance ratio is the average of the detector performance ratios for all detectors tested by a participant. The method performance ratio is the mean of the participants' performance ratios for all participants testing this method, except for outliers. An outlier is a participant performance ratio below 0.5 or above 1.5.

(c) The low bias for RP is explained by wax from our CN generator partially plugging the filter in these units. RP's were run for shorter exposure times in RMP4FU to alleviate this problem.

(d) 4.2 percent of the methods that completed RMP4P failed RMP4.

(e) For RMP4P, there were 74 CC failures. 68 percent of failures were from primary suppliers and 32 percent of failures were from participants who supply CC's only for themselves. For the RMP4FU, there were 15 CC failures. Ten of these failures were CC's from a single processing laboratory.

reduction in air flow rates during the exposure period*. NAREL staff have experienced similar problems with EPA RP devices in 7 day field testing in homes occupied by moderate to heavy smokers. This problem was corrected by reducing the 6-7 day exposure time in the performance test to 3-4 days in the followup test.

CC detectors were biased 16 percent high and AT detectors were biased 7 percent low. Experience with the international intercomparison program (Fi88a, Fi88b, Fi87, Fi85a, Fi85b, Fi83, Fi81, Ge87, Pe87, Pe86, USBOM82) has shown that the agreement in radon and RDP measurements between organizations operating radon and RDP calibration facilities would generally fall within a ± 10 percent band. Specifically, EPA staff would normally expect that NAREL and other U.S. organizations operating radon and RDP calibration chambers could simultaneously measure the same radon or working-level environment and produce results that would differ by no more than ± 10 percent. In most instances, the agreement would be better. When the RMP program bias test was established at ± 25 percent, the persons who formulated this policy reached a consensus that a bias check of ± 15 percent was proper. Ten percent was added to obtain the ± 25 percent in recognition that many detectors tested in RMP would be calibrated in a chamber not used for RMP testing and that, in general, a difference between measurements of chamber operators of ± 10 percent or less could be expected.

Considering the above discussion, it is not surprising that AT were biased low by 7 percent since the great majority of the 75 sets of detectors tested were produced by two manufacturers who had calibration data from sources other than the NAREL chambers. The 7 percent bias is 3 percent less than was allowed for calibration and test chamber differences in setting the RMP 25 percent bias criteria. The 16 percent high bias in the CC participants results is higher

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*Wax from the EML CN generator was also present in the EML chamber during RMP Rounds 1-3.

than would normally be expected due to chamber differences. Several possible contributing factors were identified and a discussion of each will be given in section 6. To evaluate some of the factors, radon concentration uniformity testing in chamber A (beyond the tests already performed) was needed. Also, it appeared that tests of CC response in chamber A, using EPA CC's, could be enlightening. These tests and the original chamber A radon concentration uniformity tests are discussed in section 6.

6.0 EPA Chamber A and Charcoal Canister Testing

Between April and September, 1987, NAREL staff conducted seven tests in chamber A using EPA CC's. The tests were conducted to document radon concentration uniformity within chamber A using both CC's and continuous radon monitors (CRM) and to see if EPA could cause its own CC's to experience a major bias in chamber A. The environmental parameter values (temperature, relative humidity, etc.) and selected results for these tests are listed below and in Table 4. A discussion of the seven tests and the results shown in Table 4 follow.

The range of values for test parameters which remained nearly constant are

* chamber temperature, 68-70 degrees F,
* chamber relative humidity, 46-50 percent,
* outside air flow rate, 0 cubic feet per minute (cfm),
* chamber air recirculation rate, 95-110 cfm,
* periodically, a humidifier fan would run to distribute moisture across the chamber volume to maintain relative humidity, and
* air velocities across the chamber volume ranged from <10 to ~70 feet per minute (fpm).

Table 4: Summary of NAREL Radon Chamber A Tests

[Column] Row	Test Number Dates [1]	CC Brand [2]	Exp. Time (hr) [3]	CN Conc. (Particle) (cm³) [4]	Chamber Average Radon Concentration (pCi/L) Continuous Monitors ±% Std. Dev. [5]	Chamber Average Radon Concentration (pCi/L) CC's ±% Std. Dev. [6]	No. CC's Exposed [7]	Perform. Ratio (PR) [8]	CC Measurements Range of Deviation from CC Mean (Percent) for Equimpent Racks [9]	CC Measurements Range of Deviation from CC Mean (Percent) for Shelf Levels [10]	Continuous Monitor Measurements Range of Deviation of CRM's from CRM Mean Percent [11]
1	1, 4/1-3/87	1	~50	-	No Reading	40.3±4.6%	30	-	-5.0 to +3.0	-1.0 to +1.0	-
2	2, 5/8-10/87	1	~48	yes	40.8±1.0%	41.2±4.9%	72	1.01	-2.9 to +3.9	-1.5 to +1.0	-
3	3, 6/19-21/87	1	~50	yes	25.2±1.8%	27.2±4.4%	26	1.08	-	-	-
4	4, 6/22-24/87	1	~48	yes	24.2±2.3%	25.7±7.0%	22	1.06	-	-	-
5a	5a, 8/5-7/87	1	~49	~50,000	31.0±2.5%	33.3±7.2%	48	1.07	-4.2 to +4.2	-3.0 to +3.3	-2.7 to +2.1
5b	5b, 8/5-9/87	1	~99	~50,000	33.1±3.3%	33.8±5.3%	20	1.02	-	-	-3.8 to +1.9
5c	5c, 8/5-6/87	1	~26	~50,000	29.4±2.5%						-2.7 to +2.1
5d	5d, 8/6-7/87	1	~25	~50,000	32.8±2.6%						-2.9 to +2.1
5e	5e, 8/5-7/87	2	~49	~50,000	31.0±2.5%	35.0±5.3%	20	1.13	-	-	-2.7 to +2.1
6a	6a, 8/25-27/87	1	~48	~2,500	25.0*	26.5±5.6%	5	1.06	-	-	-
6b	6b, 8/25-27/87	1	~48	~2,500	25.0*	27.8±5.4%	5	1.11	-	-	-
7a	7a, 8/31-9/2/87	1	~48	~250,000	24.8*	26.8±3.2%	5	1.08	-	-	-
7b	7b, 8/31-9/2/87	2	~48	~250,000	24.8*	28.5±3.8%	5	1.15	-	-	-

* Only one continuous monitor was run during these tests.

Test 1 was conducted before round 4, using 1 CC at each monitoring location, and demonstrated good uniformity of radon concentration across the chamber volume. The other 6 tests were conducted during and following round 4, using two CC's at each monitoring location. With the exception of test 1, one or more CRM's were operated so that the CRM results could be compared with the CC results. For all tests, the CRM's were calibrated with a series of scintillation cells (grab samples) filled at different times during testing. The normal CRM calibration procedure was to establish a calibration point for each CRM for each cell filled; thus, the sampling points for some of the CRM's were separated from the point where the scintillation cell was filled by a few feet. Test 1 results had demonstrated that the chamber A radon concentration was uniform across the chamber volume and this calibration method works well for uniform concentrations. However, in test 5 (the most comprehensive test), three continuous radon monitors were operated, each calibrated independently from the others to further document uniformity of radon concentration within the chamber. These calibration procedures and test results are discussed with the discussion of test 5.

EPA has used two brands of CC's in the NAREL CC program. Both brands were initially calibrated in NAREL chamber C which has negligible air velocity and does not use wax for generating CN. However, the NAREL scintillation cells were used to calibrate the CRM's in both chambers A and C. Thus, the results of testing EPA's CC's in chamber A should have shown any bias imparted to CC's by some condition in chamber A which was different than chamber C but should not have included any differences due to different organizations making basic radon measurements to document chamber levels. For these tests, brand 1 CC's were used exclusively for documenting radon concentrations across the chamber volume. However, a few brand 2 CC's were used in tests 5-7 with some interesting results (discussed later).

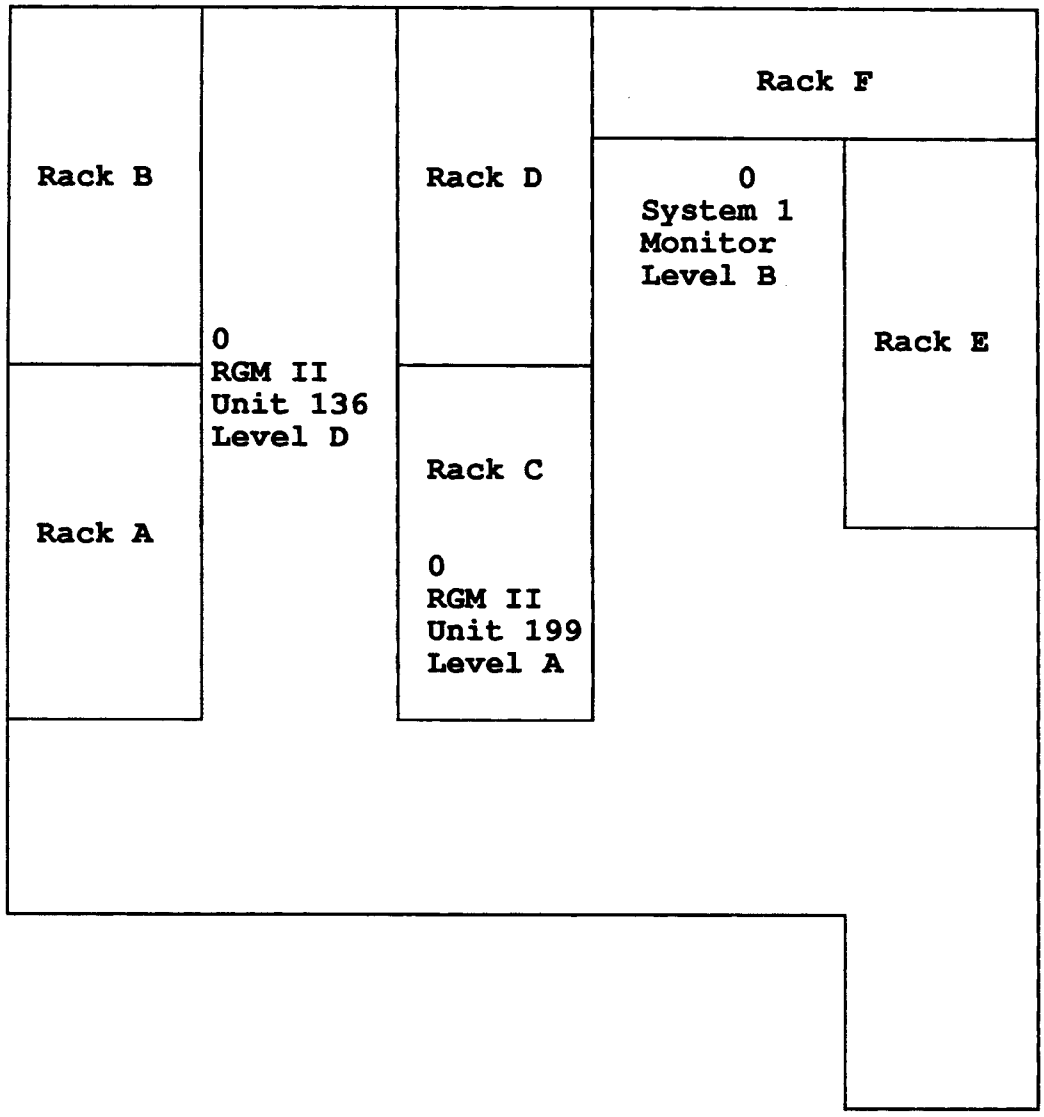
Chamber A has six equipment racks, each with four vertically spaced shelves. A plan (top) view of the arrangement of the racks(designated A-F) is shown in Figure 3. The four shelves on each rack are denoted as level A through level D from top to bottom. For tests 1, 2 and 5a, the concentration uniformity tests (where CC's were placed on each shelf of each rack), average concentrations were calculated for the chamber (using the results for all CC's) and for each level and each rack. The percent difference between the rack and level averages and the overall mean chamber concentration were computed. The range of differences (in percent) between the CC chamber mean and the means for the 6 racks is a measure of horizontal radon concentration variation in chamber A. The range of differences (in percent) between the CC chamber mean and the means for the four levels is a measure of vertical radon concentration variation.

Test 1.

During test 1 (Table 4, row 1), 30 brand 1 CC's were exposed at 30 chamber A locations for ~50 hours from 4/1-3/1987. No other monitoring devices were in chamber A during this test. The 30 CC's were placed on all shelves of each rack (24 shelves). Three cans were placed on the floor. The mean radon concentration for the 30 CC's was 40.3 pCi/L +/- 4.6% (1 standard deviation, s.d.). Rack averages ranged from 5.0% below to 3.0% above the mean CC concentration. Level averages ranged from 1.0% below to 1.0% above the mean CC concentration. The average concentration measured by the CC's on the floor was 0.2 % below the chamber mean.

Test 2.

During test 2 (Table 4, row 2), 72 brand 1 CC's were exposed at 36 chamber A locations (in pairs) for ~48 hours from 5/8-10/1987. No



Notes:

0 - Continuous monitor suction point
Level A - Top shelf
Level B - Second highest shelf
Level C - Third highest shelf
Level D - Bottom shelf

Figure 3. Top View of Equipment Racks and Continuous Radon Monitoring Points in Radon Chamber A.

other monitoring devices, except for the chamber continuous monitors, were in the chamber. As with test 1, the CC's were distributed evenly across the shelves of the chamber racks. The mean radon concentration for the 72 CC's was 41.2 pCi/L +/- 4.9% (1 s.d.). Rack averages ranged from 2.9% below to 3.9% above the mean CC concentration. Level averages ranged from 1.5% below to 1.0% above the mean CC concentration. Two CRM's were operated during this test and the average radon concentration measured by the CRM's was 40.8 pCi/L +/- 1.0% (1 s.d.). EPA defined the performance ratio (PR), for these chamber tests, as the average radon concentration measured by CC's divided by the average radon concentration measured by CRM's. This ratio gave a measure of the degree of bias of CC's when compared to the CRM's, which are a more accurate method of radon measurement. For this test, the PR was 1.01 which indicated an average high bias of ~1% for the 72 brand 1 charcoal canisters.

Test 3.

During test 3 (Table 4, row 3), 26 brand 1 CC's were exposed at 13 chamber A locations (in pairs) for ~50 hours from 6/19-21/1987. This test was run during RMP4 followup testing by placing two EPA CC's on each tray of participant CC's exposed in chamber A. The mean radon concentration for the 26 CC's was 27.2 pCi/L +/- 4.4% (1 s.d.). The EPA CC's were not distributed uniformly across the chamber volume; thus, rack and shelf averages were not meaningful and range of variation data were not computed. However, the average radon concentration obtained from the three CRM's operating during the test was 25.2 pCi/L +/- 1.8% (1 s.d.). The PR calculated for the 26 brand 1 CC's used in this test was 1.08, which indicated an average high bias of ~8% for the 26 CC's.

Test 4.

During test 4 (Table 4, row 4), 22 brand 1 CC's were exposed at 11 chamber A locations (in pairs) for ~48 hours from 6/22-24/1987. As with test 3, this test was run during RMP4 followup testing by

placing two EPA CC's on each tray of participant CC's. The mean radon concentration for the 22 CC's was 25.7 pCi/L +/- 7.0% (1 s.d.). As in test 3, the uneven distribution of EPA CC's across the chamber volume precluded calculation of rack and level range of variation data. However, the average radon concentration obtained from the three CRM's operating during the test was 24.2 pCi/L +/- 2.3% (1 s.d.). The PR calculated for the 22 brand 1 CC's used in this test was 1.06, indicating an average high bias of ~6% for the 22 CC's.

Test 5.

Test 5 was the most comprehensive of the 7 tests discussed in this report. The test period was 8/5-9/87. Four hundred-eighty previously used EPA CC's were baked in a furnace to regenerate them and then distributed uniformly across the chamber volume (and opened) to serve as a large radon "sink" during testing. These CC's were not used for radon measurements but simulated a heavy charcoal loading in chamber A. In addition to these 480 "sink" CC's, six different groups of EPA CC's were used for radon measurements as listed below:

5a. 48 brand 1 CC's exposed for two days,
5b. 20 brand 1 CC's exposed for four days,
5c. 20 brand 1 CC's exposed for one day (first day of test),
5d. 20 brand 1 CC's exposed for one day (second day of test),
5e. 20 new brand 2 CC's exposed for two days,
5f. 20 regenerated brand 2 CC's exposed for two days.

The total chamber charcoal loading (~42 kg) was almost twice the maximum load due to participant CC's during RMP4. The test results for the six groups will be discussed individually.

Group 5a.

During test 5a (Table 4, row 5a), 48 brand 1 CC's were exposed at 24 chamber A locations (in pairs) for ~49 hours from 8/5-7/1987. The "radon sink" CC's were placed on trays (20 per tray on 24 trays) and two of the group 5a CC's were placed on each tray. One tray of CC's was placed on each shelf of each rack. The mean radon concentration for the 48 CC's was 33.3 pCi/L +/- 7.2% (1 s.d.). Rack averages ranged from 4.2% below to 4.2% above the mean CC concentration. Level averages ranged from 3.0% below to 3.3% above the mean CC concentration.

Three CRM's were operated during this test. The intakes for these monitors were spatially distributed across the chamber volume (see Figure 3) such that a chamber air sample was drawn (from left to right, facing the front of the chamber from the outside) of the

* near the bottom shelf (level D) on the left side and about equidistant from front and back,
* near the top shelf (level A) in the middle of the chamber near the front and
* near the second shelf from the top (level B) on the right side near the rear

chamber. Each CRM was calibrated independently with periodic scintillation cell grab samples taken within two inches of the CRM intakes. By calibrating the CRM's independently for this test, EPA staff were able to use the results to study chamber radon concentration uniformity and to compare the CRM results to the results obtained with the CC's. The mean radon concentration for the three CRM's was 31.0 pCi/L +/- 2.5% (1 s.d.). Individual CRM readings ranged from 2.7% below to 2.1% above the mean CRM concentration.

For this test, the PR for the brand 1 CC's was 1.07, which indicated an average high bias of ~7% for the 48 CC's.

Group 5b.

During test 5b (Table 4, row 5b), 20 brand 1 CC's were exposed at 10 chamber A locations (in pairs) for ~99 hours from 8/5-9/1987. The mean radon concentration for the 20 CC's was 33.8 pCi/L +/- 5.3% (1 s.d.). Since only 10 chamber locations were monitored, the brand 1 CC's were not distributed uniformly across the chamber volume so that rack and shelf averages would be meaningful. Consequently, range of variation data was not computed.

The average radon concentration obtained from the three independently calibrated and spatially separated CRM's was 33.1 pCi/L +/- 3.3% (1 s.d.). Individual CRM readings ranged from 3.8% below to 1.9% above the mean CRM concentration.

The PR calculated for these 20 brand 1 CC's was 1.02, indicating an average high bias of ~2% for the 20 CC's. This was the lowest bias for any group of CC's exposed during test 5. This was probably because the strongest calibration data base for the brand 1 CC's is for four days exposures.

Groups 5c and 5d.

During test 5c, 20 brand 1 CC's were exposed at 10 chamber A locations (in pairs) for ~26 hours from 8/5-6/1987. During test 5d, 20 brand 1 CC's were exposed at 10 chamber A locations (in pairs) for ~25 hours from 8/6-7/1987. The EPA brand 1 CC's are not well calibrated for a one day exposure. Due to this lack of calibration data, the information obtained was not useful and will not be discussed further. However, the data from the three independently calibrated CRM's was useful in studying uniformity of radon concentration across chamber A for the first and the second day of the test. For test 5c (8/5-6/1987), the mean radon concentration for the three CRM's was 29.4 pCi/L +/- 2.5% (1 s.d.). Individual CRM readings ranged from 2.7% below to 2.1% above the mean CRM concentration (Table 4, row 5c). For test 5d (8/6-7/1987), the mean

radon concentration for the three CRM's was 32.8 pCi/L +/- 2.6% (1 s.d.). Individual CRM readings ranged from 2.9% below to 2.1% above the mean CRM concentration (Table 4, row 5d).

Group 5e.

During test 5e (table 4, row 5e), 20 brand 2 CC's were exposed at a single chamber A location for ~49 hours from 8/5-7/1987. The test period was the same as for the brand 1 CC's of group 5a. The purpose of this group was to compare the response of brand 1 and brand 2 CC's in chamber A for the two-day exposure period recommended for brand 2 CC's. The mean radon concentration for the 20 brand 2 CC's was 35.0 pCi/L +/- 5.3% (1 s.d.) which yielded a PR of 1.13, a high bias of 13%. The 48 brand 1 CC's (group 5a) exposed during the same time period yielded a PR=1.07. Thus, during this test, the brand 2 CC's were biased almost twice as high as the brand 1 CC's in chamber A.

This test was the first time EPA staff had observed a difference in response between the brand 1 and brand 2 CC's, which were both calibrated in chamber C. EPA staff began looking at the differences between chamber C (where the CC's were calibrated) and chamber A. Air velocity measurements were made in chambers A and C and differences in the average air velocities in the chambers were documented (C has negligible velocity). Also, it seemed apparent that the air velocity in chamber A caused a minor high bias in brand 1 CC's but a more pronounced high bias in brand 2 CC's. Additional testing (beyond the seven tests discussed in this report) for velocity sensitivity of both brands of CC's was performed which clearly documented the velocity sensitivity of both brands and the generally greater sensitivity to air velocity of brand 2 when compared to brand 1 (Gr88). As an example, one group of tests using brand 2 CC's was conducted in Chamber C from January 6 through January 16, 1988, with chamber temperature ~70 degrees F, relative humidity ~50% and chamber radon concentrations of 111-137 pCi/L. The CC's were exposed for the recommended two days. The agreement was

excellent between the brand 2 CC's and the CRM's where there was no perceptible air velocity. However, when the brand 2 CC's were exposed with air velocity (using a fan), they experienced a 16% high-bias for ~50 feet/minute (fpm), a 23% high-bias for ~100 fpm and a 27% high-bias for ~200 fpm air velocity.

A possible explanation may be that CC's calibrated under conditions of negligible velocity probably have a concentration gradient established between the air near the top charcoal surface and the bulk chamber air because diffusion from the bulk air would be the primary mechanism to replace the radon which is adsorbed by the charcoal. This would lead to a lower radon concentration in the air next to the charcoal surface than in the bulk chamber air (the air monitored by the chamber continuous radon monitors used to calibrate the CC's). Thus, the CC counting rate would be lower in this case than if the CC charcoal surface were exposed to the bulk air concentration. When CC's calibrated in this manner are exposed to an environment where velocity is present, only a small velocity would be needed for turbulence to dominate, and completely override diffusion, as the mechanism for radon replacement near the charcoal surface. In this situation, the air near the charcoal could be kept at the chamber bulk air concentration. Thus, a CC calibrated in a still environment would overrespond when exposed in an environment with air velocity present.

Group 5f.

During test 5f, 20 regenerated brand 2 CC's were exposed at a single chamber A location (adjacent to the group 5e CC's for ~49 hours from 8/5-7/1987. EPA did not have calibration data for regenerated brand 2 CC's and it was obvious that the calibration data for new CC's would not work with regenerated CC's. Due to the lack of calibration data, the information from this test was not useful and will not be discussed further.

Transient Response of CRM's

During test 5, the charcoal loading of chamber A was sufficiently heavy to cause the chamber radon concentration to decrease to a minimum of ~63% of the initial concentration ~5 hours after the test began. The concentration did not fully recover during the four days of testing. Two days after the test began, the radon concentration had recovered to ~83% and four days after testing began to ~87% of the initial concentration. However, even with the heavy charcoal loading and the associated radon concentration transient, the concentrations across the chamber volume (measured by the three independently calibrated CRM's) remained essentially constant as is shown in Table 5.

Test 6 and 7.

Tests 6 and 7 were identical tests with one exception. During test 6, the condensation nuclei (CN) generator was not running and the particle count in chamber A was in the range of 5,000 particles/mL. During test 7, the CN generator was running at maximum output and the particle count (wax particles) was in the range of 500,000 particles/mL. During these tests, 5 each of the EPA brand 1, new brand 2 and regenerated brand 2 CC's were exposed at a single location. The purpose of these tests was to try to define any difference in response of the EPA CC's exposed with and without wax particles in the environment. No other monitoring devices, except for the chamber continuous radon and continuous working-level monitors used to document chamber concentrations, were in the chamber. Due to the lack of calibration data for the regenerated brand 2 CC's, the information obtained was not useful and will not be discussed further.

Table 5: Test 5 Transient Radon Relative Concentrations Measured by Three Independently Calibrated Continuous Radon Monitors

		Relative Radon Concentration* (% of initial concentration)		
Date	Time	RGMII Unit 136	RGMII Unit 199	System 1
8/5/87	0800	100	100	100
	0900	100	98	99
	1000	94	98	96
	1100	82	86	82
	1200	68	73	67
	1300	64	66	63
	1400	62	63	63
	1500	64	65	64
	1600	64	66	67
	1700	66	67	63
	1800	67	69	67
8/7/87	0900	83	85	80
8/9/87	0900	90	86	85

*The air intakes for these CRM's are spatially separated for assessment of uniformity of radon concentrations (see Figure 3).

Test 6 (Table 4, rows 6a and 6b) extended over a ~48 hour period from 8/25-27/1987. During this period, the mean CRM radon concentration (one monitor) was 25.0 pCi/L. The mean radon concentration for the 5 brand 1 CC's was 26.5 pCi/L +/- 5.6% (1 s.d.). The PR calculated for the brand 1 CC's was 1.06, indicating a high bias of ~6%. The mean radon concentration for the 5 new brand 2 CC's was 27.8 pCi/L +/- 5.4%. The PR calculated for the brand 2 CC's was 1.11, indicating a high bias of ~11%.

Test 7 (Table 4, rows 7a and 7b) extended over a ~48 hour period from 8/31-9/2/1987. During this period, the mean CRM radon concentration (one monitor) was 24.8 pCi/L. The mean radon concentration for the 5 brand 1 CC's was 26.8 pCi/L +/- 3.2% (1 s.d.) which yielded a PR of 1.08, indicating a high bias of ~8%. The mean radon concentration for the 5 new brand 2 CC's was 28.5 pCi/L +/-

3.8%. The PR calculated for the 5 brand 2 CC's was 1.15, indicating a high bias of ~15%.

Discussion

A great deal of testing was conducted in NAREL chamber A with EPA CRM's and CC's following RMP4. The purpose was to evaluate uniformity of radon concentration across the chamber A volume and the response of two brands of CC's used in the NAREL CC program. The significant findings which resulted from these tests are stated and discussed below:

* For air recirculation rates near 100 cfm and operation of the humidifier fan in NAREL chamber A, air velocity varied across the volume from <10 to ~70 fpm.

* The response of EPA 4-inch, open faced CC's was shown to be dependent on the air velocity near the face of the CC (see explanation of test 5e).

* EPA operates a CC program which has utilized two brands of 4 inch, open-faced CC's. Both brands were initially calibrated in NAREL chamber C where air velocities are negligible. When these CC's were exposed in NAREL chamber A under conditions where air velocities ranged from <10 to ~70 fpm, the weighted-mean high bias for the 198 brand 1 CC's tested was 4.5% and for the 30 brand 2 CC's, 13.0%. Thus, for these tests, the weighted high bias of the brand 2 CC's was almost three times the weighted high bias of the brand 1 CC's.

* For air recirculation rates near 100 cfm and cyclic operation of the humidifier fan, extensive testing using both brand 1 CC's and three CRM's demonstrated that radon concentrations across the chamber A volume remained essentially uniform, even with a heavy charcoal load in the chamber. For the uniformity tests using CC's (tests 1, 2 and 5a), CC's were placed on each level of each chamber equipment rack. Average radon concentrations were computed for all racks, all

levels and the entire chamber. For these three tests (referring to Table 4) the greatest CC standard deviation of the mean was 7.2% and rack averages ranged from a low of 5.0% below to a high of 4.2% above the mean CC concentrations. Level averages ranged from a low of 3.0% below to a high of 3.3% above the mean CC concentrations. For the CRM uniformity tests (tests 5a-5d), three CRM's were spatially distributed across the chamber volume (see Figure 3 and the discussion of Group 5a). For these four tests, the highest CRM standard deviation of the mean was 3.3% and the individual CRM readings ranged from a low of 3.8% below to a high of 2.1% above the mean CRM concentrations (see Table 4). EPA believes that the consistently low standard deviation of the mean concentration and the consistently low rack and shelf ranges of variation from the mean, using both CC's and CRM's, demonstrated good uniformity of radon concentration throughout the chamber A volume, even when the chamber was heavily loaded with charcoal.

Although both measurement methods yielded low ranges of variations, the CRM data generally displayed less variation than the CC data. This was probably due to the effects of velocity variation at different points in chamber A upon the response of brand 1 CC's. In addition, NAREL staff believe that CRM's are an inherently more accurate method for radon measurements than CC's.

* When chamber A had a heavy loading of charcoal (~42 kg) with an air recirculation rate near 100 cfm and operation of the humidifier fan, the radon concentration in the chamber decreased to about 60-65% of the initial value after ~5 hours and slowly recovered to ~85-90% after 4 days. Even during this concentration transient induced by the heavy charcoal load, chamber A radon concentrations remained uniform across the volume (see Table 5).

* The brand 1 CC's exposed with wax particles in the chamber air were biased ~2% higher than those exposed without wax particles (~8% bias with wax, ~6% bias without wax). The new brand 2 CC's exposed with wax particles were biased ~4% higher than those exposed without

wax particles (~15% bias with wax, ~11% bias without wax).

7.0 Discussion of Possible Reasons for Round 4 High Bias of Charcoal Adsorbers

As part of the effort directed toward understanding the reasons for the high bias of the CC's tested in RMP4P, several possible reasons were hypothesized. Tests using NAREL CC's in chamber A (described in section 6) were carried out, where needed, to determine the plausibility of the various possible reasons. In this section, the possible reasons considered by EPA for the bias are listed and discussed.

A. The CC bias could have been due, in part, to incorrect radon measurements by NAREL during round 4.

EPA staff identified several points which supported the validity of the NAREL radon target values for round 4. First, the method performance ratios (PR) for 4 methods for measuring radon (which were tested simultaneously with CC's) showed good agreement with EPA target values (see Table 3). These other methods were continuous radon (15 participants, PR=1.01), grab radon (40 participants, PR=0.97), electret-PERM (5 participants, PR=1.01) and alpha track (75 participants, PR=0.93). Second, NAREL had consistently performed well in the radon international intercomparison program (see Table 1). The radon grab sample method that is used in the intercomparison program is also used to calibrate the NAREL continuous radon monitors. Data from these continuous monitors was used to establish the radon target values for methods CC, CR, EP and AT. (The fifth radon measurement method, GR, was compared directly to the NAREL grab sample results, as discussed previously). Third, for several specific exposure periods checked, the average of the NAREL scintillation cells filled during the periods agreed well with the official target value established from the continuous monitors. Fourth, scintillation cell measurements by Argonne National Laboratory agreed with NAREL measurements in RMP4P within

approximately 4 percent (Lu87). Fifth, in the followup GR testing for RMP4, NAREL filled its own scintillation cells, four cells from the U.S. DOE Environmental Measurements Laboratory (EML) in New York, and the participants' cells at the same time. The EML results agreed with the NAREL results within approximately 3 percent. Based on the above, EPA believes that the round 4 radon target values were correct.

B. There could have been a high bias in a chamber used to calibrate participant CC's as compared to the NAREL chamber used to expose CC's during RMP4P (normally differences should be less than 10 percent, as discussed previously).

EPA understood that another exposure chamber, used to calibrate several CC participants entered in RMP4P, experienced a period of time before RMP4 when the reported radon chamber concentration appeared to have been overestimated by more than 10 percent. This could have contributed directly to the high bias in RMP4P.

C. CC participants who underestimated in previous RMP rounds could have adjusted their calibration factors upward, to yield higher results, without obtaining additional calibration data.

Two round 4 CC suppliers (representing about 20 of the CC participants) indicated to EPA staff that, based on RMP3 results, they made an upward adjustment in their calibration factors without additional calibration data (one by 15 percent and one by 8 percent). There may have been other participants who also made an arbitrary upward adjustment in their calibration factor between rounds 3 and 4.

D. At times, a large loading of CC's going into chamber A caused the radon concentration to decrease for 18-24 hours. The continuous monitors used to establish the official chamber A radon concentration recorded this initial decrease and recovery. If CC's did not measure the decrease, due to their time-dependent response, this could cause an overestimation.

NAREL staff examined several exposure periods to ascertain the magnitude of error if participants' CC's failed to sense the decrease. An example was the CC exposure period from 0645, 4/24/87 to 0749, 4/27/87, the period where the single largest concentration decrease occurred due to heavy loading of CC's into the chamber. The decrease started when CC's were loaded into the chamber, reached a value of 75 percent of the initial concentration within 5-1/2 hours and was essentially fully recovered within 24 hours. The radon concentration remained relatively constant during the rest of the exposure period. For the 3 day CC exposure period, the continuous radon monitor record yielded an average radon concentration of 37.7 pCi/L. If one hypothesizes that some 3-day CC's only responded to chamber concentrations during, say, the last two days of the exposure period (i.e., they "missed the dip"), the continuous monitor record indicated an average of 39.0 pCi/L for that period. For this worst case decrease, the bias created by "missing the dip" would be +3.4 percent.

E. Temperature in the RMP test chambers could have been different than in the calibration chamber.

The effect of temperature changes on the response of participants' CC's should have been accounted for in any rigorous CC calibration program. The chamber temperature during RMP4 exposures (~70° F) was measured both electronically and with mercury bulb thermometers, and was stated on each RMP participant's results reporting form. One of the purposes of the RMP program is to identify inadequate calibration data.

F. Inadequate calibration of participants' CC's to account for relative humidity variation.

Similar to temperature, this effect (if present), should be accounted for in any rigorous CC calibration program. Chamber relative humidity during RMP4 was ~50 percent.

G. Large quantities of CC's in the RMP chambers might have caused non-uniform radon concentrations across the chamber volume which could affect participants' CC's exposed at some locations.

As discussed in Section 6.0, Test 5 was run with the NAREL Chamber A loaded with approximately 42 kg of charcoal, almost twice the highest charcoal loading encountered in RMP4. The chamber temperature, relative humidity and air velocity were virtually the same as during RMP4. EPA studied chamber A concentration uniformity under these conditions using 3 spatially distributed and independently calibrated CRM's and using brand 1 CC's. In four uniformity tests (using the three CRM's for each test), the greatest standard deviation of the mean concentration (mean for the three CRM's) was 3.3% and the individual CRM readings ranged from a low of 3.8% below to a high of 2.1% above the mean. All of the CRM uniformity tests were conducted while chamber A was heavily loaded with charcoal. For the three concentration uniformity tests run using CC's, two were with essentially no charcoal loading and one was with heavy charcoal loading. Average radon concentrations for each of six equipment racks (to measure horizontal variation) and for each of four vertical levels was computed. For the three tests, Table 4 shows that the greatest standard deviation of the mean CC concentration (for the chamber) was 7.2%. Rack averages ranged from a low of 5.0% below to a high of 4.2% above the mean CC concentrations. Level averages ranged from a low of 3.0% below to a high of 3.3% above the mean CC concentration. EPA believes that the CRM's provided the highest quality data for these tests since the brand 1 CC data was probably somewhat sensitive to air velocity variation across the chamber. However, the percent standard deviations and ranges of variation were low for both CRM's and CC's. EPA believes that both sets of data demonstrated good concentration uniformity throughout chamber A.

H. <u>There could have been an aerosol present in chamber A which has a high solubility for Rn-222 and which is, itself, adsorbed more efficiently by charcoal than Rn-222. Possible sources are:</u>

a. foam insulation used in manufacture of chamber wall panels,
b. silicon rubber caulk used to seal interior of chamber,
c. carnauba wax used in CN generator,
d. coating on wire baskets used to expose CC's, AT's and EP's.

As stated earlier in the report, the weighted mean bias for the NAREL brand 1 CC's used in the seven chamber tests (almost 200 CC's tested) was a positive 4 percent. If items a-d contributed to a CC bias in RMP4, the effects should have been present during the seven chamber tests, since the tests were conducted during and immediately after RMP4. Also, the effect should have been a negative bias because the organic compounds which might be released from these materials would compete with the Rn-222 for charcoal adsorption sites.

I. <u>It is possible that some CC's were sensitive to the velocity of the surrounding air.</u>

The hypothesis was that possible differences in air velocities between the NAREL chamber used to expose CC's in RMP4 and other calibration chambers, or between different locations within NAREL chamber A, had a significant effect on the response of CC's. NAREL staff ran tests to determine the effect of air velocity on the EPA 4-inch open-faced CC's. NAREL has used two brands of CC's, each with a different type of charcoal, in the EPA program. The calibration data for both brands of NAREL CC's was generated in chamber C where the air velocity is 0.1-0.3 feet per minute (essentially stagnant conditions). During RMP4, air velocities at some locations in

chamber A reached ~70 feet per minute*. This did not appear to be a significant problem in the initial tests in chamber A with brand 1 CC's. For the seven initial tests, the weighted average bias for these brand 1 CC's was about 4 percent high as previously stated. This did not show a significant bias shift in brand 1 CC's between chambers A and C which have vastly different designs. However, when the brand 2 CC's were tested they showed a significantly higher bias in chamber A than did brand 1. Additional testing (beyond these seven tests) was performed which clearly documented the velocity sensitivity of both brands of CC's and the generally greater sensitivity to air velocity of brand 2 CC's when compared to brand 1 (Gr88). As an example (discussed previously), one group of tests using brand 2 CC's (exposed for two days) yielded very good agreement between CC's and CRM's when exposed with no air velocity. However, when velocity was introduced, the CC's experienced a 16% high-bias for ~50 fpm, a 23% high-bias for ~100 fpm and a 27% high bias for ~200 fpm air velocity. Using this data, NAREL staff concluded that air velocity in chamber A during round 4 (maximum was ~70 fpm) could have been a contributing factor to the overresponse of participants' CC's. It appears that the RMP4 exposed an inherent weakness in the performance of open-faced CC's; the sensitivity of CC response to air velocity. Because of this conclusion, NAREL staff believed that RMP participants using charcoal adsorbers needed to test their devices to determine the effect of air velocity on response. A summary of the EPA test results and a recommendation that participants determine the velocity sensitivity on their CC detectors was published in two widely circulated newsletters and in a letter sent to the RMP participants (see Appendix B).

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*The velocity measurements in Chamber A showed velocities between <10 to ~70 fpm for the RMP4 test conditions. Using the same instrument used to measure the Chamber A air velocities, velocity measurements were also made in a local residence with a forced air heating/cooling system. Velocities at likely CC monitoring locations in the home ranged from <10 up to ~70 fpm, similar to RMP4 test conditions.

8.0 Summary

In this report, two EPA radon and radon decay products test chambers (chambers A and C) located at the National Air and Radiation Environmental Laboratory in Montgomery, Alabama are described. These chambers were used to expose detectors submitted for testing in Round 4 of the National Radon Measurement Proficiency Program and are used routinely for calibration purposes. Also described are the measurement and calibration procedures which were used to establish the official target values for radon and radon decay products concentrations during RMP Round 4 testing. The results for RMP Round 3 (conducted at the U.S. DOE Environmental Measurements Laboratory radon chamber in New York) and RMP Round 4 (conducted in the two NAREL chambers) are discussed and compared. Following Round 4, the NAREL staff analyzed the collective performance for each measurement method tested in these rounds and found that all methods agreed with the target values within expected limits except for RPISU's and charcoal adsorbers. The 15 percent underestimation of the RPISU's was traced to plugging of the filters by wax. When retested with shorter exposure time, the problem was resolved. As a group, CC's were biased 16 percent above the target values in Round 4 whereas they were biased 7 percent below the target values in Round 3.

After analyzing the RMP4 results, NAREL staff spent several months evaluating the difference in charcoal adsorber response between Rounds 3 and 4 by performing radon chamber tests using EPA 4-inch, open-faced charcoal adsorbers. Several potential causes for the high-bias of CC's in Round 4 were examined. EPA staff believe that the round 4 high-bias for CC's was caused by the synergistic combination of several factors which include:

- Participants who were biased low in previous rounds adjusting their calibration factors upward to yield higher results without obtaining additional calibration data;

- Overestimation of radon concentrations in a chamber used to calibrate some RMP4 participants' charcoal adsorbers;

- Inadequate humidity corrections for some charcoal adsorbers; and

perhaps most importantly,

- Some charcoal adsorbers having a response sensitivity which varied with air velocity within the velocity range found in chamber A during RMP4.

These factors, and others which were tested and ruled out, are discussed in Section 7.0 of the report.

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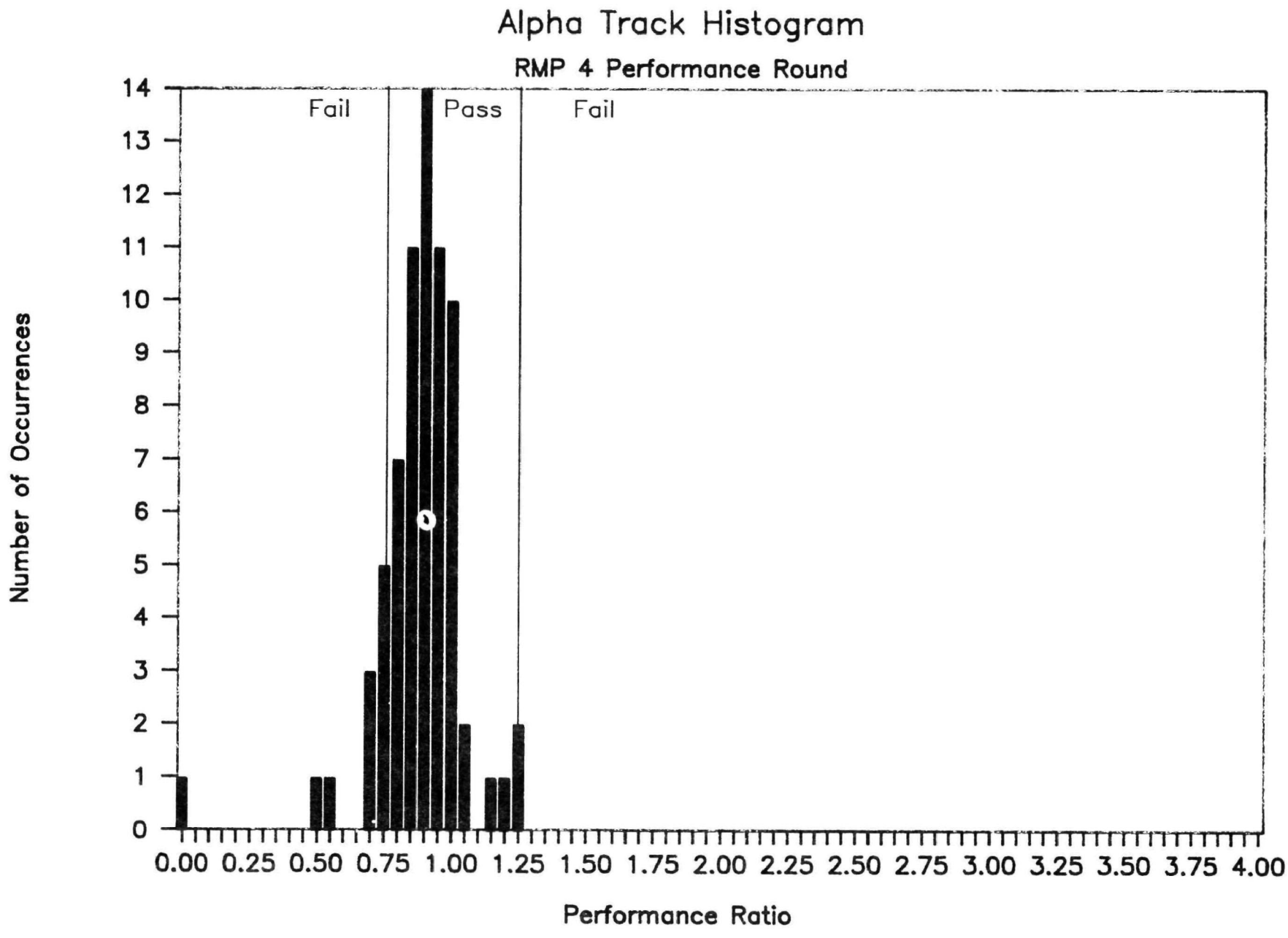
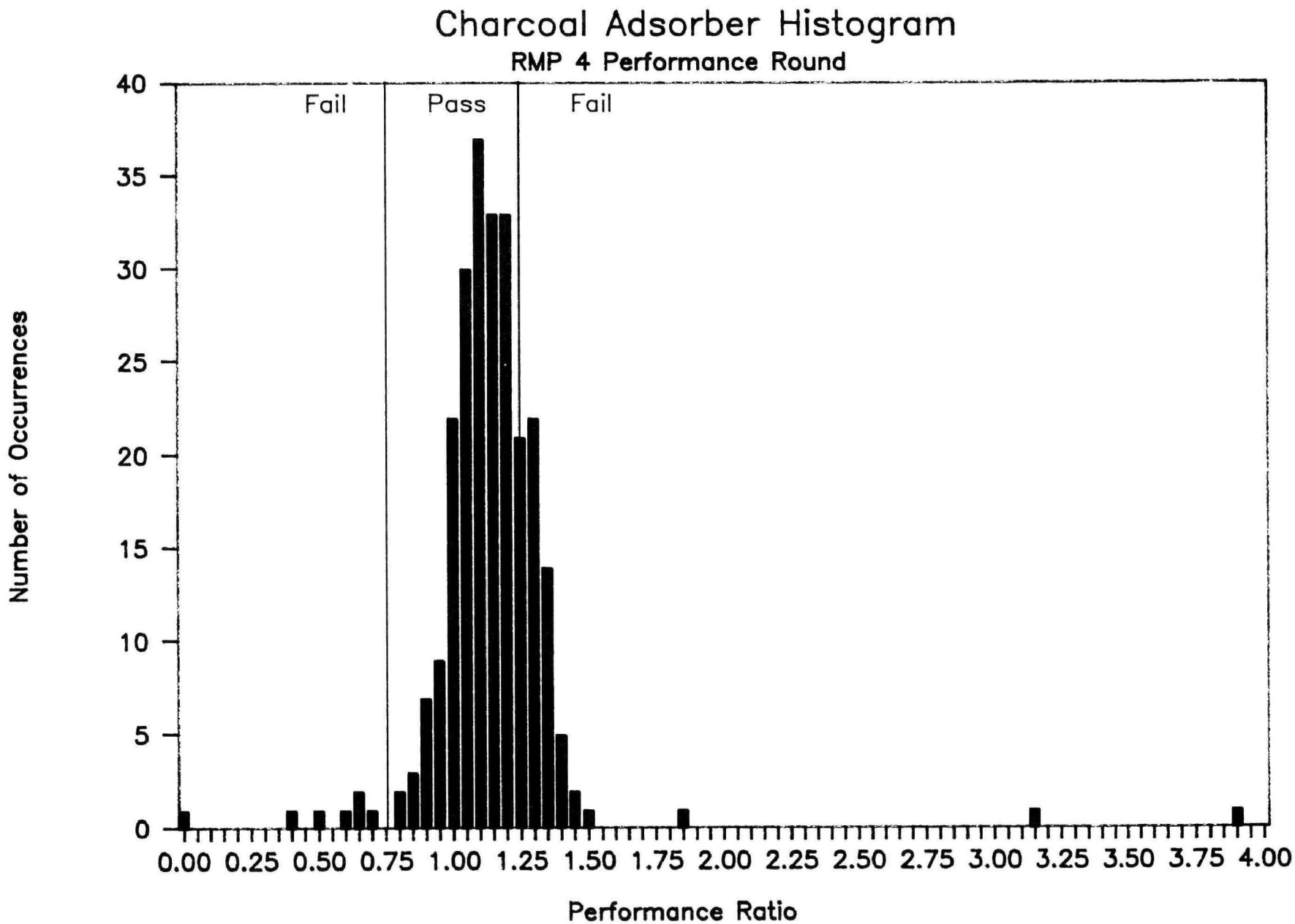
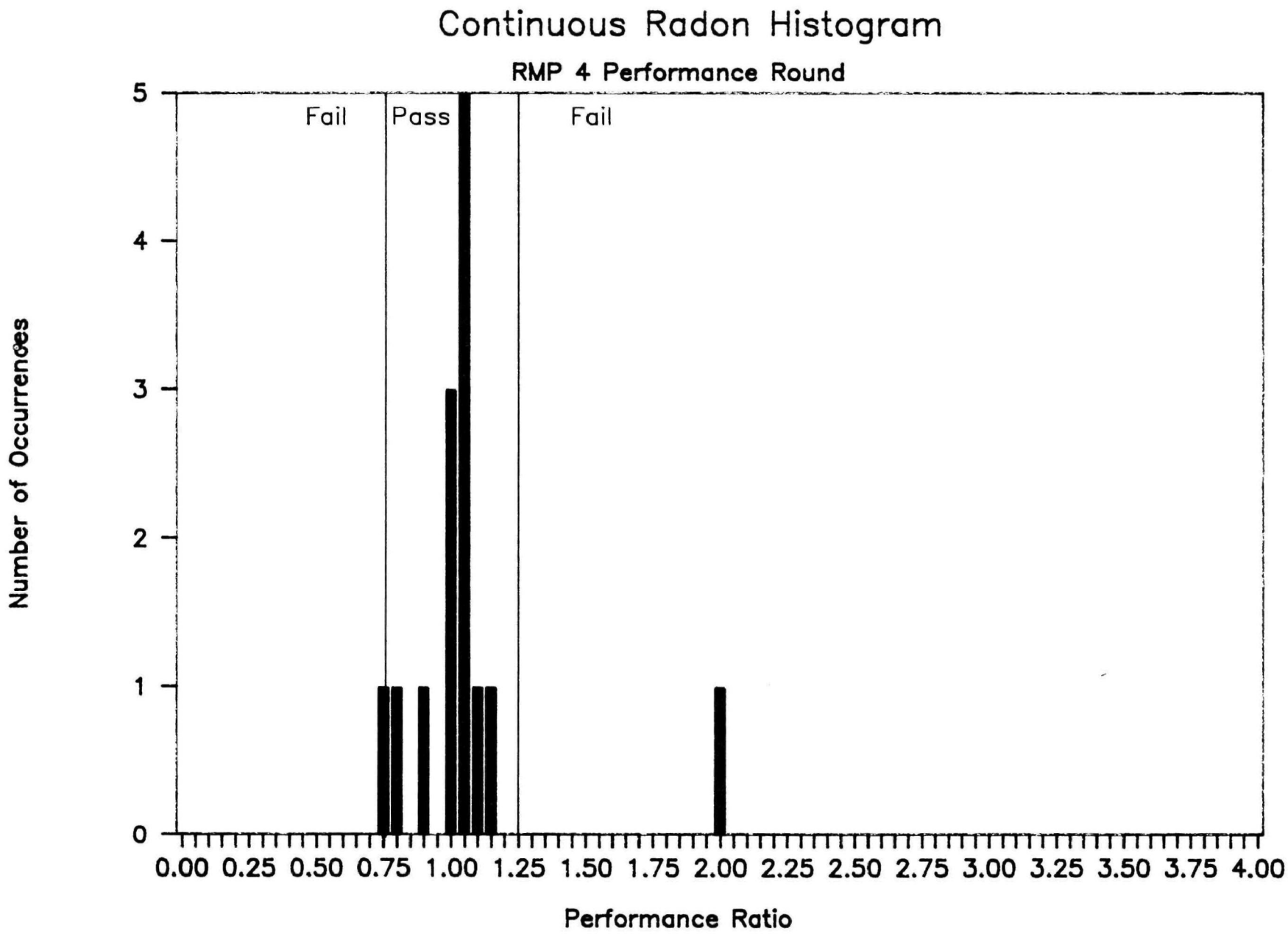
Appendix A

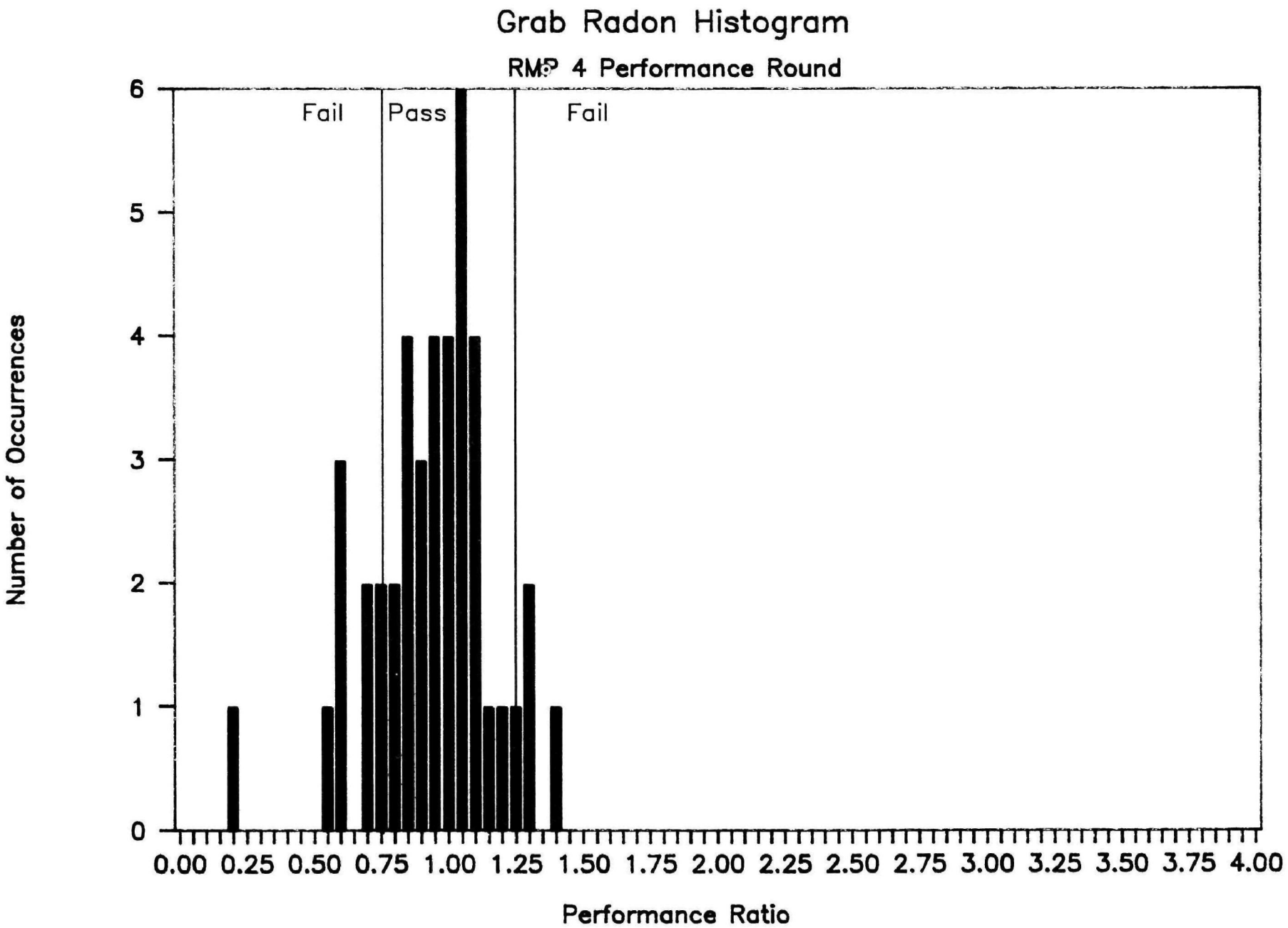
Histograms for RMP4 Performance Round
(Participant Performance Ratio)

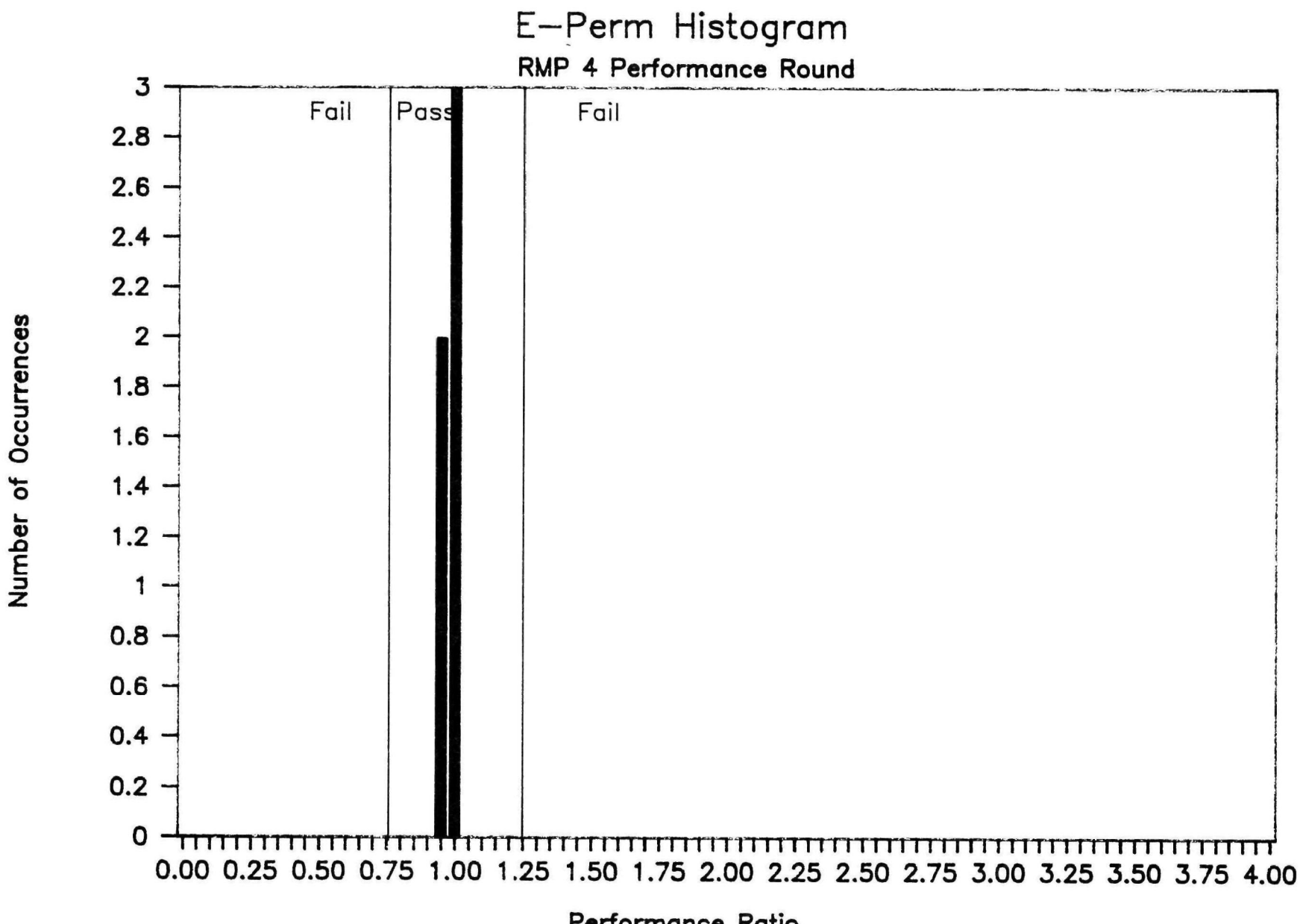
Note: A detector performance ratio is the quotient of a participant's detector reading divided by the official target value. A participant performance ratio is the average of the detector performance ratios for all detectors tested by a participant. The method performance ratio is the mean of the participants performance ratios for all participants testing this method, except for outliers. An outlier is a participant performance ratio below 0.5 or above 1.5. The histograms were constructed using participant performance ratios.

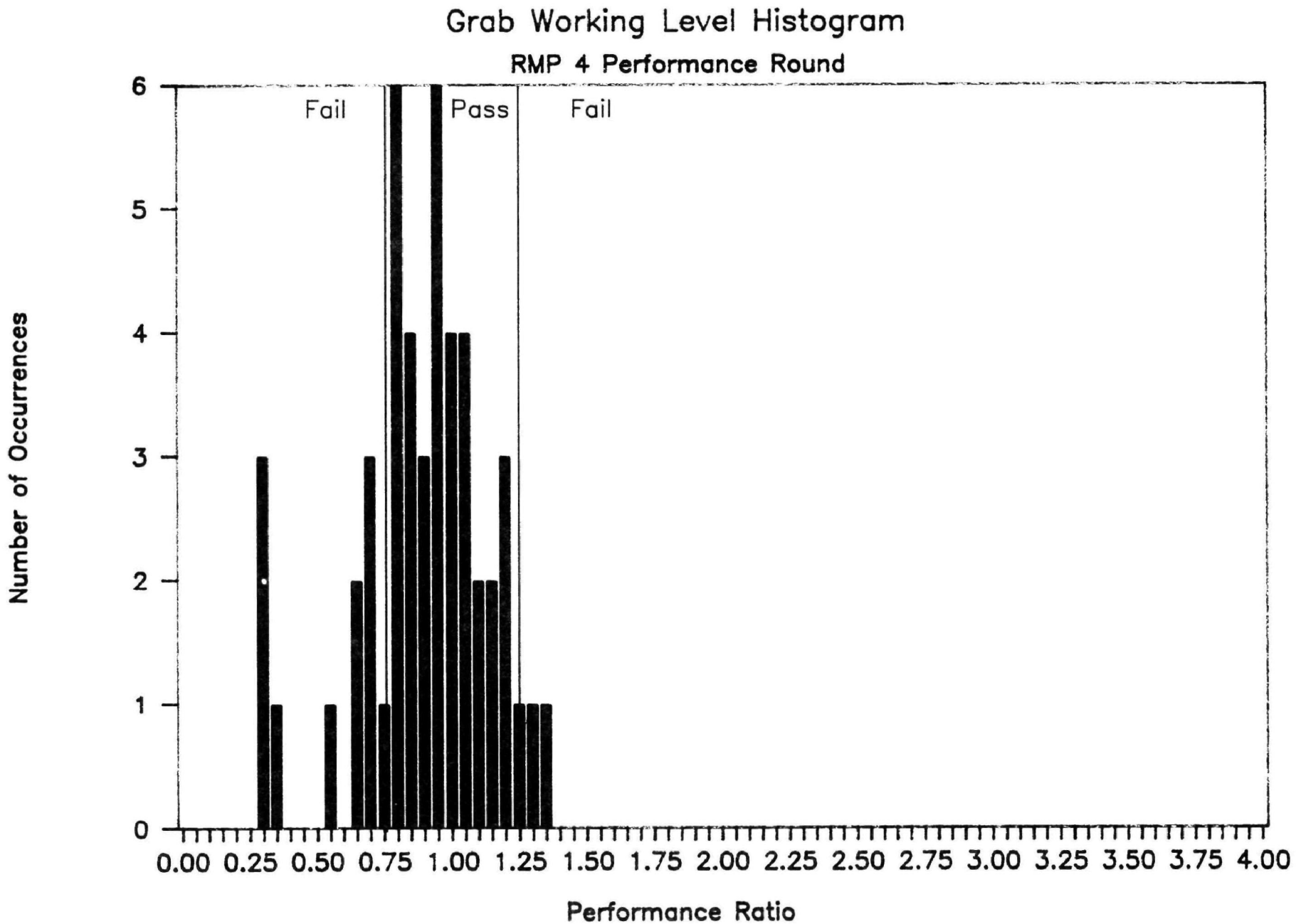

Alpha Track Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio

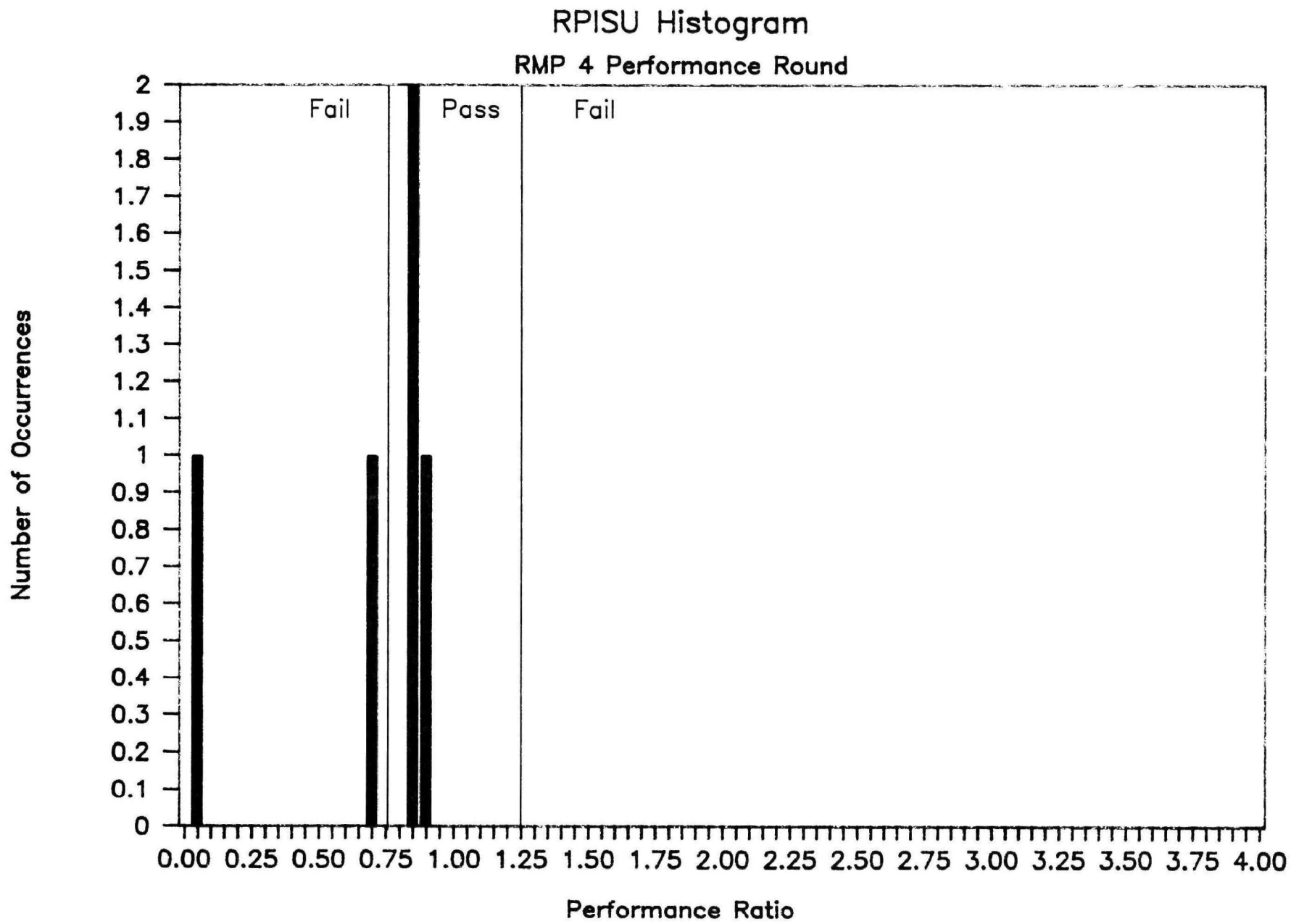

Charcoal Adsorber Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
0
5
10
15
20
25
30
35
40
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio

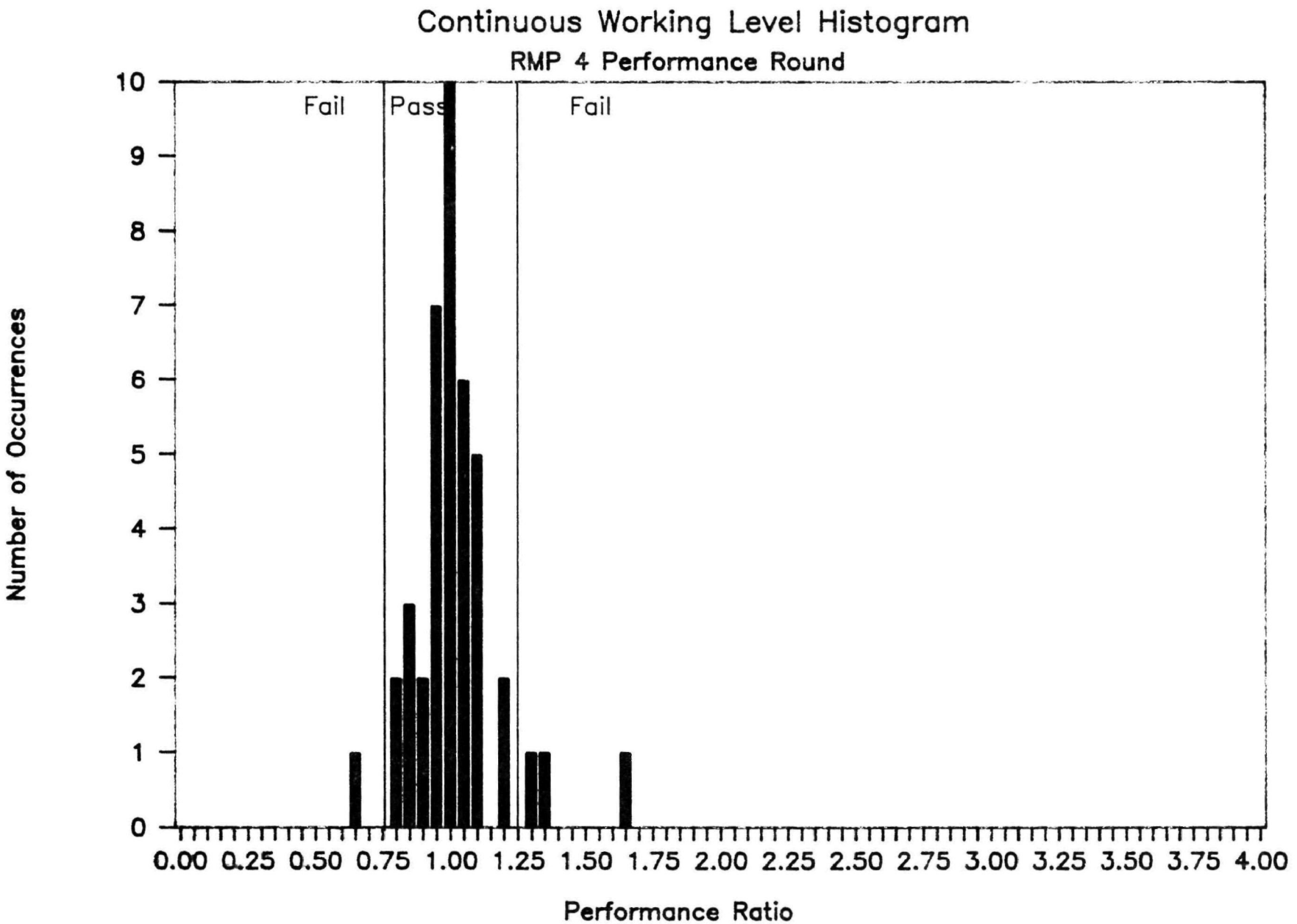

Continuous Radon Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
0
1
2
3
4
5
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio


Grab Radon Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
0
1
2
3
4
5
6
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio


E–Perm Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio


Grab Working Level Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
0
1
2
3
4
5
6
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio


RPISU Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio


Continuous Working Level Histogram
RMP 4 Performance Round
Fail
Pass
Fail
Number of Occurrences
0
1
2
3
4
5
6
7
8
9
10
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
Performance Ratio

Appendix B

Notifications of Velocity Sensitivity of Openfaced Charcoal Adsorbers

Note: Prior to March of 1990, the National Air and Radiation Environmental Laboratory was known as the Eastern Environmental Radiation Facility.

The discovery, during RMP round 4, of the open-faced charcoal adsorber response sensitivity to air velocity was communicated to the radon measurement community in the three documents included in this appendix:

- Article in Radon Reporter (AARST), Volume 1, Number 2, Spring 1988.

- Note, Health Physics Society Newsletter, Volume XVI, Number 2, February 1988.

- Letter to RMP Participants from J. Michael Smith, EPA, February 25, 1988.

EPA SUGGESTS CHARCOAL CANISTER DESIGN CHANGE

Dear Editor:

Round 4 of the Environmental Protection Agency's (EPA) Radon Measurement Proficiency (RMP) Program was conducted at EPA's Eastern Environmental Radiation Facility (EERF) in Montgomery, AL during April-June 1987. During Round 4 the EERF tested four radon measurement techniques (charcoal adsorbers, alpha track detectors, grab radon monitors, continuous radon monitors) and three radon progeny measurement techniques (RPISU's, grab radon progeny monitors and continuous radon progeny monitors). The total number of methods tested was approximately 500 in the performance test. Following Round 4, EERF staff statistically analyzed the collective performance for each of these seven measurement techniques and found that all techniques agreed with our known values within expected limits except for charcoal adsorbers. As a group, charcoal adsorbers were biased 16 percent above the known values in the performance test. This was puzzling since, in previous rounds (conducted in a different chamber), charcoal adsorbers were biased 6-8 percent below the known values.

Since the conclusion of Round 4, EERF staff have spent several months evaluating this shift in charcoal adsorber response by performing chamber tests using our own charcoal adsorbers. We have examined several potential radon chamber problems (for example, the possibility of non-uniform distribution of radon in our chamber under conditions of heavy charcoal loading, etc.) and have demonstrated that none of these potential problems were present in our chamber during Round 4 to adversely affect charcoal adsorber response. We believe that the 16 percent high bias of charcoal adsorbers during the performance test in Round 4 and the shift from a negative to positive bias between Rounds 3 and 4 is the synergistic combination of several factors which may include: participants arbitrarily adjusting calibration factors; bias in a chamber used to calibrate participant's charcoal adsorbers; inadequate calibration for differing humidities for certain charcoal adsorbers; and perhaps most importantly, certain charcoal adsorbers having a response sensitivity which varies with air velocity. These factors and others which we tested and ruled out will be discussed in more detail in a forthcoming EPA report.

We believe that the velocity effect is not well recognized and is of particular importance to the users of charcoal adsorbers. During our charcoal adsorber testing in the past few months, we have obtained data which indicates that, at constant temperature, relative humidity and radon concentration, the air velocities in the vicinity of open-faced charcoal adsorbers of the EPA design significantly affects the response. For example, in one series of 2-day tests, charcoal adsorbers exposed under dormant air conditions agreed within 5 percent with our continuous radon monitors (most of the time they agreed within 1 percent); at a velocity of ~50 feet per minute the same type adsorbers were biased 16 percent high; a velocity of ~100 feet per minute, 23 percent high; and at ~200 feet per minute, 27 percent high. Our more recent testing indicates that adsorbers with diffusion barriers may exhibit a sensitivity to velocity, although less pronounced than for open-faced adsorbers.

During Round 4, air velocities at some locations within the test chamber were of the same magnitude as found at some suitable monitoring locations in residences with forced air heating/cooling systems. Since Round 4 and our discovery of the velocity sensitivity of charcoal adsorbers, steps have been taken to significantly reduce the air velocity in EERF's test chamber used for the RMP Program.

We believe that organizations using charcoal adsorbers should test their devices to determine the effect of air velocity on their charcoal adsorber response. If a sensitivity to air flow is noted, these organizations may wish to modify their design to obtain charcoal adsorbers which are less sensitive to velocity effects. The EPA is currently testing various detector designs to find a configuration that minimizes humidity and air velocity effects while maintaining adequate sensitivity. Those organizations who choose not to modify velocity-sensitive charcoal adsorbers should take particular precautions to assure that their adsorbers are exposed in the field in accordance with EPA protocols which call for testing in areas with minimal drafts. However, we believe that the limitations of assuring no air movement in either field or chamber testing is unrealistic. Therefore, EPA believes that the proper solution to this problem is to modify the design of charcoal adsorbers so they are less sensitive to air velocity.

We hope that the information in this letter will be helpful to organizations measuring radon levels using charcoal adsorbers. The EERF staff would be interested in learning the results of testing conducted by other organizations regarding the effects of air velocity on their charcoal adsorber response.

Charles R. Porter, Director
Eastern Environmental
Radiation Facility

Problem with Charcoal Adsorbers

Round 4 of the EPA Radon Measurements Proficiency Program (RMP) was conducted at EPA's Eastern Environmental Radiation Facility (EERF) in Montgomery, Alabama, during April-June 1987. During Round 4 the EERF tested five radon measurement techniques (charcoal adsorbers, alpha track detectors, electret-perms, grab radon monitors, continuous radon monitors) and three radon progeny measurement techniques (RPISUs, grab radon progeny monitors and continuous radon progeny monitors). The total number of methods tested was approximately 500 in the performance test. Following Round 4, EERF staff statistically analyzed the collective performance for each of these eight measurement techniques and found that all techniques agreed with our known values within expected limits except for charcoal adsorbers. As a group, charcoal adsorbers were biased 16 percent above the known values in the performance test. This was puzzling since, in previous rounds (conducted in a different chamber), charcoal adsorbers were biased 6-8 percent below the known values.

Since the conclusion of Round 4, EERF staff have spent several months evaluating this shift in charcoal adsorber response by performing chamber tests using our own charcoal adsorbers. We have examined several potential radon chamber problems (for example, the possibility of non-uniform distribution of radon in our chamber under conditions of heavy charcoal loading, etc.) and have demonstrated that none of these potential problems was present in our chamber during Round 4 to adversely affect charcoal adsorber response. We believe that the 16 percent high bias of charcoal adsorbers during the performance test in Round 4 and the shift from a negative to positive bias between Rounds 3 and 4 is the synergistic combination of several factors which will be described in a forthcoming EPA report and/or article to be submitted to the *Health Physics* Journal.

We believe that one of these factors is not well recognized and is of particular importance to the users of open-faced (no diffusion barrier) charcoal adsorbers. During our charcoal adsorber testing in the past few weeks, we have obtained data that indicates that, at a constant temperature, relative humidity and radon concentration, the air velocities in the vicinity of certain open-faced charcoal adsorbers significantly affect the response. For example, in one series of two-day tests, charcoal adsorbers exposed under dormant air conditions agreed within five percent with our continuous radon monitors (most of the time they agreed within one percent); at a velocity of ~ 50 feet per minute the same type adsorbers were biased 16 percent high; at a velocity of ~ 100 feet per minute, 23 percent high; and at ~ 200 feet per minute, 27 percent high. A member of our staff measured air velocities of ~ 50 feet per minute or more at points in his own home where charcoal canisters could be placed.

We believe that organizations performing radon tests, at least those using open-faced devices where the charcoal is exposed directly to the air being monitored, should begin testing their devices to determine the effect of air velocity on their charcoal adsorber response. If a sensitivity to air flow is noted, continued home testing using these devices should be done in strict conformance with EPA protocols which require testing in areas with minimal or no drafts.

At the time of this writing, we are preparing a letter, discussing our preliminary findings, for transmittal to RMP charcoal adsorber participants. We have already discussed, informally, our findings with officials of the American Association of Radon Scientists and Technologists, Inc. We will appreciate your publishing this note in the Health Physics *Newsletter* to alert other interested parties.

Charles R. Porter
Director, EERF
Montgomery, Alabama

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RADIATION PROGRAMS
Eastern Environmental Radiation Facility
1890 Federal Drive, Montgomery, AL 36109
(205) 272-3402 • FTS 534-7615

February 25, 1988

Dear RMP Participant:

Round 4 of the EPA Radon Measurements Proficiency Program (RMP) was conducted at EPA's Eastern Environmental Radiation Facility (EERF) in Montgomery, AL during April-June 1987. During Round 4 the EERF tested 4 radon measurement techniques (charcoal adsorbers, alpha track detectors, grab radon monitors, continuous radon monitors) and 3 radon progeny measurement techniques (RPISU's, grab radon progeny monitors and continuous radon progeny monitors). The total number of methods tested was approximately 500 in the performance test. Following Round 4, EERF staff statistically analyzed the collective performance for each of these seven measurement techniques and found that all techniques agreed with our known values within expected limits except for charcoal adsorbers. As a group, charcoal adsorbers were biased 16 percent above the known values in the performance test. This was puzzling since, in previous rounds (conducted in a different chamber), charcoal adsorbers were biased 6-8 percent below the known values.

Since the conclusion of Round 4, EERF staff have spent several months evaluating this shift in charcoal adsorber response by performing chamber tests using our own charcoal adsorbers. We have examined several potential radon chamber problems (for example, the possibility of non-uniform distribution of radon in our chamber under conditions of heavy charcoal loading, etc.) and have demonstrated that none of these potential problems were present in our chamber during Round 4 to adversely affect charcoal adsorber response. We believe that the 16 percent high bias of charcoal adsorbers during the performance test in Round 4 and the shift from a negative to positive bias between Rounds 3 and 4 is the synergistic combination of several factors which may include: participants arbitrarily adjusting calibration factors; bias in a chamber used to calibrate participant's charcoal adsorbers; inadequate calibration for differing humidities for certain charcoal adsorbers; and perhaps most importantly, certain charcoal adsorbers having a response sensitivity which varies with air velocity. These factors and others which we tested and ruled out will be discussed in more detail in a forthcoming EPA report.

We believe that the velocity effect is not well recognized and is of particular importance to the users of open-faced (no diffusion barrier) charcoal adsorbers. During our charcoal adsorber testing in the past few weeks, we have obtained data which indicates that, at constant temperature, relative humidity and radon concentration, the air velocities in the vicinity of open-faced charcoal adsorbers of the EPA design significantly

affect the response. For example, in one series of 2-day tests, charcoal adsorbers exposed under dormant air conditions agreed within 5 percent with our continuous radon monitors (most of the time they agreed within 1 percent); at a velocity of ~ 50 feet per minute the same type adsorbers were biased 16 percent high; at a velocity of ~ 100 feet per minute, 23 percent high; and at ~ 200 feet per minute, 27 percent high. During RMP Round 4, air velocities at some locations within EERF's big radon chamber were on the order of 50 feet per minute. EPA has determined that air velocities of 50 feet per minute or more occur in homes with forced air heating and/or cooling systems.

We believe that organizations performing charcoal adsorber tests, at least those using open-faced devices similar to the EPA design where the charcoal is exposed directly to the air being monitored, should begin testing their devices to determine the effect of air velocity on their charcoal adsorber response. If a sensitivity to air flow is noted, continued home testing using these devices should be done in strict conformance with EPA protocols which require testing in areas with minimal or no drafts.

We hope that the information in this letter will be helpful to RMP participants enrolled to test charcoal adsorbers. The EERF staff would be interested in learning the results of testing conducted by other organizations regarding the effects of air velocity on their charcoal adsorber response.

Sincerely,

J. Michael Smith

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