EML-568

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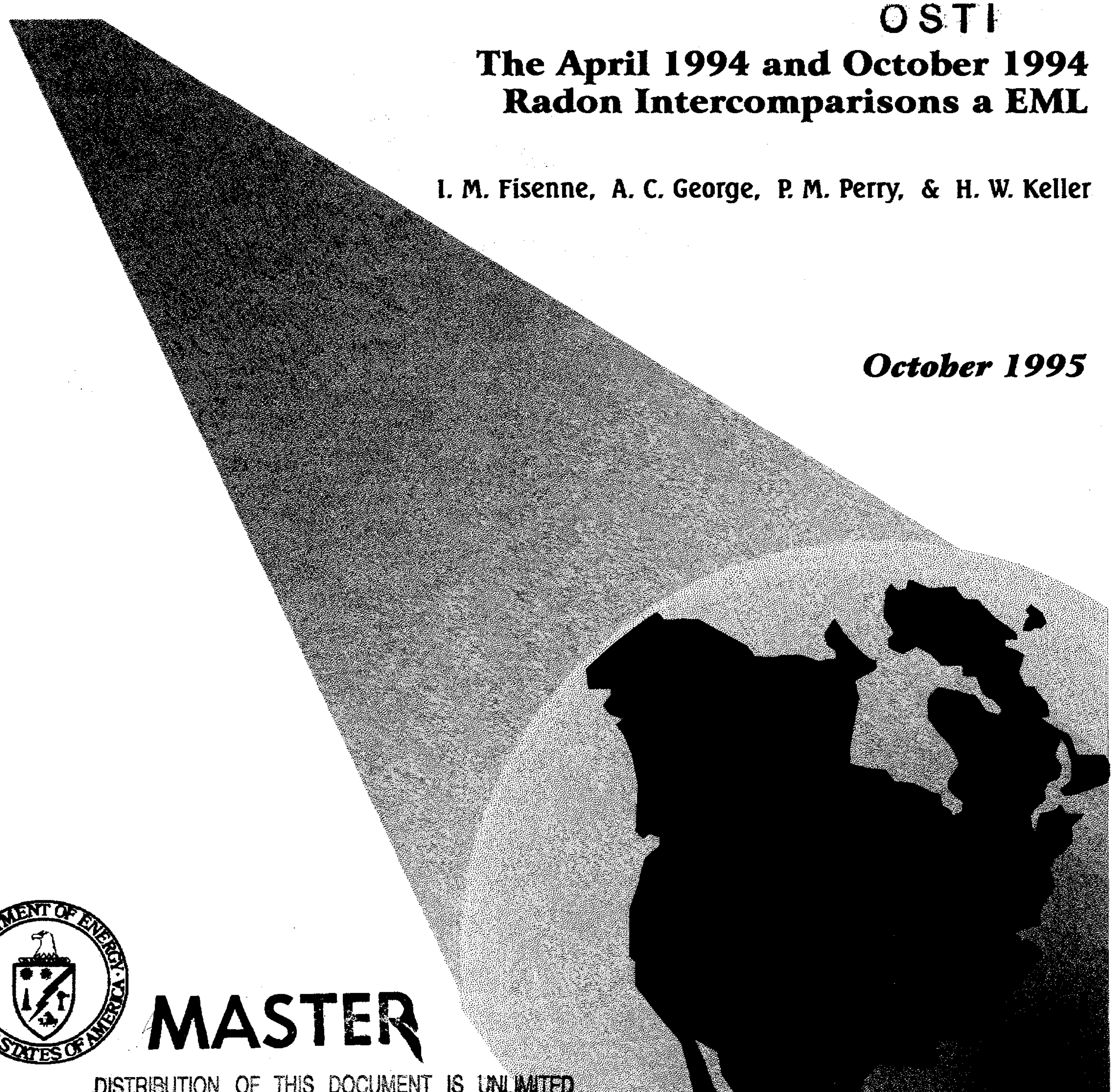

The April 1994 and October 1994 Radon Intercomparisons a EML

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THE APRIL 1994 AND OCTOBER 1994 RADON INTERCOMPARISONS AT EML

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October 1995

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ABSTRACT

The two Calendar Year 1994 radon gas intercomparison exercises were conducted in the EML exposure chamber. Thirty-two groups including U. S. Federal facilities, USDOE contractors, national and state laboratories, universities and foreign institutions participated in these exercises. The majority of the participants' results were within ±10% of the EML value at radon concentrations of 570 and 945 Bq m^{-3}.

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INTRODUCTION

Quality assurance/quality control (QA/QC) are the backbone of many commercial and research processes and programs. QA/QC research tests the state of a functioning system, be it the production of manufactured goods or the ability to make accurate and precise measurements. The quality of the radon measurements in the U.S. have been tested under controlled conditions in semi-annual radon gas intercomparison exercises sponsored by the Environmental Measurements Laboratory (EML) since 1981.

The reputation of EML as a premier laboratory in QA/QC methodology and environmental radon, progeny and aerosol measurements has attracted 76 groups, including 11 foreign institutions, to participate in our exercises. A list of the participants is given in Appendix 1.

The effectiveness of the EML radon gas intercomparisons and the practical assistance extended by the EML staff to participants has been demonstrated at both the national and international levels through various intercomparisons. For example, Hutchinson *et al.* (1992) reported on an international radon-in-air intercomparison. Ten well-respected laboratories in the field of radon measurements were invited to participate by the U.S. Department of Commerce, National Institute of Standards and Technology (NIST). Six were U.S. facilities, one Australian laboratory and three European laboratories. All, including NIST, had close ties to EML and had intercompared on both a formal and informal basis in the past. The results showed a ratio to the NIST expected value ranging from 0.99 to 1.07. This agreement was good considering the experimental nature of the NIST radon transfer samples.

A similar intercomparison was organized by the National Physical Laboratory (NPL), UK in 1992, which includes EUROMAT (a European Collaboration in Metrology), and NIST (Dean and Burke, 1994). Thirteen laboratories, including NPL and NIST from 11 countries participated. Ten laboratories reported results, and the ratio to the NPL value ranged from 0.8 to 1.2. The intercomparison was deemed a success "in providing an overall picture of ^{222}Rn metrology in European laboratories." It appears that increased emphasis on intercomparisons and QC procedures will be necessary to place the U.S. and European programs on an equal footing.

Clearly, the U.S. efforts in QA/QC, supported by OHER, have demonstrated measurement capabilities across all sectors of the radon measurement community. Performance of OHER contractors outside of expected bounds, usually $\pm$10% for radon gas measurements, has been identified to the program managers for possible action. The QA/QC linkage has provided added value to the measurement databases accumulated over the past 15 years.

The present report summarizes the results of the 25th and 26th radon gas intercomparison exercises and is the eleventh in this series (Fisenne et al., 1981; 1983; 1985a; 1985b; 1987; 1988; 1990a; 1992; 1993; 1994).

THE EML RADON/AEROSOL CALIBRATION FACILITY

Construction of the new walk-in radon/aerosol chamber began in 1993. The primary uses of the chamber are as a research tool in radon, thoron, progeny and aerosol studies, and for QA/QC intercomparisons of these substances. A full description of the chamber, including drawings, and ancillary monitoring equipment will appear in next update of the EML Procedures Manual under the subcategory "Special Facilities".

Briefly, the rectangular chamber (3.1 x 3.83 x 2.59 m interior dimensions) has a volume of 30.75 m^3. There are a separate mixing room for dilution of radon gas prior to introduction into the main chamber (3.5 m^3) and an anteroom for transfer of instruments in and out of the main chamber (5.8 m^3). Two windows allow viewing of the chamber interior. Ten sampling ports into the main chamber are located 1 m above the floor. The interior surfaces of the chamber are stainless steel and exterior surfaces are enamelled aluminum. Several personnel safety features have also been included in the chamber design.

The radon and thoron gases are obtained from sealed commercially available ^{226}Ra and ^{228}Th sources. Radon concentrations can be produced over the range of 100 to 5000 Bq m^{-3} and thoron over the range of 50 to 5000 Bq m^{-3}. The dynamic range for temperature is 5 to 40°C and humidity, dewpoint -10°C temperature to 95%. The main chamber is nearly particle free (<50 particles cm^{-3}), permitting a progeny equilibrium factor range from 0.01 to 0.5. Aerosol generation systems can provide concentrations of $>10^5$ particles cm^{-3}.

The primary measurements of radon gas at EML are performed in the EML pulse ionization chambers (PICs). These chambers, their calibration and maintenance methodology have been described in two publications (Fisenne and Keller, 1985c; Fisenne et al., 1990b), as well as in the EML Procedures Manual.

SAMPLER CHECKS AT EML

Prior to Filling with an Elevated Radon in Air Concentration

The checks performed on samplers received at EML were last described in full in 1987 and have basically remained unchanged. They are summarized here for the convenience of the reader.

Each participant is requested to send no more than four samplers for filling during the intercomparison. The majority of samplers received at EML for radon gas intercomparisons are scintillation cells. These ZnS(Ag) coated containers range from large volume (1.4 L) metal bodied, plastic faced cells to small (<0.06 L) all plastic cells to 0.5 L glass soda bottles. The scintillation cells may have one or two valves, designated in type as evacuated or flow through cells. The single valved cells are generally of small volume (<0.15 L). The flow through cells are made of either metal or plastic construction, and usually have a volume of >0.3 L. Other containers are metal flasks, gas cylinders and evacuated aerosol cans.

The trend over the last few years among the EML intercomparison participants has been to purchase and use commercially available metal body, glass faced scintillation cells. The majority of these cells are of the flow through type, i.e., two valves. Quick connect fittings are less favored on newer scintillation cells because of their difficulty in handling. In any scintillation cells, the area most likely to produce leaks is the body to face seal. A high integrity seal is most difficult to obtain with dissimilar materials, for example, glass to metal bonding. Leak-tight scintillation cells are available from at least one commercial vendor.

When it is deemed that no damage to a sampler will occur, scintillation cells and metal flasks are evacuated to 0.13 kPa (1 mm of Hg), stored for 24 to 48 h and the pressure in the vessel measured to determine the leakage rate. A significant leakage rate, most often to atmospheric pressure, could present problems during return air freight shipments.

After Filling with an Elevated Radon in Air Concentration

After filling the sampler in the radon calibration chamber (procedure described below), scintillations cells are stored for 3 h prior to measurement on 12.7- cm diameter photomultiplier tube systems. It is assumed that the sampler set from a particular facility is matched for background count rate and detection efficiency. Each cell is then measured for 5 min as an indication that it has been filled with an elevated radon concentration.

SAMPLER FILLING PROCEDURE

EML radon intercomparisons are planned for Mondays to minimize transportation delivery difficulties and to avoid burdening the participants with weekend deliveries.

The Friday prior to the filling date, all samplers are placed in the EML radon calibration chamber. Single valve scintillation cells and metal flasks are evacuated to 0.13 kPa. Air is pulled through flow through samplers connected in series.

On the filling date, the single valve scintillation cells and metal flasks are evacuated to 0.13 kPa and opened to the chamber atmosphere. The evacuation/opening procedures are repeated twice more. The cells and flasks are evacuated once more prior to the final filling. This ensures a complete filling of the cell with the elevated radon atmosphere in the chamber, even if a cell leaks significantly.

The final filling takes place over a period of about 15 min. Generally there are 120 to 150 samplers in the chamber, the majority being of the flow- through type which are set up in trains of four samplers each. Evacuated scintillation cells and metal flasks are opened to the chamber atmosphere. For flow-through samplers, the chamber air is pulled through the scintillation cell and metal flask serial trains for 5 min. More than 10 times the volume of each flow through sampler train is drawn through with low flow rate pumps (4 L min^{-1}). Precautions are taken to ensure a turbulent flow pattern through the sampler trains. Laminar flow would result in an incomplete filling of the sampler with the radon atmosphere. When the last flow-through train has been filled, each sampler is closed and all samplers are removed from the chamber. If possible the scintillation cells are measured individually prior to return shipment. All samplers are dispatched to the parent facility by 5 p.m. EST on the filling day.

REPORT FORMAT

The results of each intercomparison exercise are documented in three tables and one figure. The first table lists the participants' affiliations, a description of their samplers (including materials of construction, volume capacity, method of filling and availability for purchase) and an identification of the detection system for the radon gas.

The second table lists the individual PIC measurements, each accompanied by a 1s Poisson error term. The EML reference radon concentration is the mean and standard deviation (SD) of the PIC measurements. This table includes measurements performed at EML with scintillation cells. The EML scintillation cell data are treated as one participant. The data are viewed as indicative of the performance possible with this type of collector/detector. It is also a QA/QC effort at EML to document the performance of the scintillation cells which are used to determine the radon concentrations for other intercomparisons and research programs conducted in the EML radon calibration chamber.

The third table summarizes the data from all the participants. Although EML requests that the results obtained for each sampler be reported separately and a 1s Poisson error accompany each result, space considerations have led to the development of this compressed tabulation. Column 1 identifies the EML measurements by PIC and scintillation cells and the participants by coded number. Column 2 states the number of samplers filled for the individual participant. Column 3 gives the number of reported results which were accepted for inclusion in the report. Column 4 notes the range, i.e., minimum and maximum, of the reported concentrations. Column 5 shows the 1s Poisson error term expressed as a percentage. It has been our experience that the Poisson error tends to be the same for all the accepted values from a participant. Column 6 is mean and SD of each participant's individual values. This is calculated for comparison with the reference mean and the means obtained by the other participants. Column 7 is the ratio and the error of the ratio of each participant's mean to the EML PIC reference mean. The error of the ratio is propagated from the means and SDs of the participant and EML. The figure is a graphical presentation of column 7, i.e., the ratio and error of the ratio to the EML PIC reference value.

TWENTY-FIFTH RADON INTERCOMPARISON EXERCISE

The 25th radon intercomparison exercise drew 27 participants. The list of participants is given in Table 1. The mean radon concentration results obtained at EML for Two samplers measured in the PIC was 570 ± 12 Bq m^{-3} and 566 ± 5 Bq m^{-3}, for four scintillation cells. The individual results for the EML samplers are given in Table 2.

The reported results of the participants are shown in Table 3. The ratios of the reported mean values to the EML PIC mean value are depicted in Figure 1.

Twenty-one of the 27 participants (78%) reported mean radon concentration values within ±10% of the PIC value. All the reported means were within ±25% of the PIC value.

TWENTY-SIXTH RADON INTERCOMPARISON EXERCISE

Twenty-six groups (Table 4) participated in the 26th radon intercomparison exercise. The radon concentration determined from 18 samplers measured in the PIC was 945 ± 15 Bq m^{-3}, and 935 ± 29 Bq m^{-3} for four scintillation cell measurements. The complete EML measurement data are given in Table 5.

The participants' reported results are summarized in Table 6, and the ratios to the EML PIC value depicted graphically in Figure 2. Twenty-four groups (79%) were within ±10% of the EML PIC value and 96% of the groups were within ±25% of this value.

INTERCOMPARISON EXERCISES SUMMARY

A summary of the number of participants, radon calibration chambers conditions and the results reported from the 26 radon gas intercomparison exercises is given in Appendix 3.

The graphical representation of the 1981 through 1994 summaries is shown in Figure 3.

DISCUSSION

The need for documented QA/QC performance data is a continuous process, its value most often is in retrospective evaluations. This has been demonstrated in numerous cases, such as the reconstruction of the radiation doses to the U.S. population from fallout. Not only did a database exist to be mined but it also had an integral QA/QC component for data validation.

The 25th and 26th radon intercomparison exercises followed previous patterns in which the majority of the groups were within $\pm 10\%$ of the EML value. There was still one spectacular outlier, demonstrating the need for some form of independent QA/QC evaluation.

We were particularly pleased to have the participation of the Czech Reference Laboratory for Radon and Daughters, Milin, Czech Republic and the National Atomic Energy Commission, Buenos Aires, Argentina, as well as our Canadian and Swiss colleagues. This reflects the continued appreciation of the scientific community for the QA/QC programs performed at EML for OHER.

The utility of the EML intercomparisons in providing validation of field exposure measurements may soon come into play on an international basis. Recently, Dr. Jaak Sinnaeve of the Commission of the European Communities, Brussels, Belgium, gave a seminar at EML entitled "The Future of Radiation Protection in the European Community." This ambitious coordinated plan includes an environmental dosimetry component. Radon is an important sub-set of this component which includes sources, pathways and countermeasures. The European action level for radon is set at 400 Bq m^{-3}, a factor of 2.7 greater than the U. S. Environmental Protection Agency's action level of 150 Bq m^{-3}. In conjunction with radiobiological studies of the physico-chemical properties of aerosols and the identification of cells at risk in the respiratory tract for the induction of lung cancer, an epidemiological study is under way in the Ardennes region. The study includes 3500 lung cancers with 10^4 to 1.2×10^4 controls. Yet this study group and the controls are insufficient to affirm or disprove a link between elevated environmental radon exposures and disease. To increase the power of the statistical test, the Ardennes study will be pooled with the U.S. database. Both databases must have validated exposure information for the collaborative effort to prove effective in its task.

We believe that the EML efforts in QA/QC for radon and progeny has provided independent, documented evidence of the validity for the U.S. database. The 1994 radon intercomparisons, while on the whole indicating most analyses are within acceptable limits, still point out the need to continue the program and to coordinate our QA/QC efforts with our European colleagues. This is especially true since validation information must be collected contemporaneously with field measurements. It is also necessary to document the validation information so that at sometime in the future a database can be used with confidence.

OHER has been a leader in the recognition of the requirement of a strong QA/QC program and has been generous in its support of the EML efforts. This confidence will be brought to bear in joint U.S.-European studies.

ACKNOWLEDGMENTS

Many EML staff members provide essential services that make these intercomparison exercises successful. The authors wish to express their appreciation to:

Kevin Clancy, Administrative Branch - receipt, dispatch, parcel control and telephone inquires

William Jackson and Arnold Boyd, Storeroom - packing and dispatch of the sampler packages

Camille Marinetti, Applied Mathematics Branch - graphical presentations.

Irvin Haskell, Instrumentation Division - maintenance of the pulse ionization chamber systems.

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Table 1

Participants in the April 18, 1994 RADON INTERCOMPARISON EXERCISE

Facility	Sampler type, volume filling method, availability	Detection System
EML	Metal flasks, 0.08 and 0.16 L, flow-through or evacuated, I	PIC
EML	Metal SC, 0.5 L, flow-through, C	PMT
A' Testing Company, Inc., Evergreen, CO	Glass SC, 0.3 L, flow-through, I	
Argonne National Laboratory, Analytical chemistry Division, Argonne, IL	Aerosol cans, 0.5 L, evacuated, C, transfer to SC	PMT
Atomic Energy of Canada, Ltd., Waste Management Office Port Hope, Ontario, Canada	Metal SC, 0.3 L, flow-through, C	PMT
Bowser-Morner, Radiological Services Div., Dayton, OH	Metal SC, 0.5 L, flow-through, C	PMT
Clarkson University Department of Chemistry Potsdam, NY	Metal SC, 0.19 L, flow-through, C	PMT
Commonwealth of Pennsylvania Dept. of Environmental Resources, Harrisburg, PA	Metal SC, 0.30 L, flow-through, C	PMT
GEOMET Technologies, Inc., Germantown, MD	Metal SC, 0.32 L, flow-through, C	PMT
Health and Welfare, Bureau of Radiation and Medical Devices, Ottawa, Ontario, Canada	Metal SC, 0.16 L, flow-through, C	PMT
Infiltec, Falls Church, VA	Metal SC, 0.30 L, flow-through, C	PMT
Lawrence Berkeley Laboratory, Applied Science Division, Berkeley, CA	Metal SC, 0.1 L, flow-through, C	PMT
Maryland Radon Laboratory Columbia, MD	Metal SC, 0.32 L, evacuated, I	PMT
New Mexico Institute of Mining and Technology, Dept. of Physics, Socorro, NM	Metal SC, 0.1 L, evacuated, C Metal SC, 0.1 L, evacuated, C	PMT
New York University School of Medicine New York, NY	Plastic SC, 1.4 L, flow-through, I	PMT

Table 1 (Cont'd)

Facility	Sampler type, volume filling method, availability	Detection System
Rust Geotech Grand Junction, CO	Plastic SC, 0.5 L, flow-through, C	PMT
State of New York, Center for Environmental Health, Albany, NY	Metal SC, 0.2 L, flow-through, C	PMT
State of New York, Wadsworth Center for Laboratories and Research, Albany, NY	Metal SC, 0.13 L, evacuated, C	PMT
Swedish Radiation Protection Institute, Environmental Lab, Stockholm, Sweden	Metal flask, 4 L, evacuated, C	AS
TCS Industries, Harrisburg, PA	Metal SC, 0.32 L, flow-through, C	PMT
Tech/Ops Landauer, Inc. Glenwood, IL	Metal SC, 0.38 L, evacuated, C	PMT
TMA/Eberline, Oak Ridge, TN	Plastic SC, 0.5 L, flow-through, C	PMT
USDI, Geological Survey, Office of Energy & Marine Geology, Denver, CO (USGS1)	Metal SC, 0.19, 0.21, 0.3 L, flow-through, C	PMT
USDI, Geological Survey, Office of Engergy & Marine Geology, Denver, CO (USGS2)	Metal SC, 0.19 L, flow-through, C	PMT
USEPA, National Air & Radiation Environmental Laboratory, Montgomery, AL	Metal SC, 0.13 L, evacuated, C	PMT
USEPA, Office of Radiation Programs, Las Vegas, NV	Metal SC, 0.38 L, evacuated, C	PMT
University of Florida, Nuclear Science Center, Gainsville, FL	Metal SC, 0.30L, flow-through, C	PMT
Wilkes University, School of Science	Metal SC, 0.32, flow-through, C	PMT

Notes:

AS = alpha spectrometry in a reference volume chamber
C = commercially available
I = in-house construction
PIC = pluse ionization chamber
PMT = photomultiplier tube
SC = scintillation cell

Table 2

EML RADON CONCENTRATION RESULTS FOR INDIVIDUAL SAMPLERS

Reference Date – April 18, 1994
Reference Time – 0630 EST

Measurement date	Sampler Type	Sampler Volume (L)	Detection System	Concentration ±SD[b] (Bq ^{222}Rn m^{-3})
4/18/94	Metal flask	0.08	PIC	587 ± 9
				580 ± 9
				579 ± 9
				585 ± 9
				550 ± 9
	Metal flask	0.16	PIC	579 ± 6
				570 ± 6
				576 ± 6
				562 ± 6
4/19/94	Metal flask	0.08	PIC	579 ± 9
				564 ± 10
				567 ± 10
				585 ± 10
	Metal flask	0.16	PIC	564 ± 6
				568 ± 6
				574 ± 6
				570 ± 6
				587 ± 7
4/20/94	Metal flask	0.08	PIC	567 ± 10
				551 ± 10
	Metal flask	0.16	PIC	554 ± 7
				560 ± 7
			n	22
			Mean	570
			SD	12
			SE	2
			Median	570
4/18/94	Metal scintillation cells	0.5	PIC	567 ± 12
				559 ± 12
				567 ± 12
				570 ± 12

Table 3

SUMMARY OF THE REPORTED RADON CONCENTRATIONS FOR THE TWENTY-FIFTH INTERCOMPARISON EXERCISE

Reference Date – April 18, 1994

Facility Code No.	No. of samplers filled	No. of results accepted	Range (Bq ^{222}Rn m^{-3})	Relative SD of a single measurement (%)	Mean ± SD (Bq ^{222}Rn m^{-3})	Ratio Facility Mean / EML Mean
EML-PIC	22	22	550 - 587	2	570 ± 12	—
EML-SC-01	4	4	559 - 570	2	566 ± 4	0.99 ± 0.02
02	4	4	577 - 608	13	597 ± 14	1.05 ± 0.03
03	4	4	609 - 681	24	648 ± 31	1.13 ± 0.06
04	4	4	585 - 805	4	734 ± 101	1.29 ± 0.18
05	4	4	554 - 598	6	579 ± 20	1.02 ± 0.04
06	4	4	551 - 569	4	560 ± 9	0.98 ± 0.03
07	4	4	542 - 563	2	552 ± 9	0.97 ± 0.03
08	4	4	589 - 660	3	624 ± 29	1.09 ± 0.06
09	3	3	540 - 552	1	545 ± 6	0.96 ± 0.02
10	4	4	461 - 536	3	498 ± 39	0.87 ± 0.07
11	4	4	489 - 525	2	512 ± 16	0.90 ± 0.03
12	4	4	539 - 548	4	545 ± 4	0.96 ± 0.02
13	4	4	574 - 625	1	599 ± 25	1.05 ± 0.05
14	4	4	564 - 600	2	588 ± 16	1.03 ± 0.04
15	4	4	667 - 732	3	683 ± 33	1.20 ± 0.06
16	4	4	530 - 554	6	540 ± 12	0.95 ± 0.03
17	4	4	581 - 618	7	600 ± 18	1.05 ± 0.04
18	4	3	577 - 634	4	605 ± 23	1.06 ± 0.05
19	4	4	488 - 648	9	560 ± 70	0.98 ± 0.12

Table 3 (Cont'd)

Facility Code No.	No. of samplers filled	No. of results accepted	Range (Bq ^{222}Rn m^{-3})	Relative SD of a single measurement (%)	Mean ± SD (Bq ^{222}Rn m^{-3})	Ratio Facility Mean / EML Mean
20	4	4	552 - 579	4	560 ± 13	0.98 ± 0.03
21	4	4	551 - 579	2	563 ± 12	0.99 ± 0.03
22	4	4	568 - 580	4	574 ± 6	1.01 ± 0.02
23	4	NR*	598	NR	598	1.05
24	4	4	450 - 550	6	495 ± 42	0.87 ± 0.08
25	4	4	540 - 562	1	552 ± 10	0.97 ± 0.03
26	4	4	563 - 615	7	588 ± 24	1.03 ± 0.05
27	4	4	492 - 507	4	501 ± 6	0.88 ± 0.02
				n	27	27
				Mean	577	1.01
				SD	54	0.09
				SE	10	0.02
				Median	566	0.99

* Not reported

Table 4

PARTICIPANTS IN THE OCTOBER 31, 1994

Facility	Sampler type, volume filling method, availability	Detection System
EML	Metal flasks, 0.08 and 0.16 L, flow-through or evacuated	PIC
EML	Metal SC, 0.5 L, flow-through, C	PMT
A' Testing Company, Inc. Evergreen, CO	Glass SC, 0.3 L, flow-through, C	PMT
Argonne National Laboratory, Analytical Chemistry Division, Argonne, IL	Aerosol cans, 0.5 L, evacuated, C, transfer to SC	PMT
Atomic Energy of Canada, Ltd. Waste Management Office Port Hope, Ontario, Canada	Metal SC, 0.3 L, flow-through, C	PMT
Bowser-Morner, Radiological Services Div., Dayton, OH	Metal SC, 0.5 L, flow-through, C	PMT
Clarkson University, Dept. of Chemistry, Potsdam, NY	Metal SC, 0.19 L, flow-through, C	PMT
Colorado State University Dept. Radiological Health Science, Fort Collins, CO	Metal SC, 0.5 L, flow-through, C	PMT
Commonwealth of Pennsylvania Dept. of Environmental Resources, Harrisburg, PA	Metal SC, 0.30 L, flow-through, C	PMT
Czech Reference Laboratory for Radon and Daughters, Milin, Czech Republic	Metal SC, 0.12 L, evacuated, I	PMT
GEOMET Technologies, Inc. Germantown, MD	Metal SC, 0.32 L, flow-through, C	PMT
Health and Welfare, Env. Radiation Hazards Division Ottawa, Ontario, Canada	Metal SC, 0.16 L, flow-through, C	PMT
Infiltec Falls Church, VA	Metal SC, 0.30 L, flow-through, C	PMT
Maryland Radon Laboratory Columbia, MD	Metal SC, 0.32 L, flow-through, C	PMT
National Atomic Energy Comm. NRB, Buenos Aires, Argentina	Glass SC, 0.25 L, evacuated, I	PMT

Table 4 Cont'd

Facility	Sampler type, volume filling method, availability	Detection System
New York University School of Medicine New York, NY	Plastic SC, 1.4 L, flow-through, I	PMT
Rust Geotech Grand Junction, CO	Plastic SC, 1.4 L, evacuated, I	PMT
Paul Scherrer Institute Radiation Hygiene Division Wurenlingen/Villigen, Switz.	Metal SC, 0.32 L, flow-through, C	PMT
Pylon Electronic Development Co., Ltd., Ottawa, Ontario, Canada	Metal SC, 0.3 L, flow-through, C	PMT
St. John's University Dept. of Physics Collegeville, MD	Metal SC, 0.32 L, flow-through, C; Plastic SC, 0.07 L, flow-through, I	PMT
State of New York Center for Environmental Health Albany, NY	Metal SC, 0.2 L, flow-through, C	PMT
State of New York, Wadsworth Center for Laboratories & Research, Albany, NY	Metal SC, 0.13 L, evacuated, C	PMT
TCS Industries Harrisburg, PA	Metal SC, 0.3 L, flow-through, C	PMT
Tech/Ops Landauer, Inc. Glenwood, IL	Metal SC, 0.38 L, evacuated, C	PMT
TMA/Eberline Oak Ridge, TN	Plastic SC, 0.5 L, flow-through, C	PMT
USEPA, Nat'l. Air & Radiation Environmental Laboratory Montgomery, AL	Metal SC, 0.13 L, evacuated, C	PMT
USEPA, Office of Radiation Programs, Las Vegas, NV	Metal SC, 0.38 L, evacuated, C	PMT
Wilkes University, School of Science and Engineering Wilkes-Barre, PA	Metal SC, 0.32 L, flow-through, C	PMT

Notes:

AS = alpha spectrometry in a reference volume chamber
C = commercially available
I = in-house construction
PIC = pulse ionization chamber
PMT = photomultiplier tube
SC = scintillation cell

Table 5

EML RADON CONCENTRATION RESULTS FOR INDIVIDUAL SAMPLERS

Reference Date — October 31, 1994
Reference Time — 0715 EST

Measurement Date	Sampler Type	Sampler* Volume (L)	Detection System	Concentration ± Sd** (Bq ^{222}Rn m^{-3})
10/31/94	Metal flask	0.08	PIC	954 ± 11
				948 ± 11
				928 ± 11
				921 ± 14
	Metal flask	0.16	PIC	925 ± 7
				944 ± 8
				946 ± 9
				974 ± 9
				947 ± 8
11/01/94	Metal flask	0.08	PIC	952 ± 14
				965 ± 11
				971 ± 11
				940 ± 11
				950 ± 11
				955 ± 12
	Metal flask	0.16	PIC	949 ± 8
				930 ± 8
				954 ± 9
			n	18
			Mean	945
			SD	15
			SE	3
			Median	950
10/31/94	Metal scintillation cell	0.5	PMT	907 ± 18
				925 ± 19
				933 ± 18
				976 ± 19

* All samples were filled by flow-through of the air
** All samples were corrected to the reference date and time

Notes:

PIC = pulse ionization chambers
PMT = photomultiplier tube
n = number of observations
SD = standard deviation

Table 6

SUMMARY OF THE REPORTED RADON CONCENTRATIONS FOR THE TWENTY-SIXTH INTERCOMPARISON EXERCISE

Reference Date - October 31, 1994

Facility Code No.	No. of samplers filled	No. of results accepted	Range (Bq ^{222}Rn m^{-3})	Relative SD of a single measurement (%)	Mean ± SD (Bq ^{222}Rn m^{-3})	Ratio Facility Mean / EML Mean
EML–PIC	18	18	921 - 994	1	945 ± 15	—
EML–SC–01	4	4	907 - 976	2	935 ± 29	0.99 ± 0.03
02	4	4	955 - 993	1	968 ± 18	1.02 ± 0.03
03	3	3	901 - 904	3	902 ± 2	0.95 ± 0.02
04	4	4	896 - 919	3	911 ± 10	0.96 ± 0.02
05	4	4	939 - 986	4	964 ± 20	1.02 ± 0.03
06	4	4	896 - 940	3	923 ± 19	0.98 ± 0.03
07	4	4	796 - 884	6	838 ± 39	0.89 ± 0.04
08	4	4	866 - 884	5	874 ± 8	0.92 ± 0.02
09	4	4	903 - 1009	9	965 ± 55	1.02 ± 0.06
10	4	2	770 - 848	7	809 ± 55	0.86 ± 0.06
11	4	4	851 - 882	2	870 ± 19	0.92 ± 0.02
12	4	4	896 - 913	3	903 ± 7	0.96 ± 0.02
13	4	3	820 - 930	6	878 ± 48	0.93 ± 0.02
14	4	4	884 - 919	3	906 ± 16	0.96 ± 0.02
15	4	4	744 - 781	1	763 ± 15	0.81 ± 0.02
16	4	4	916 - 941	3	932 ± 11	0.99 ± 0.02
17	4	4	770 - 800	2	780 ± 10	0.83 ± 0.02
18	4	4	865 - 897	1	877 ± 14	0.93 ± 0.02
19	4	4	850 - 950	8	900 ± 70	0.95 ± 0.08
20	4	3	1018 - 1084	3	1041 ± 37	1.10 ± 0.04
21	4	4	894 - 993	3	950 ± 45	1.01 ± 0.05
22	3	3	700 - 760	6	720 ± 35	0.76 ± 0.04
23	4	3	330 - 402	3	376 ± 40	0.40 ± 0.04
24	4	4	885 - 1065	2	968 ± 74	1.02 ± 0.08

Table 6 (Cont'd)

Facility Code No.	No. of samplers filled	No. of results accepted	Range (Bq ^{222}Rn m^{-3})	Relative SD of a single measurement (%)	Mean ± SD (Bq ^{222}Rn m^{-3})	Ratio Facility Mean / EML Mean
25	4	1	960 - 1100	5	1015 ± 62	1.07 ± 0.07
26	4	4	732 - 926	8	832 ± 80	0.88 ± 0.09
				n	26	26
				Mean	877	0.93
				SD	127	0.13
				SE	25	0.03
				Median	903	0.96

25th EML RADON INTERCOMPARISON

Monday, April 18, 1994 570 Bq m-3

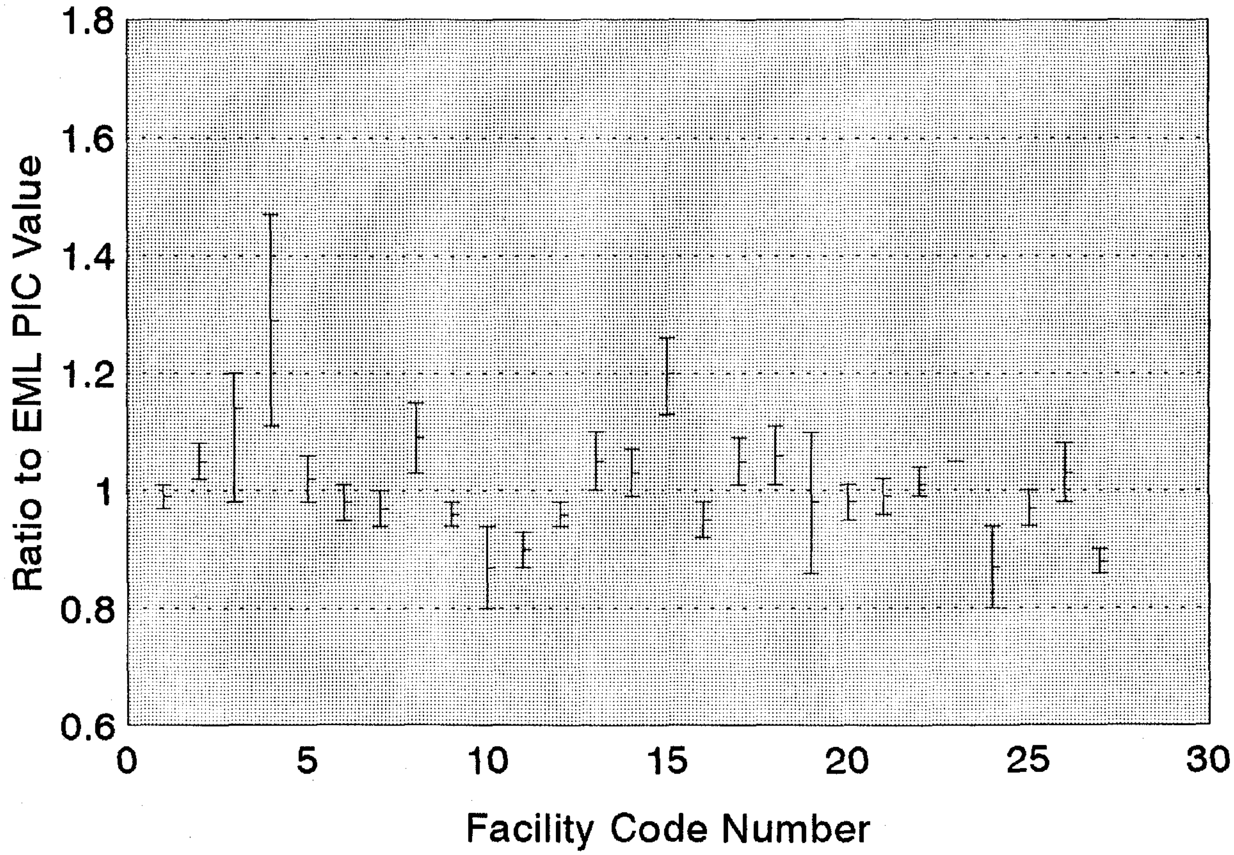

Figure 1. Ratio of the reported mean radon concentration to the mean value obtained at EML by pulse ionization chamber measurements. (The dotted lines indicate ± 10% from a ratio of one.)

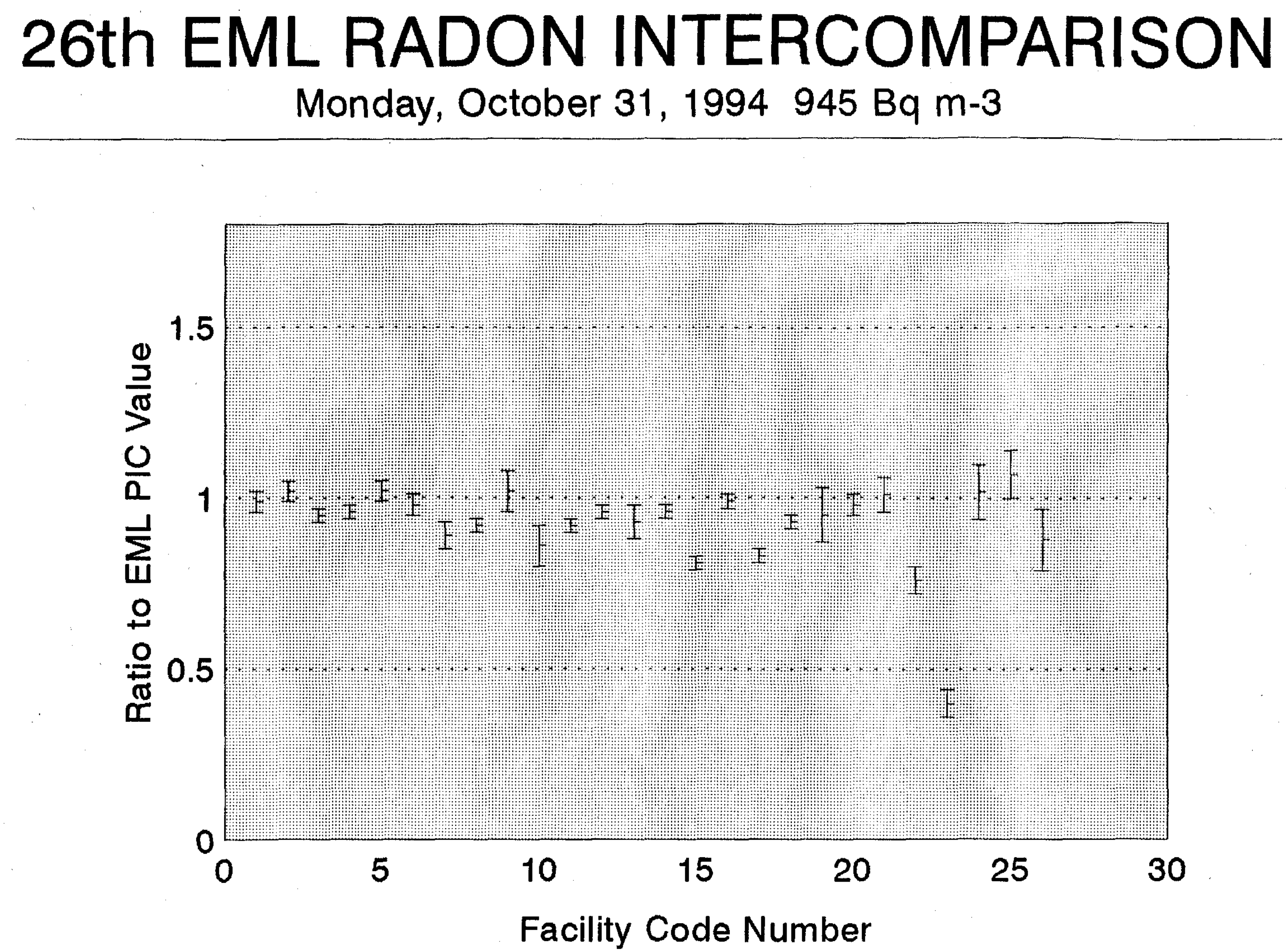

Figure 2. Ratio of the reported mean radon concentration to the mean value obtained at EML by pulse ionization chamber measurements. (The dotted lines indicate ± 10% from a ratio of one.)

EML RADON INTERCOMPARISONS

1981 through 1994

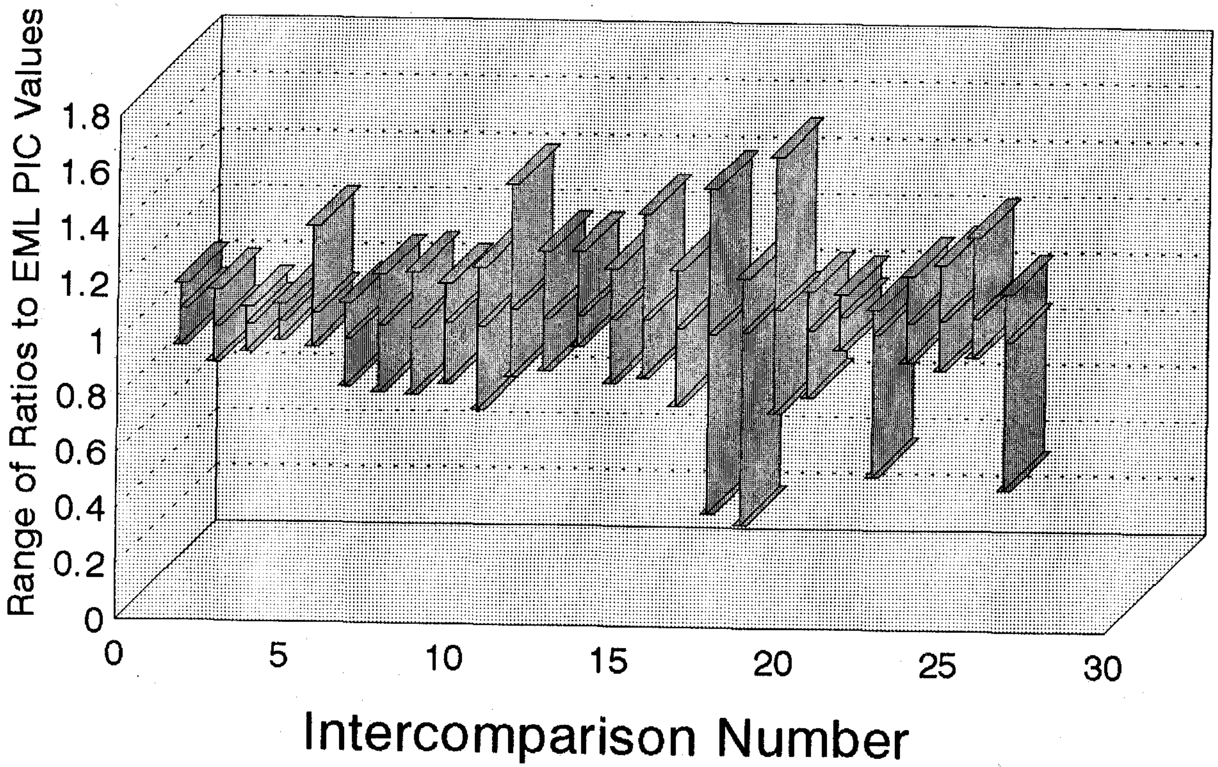

Figure 3. EML Radon Gas Intercomparisons, 1981 - 1994.

APPENDIX 1

LIST OF PARTICIPANTS IN THE EML SPONSORED RADON INTERCOMPARISON EXERCISES

A[1] Testing Company, Inc., Evergreen, CO
AIR-N-SOL Corp., Frenchtown, NJ
Argonne National Laboratory, Anal. Chem. Lab., Argonne, IL
Argonne National Laboratory, Bio. & Med. Res. Div., Argonne, IL
Atomic Energy Control Board, Ottawa, Ontario, Canada
Atomic Energy of Canada Ltd., Rad. Waste, Ottawa, Ontario, Canada
Battelle Pacific Northwest Laboratory, Edgemont, SD
Bowser-Morner, Radiological Service Div., Dayton, OH
Clarkson University, Dept. of Chemistry, Potsdam, NY (formerly UILL)
Colorado State University, Dept. Radiol. & Rad. Bio., Fort Collins, CO
Commonwealth of Pennsylvania, Dept. Env. Resources, Harrisburg, PA
Czech Reference Lab for Rn and Daughters, Milin, Czech Republic
Dames and Moore, White Plains, NY
EAL Corp., ThermoElectron Corp., Richmond, CA
ECRI, Plymouth Meeting, PA
EG&G Mound Applied Technologies, Grp. 1, Miamisburg, OH
EG&G Mound Applied Technologies, Grp. 2, Miamisburg, OH
Environmmental Radioactivity Measurements, Inc., Piermont, NY
GEOMET Technologies, Germantown, MD
Harvard University, Sch. Pub. Health, Env. Sci. & Phys., Boston, MA
Health & Welfare, Bur. Rad. & Med. Dev., Ottawa, Ontario, Canada
Honeywell/Quad Six, Inc., Ann Arbor, MI
Infiltec, Falls Church, VA
Inhalation Toxicology Research Institute, Albuquerque, NM
Institute for Radiation Protection, Neuherberg, Fed. Rep. of Germany
Lawrence Berkeley Laboratory, Applied Science Division, Berkeley, CA
Maryland Radon Laboratory, Columbia, MD
Minnesota Geological Survey, St. Paul, MN
National Atomic Energy Comm., NRB, Buenos Aires, Argentina
National Institute of Radiation Protection, Stockholm, Sweden
National Radiation Protection Board, Didcot, Oxon, UK
New Mexico Tech, Dept. of Physics, Socorro, NM
New York University, School of Medicine, New York, NY
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Paul Scheerer Institute, Wurenlingen/Villigen, SWITZ

APPENDIX 1 (Cont'd)

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Pylon Electronic Development Co., Ltd., Ottawa, Ontario, Canada
Rad Electric, Inc., Frederick, MD
Radiation Surveys, Inc., Frenchtown, NJ
Radon Inspection Service, Inc., Ridgewood, NJ
Radon QC, Santa Fe, NM
Radon Reduction and Testing, Atlanta, GA
Rust Geotech, Grand Junction, CO
Saint John's University, Dept. of Physics, Collegeville, MN
State of Illinois, Dept. of Nuclear Safety, Springfield, IL
State of Montana, Dept. of Heal. & Env. Sci., Helena, MT
State of New Jersey, Dept. of Env. Prot., Trenton, NJ
State of New York, Bur. of Env. Prot., Albany, NY
State of New York, Office of Pub. Heal., Albany, NY
State of Washington, Dept. of Heal. & Soc. Sci., Olympia, WA
Sun Nuclear Corp., Melbourne, FL
TCS Industries, Harrisburg, PA
Tech/Ops Landauer, Inc., Glenwood, IL
Teledyne Isotopes, Westwood, NJ
Tennessee Valley Authority, Western Area Rad. Lab., Muscle Shoals, AL
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TMA/Eberline, Thermo Analytical, Inc., Grp. 2 (APS), Albuquerque, NM
TMA/Eberline, Oak Ridge, TN
University of Florida, Dept. Basic Dent. Sci., Grp. 2, Gainesville, FL
University of Florida, Dept. Nucl. Eng. Sci., Grp. 1, Gainesville, FL
University of Hawaii at Manoa, Hawaii Inst. of Geophys., Honolulu, HA
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U.S. Air Force, Occup. & Env. Heal. Lab., San Antonio, TX
U.S. Department of Commerce, NIST, Gaithersburg, MD
U.S. Department of Interior, Bureau of Mines, Denver, CO
U.S. Department of Interior, Geological Survey, Reston, VA
U.S. Department of Energy, Env. Meas. Lab., New York, NY
U.S. Environmental Protection Agency, NAREL (EERF), Montgomery, AL
U.S. Environmental Protection Agency, ORP, Las Vegas, NV
U.S. Environmental Protection Agency, Region V, Chicago, IL
Wilkes University, School of Sci. & Eng., Wilkes-Barre, PA

APPENDIX 2

CONDITIONS IN THE EML RADON CALIBRATION ROOM DURING THE INTERCOMPARISON EXERCISES

Intercomparison No.	**1**	**2**	**3**
Date	4/20/81	6/15/81	1/27/82
Time (EST)	0930	0845	0930
B. P. (kPa)	100.7	101.4	102.9
Temp. (°C)	266.7	28.0	
R. H. (%)	30.0	55.0	26.0
Bq ^{222}Rn m^{-3}	1868 ± 33	1650 ± 41	1347 ± 30
Participants	9	9	11
Within ± 10%	8	6	11
Within ± 25%	9	9	11

Intercomparison No.	**4**	**5**	**6**
Date	7/12/82	6/24/83	2/6/84
Time (EST)	0700	0815	0815
B. P. (kPa)	100.9	100.0	100.4
Temp. (°C)	29.0	25.7	30.5
R. H. (%)	45.0	28.0	37.0
Bq ^{222}Rn m^{-3}	1158 ± 15	1720 ± 44	3041 ± 48
Participants	12	15	16
Within ± 10%	12	11	10
Within ± 25%	12	14	15

Intercomparison No.	**7**	**8**	**9**
Date	7/16/84	2/25/85	7/15/85
Time (EST)	0700	0800	0700
B. P. (kPa)	100.7	101.4	100.8
Temp. (°C)	25.0	25.0	26.8
R. H. (%)	70.0	48.8	37.3
Bq ^{222}Rn m^{-3}	1302 ± 22	1291 ± 3	2605 ± 56
Participants	21	24	22
Within ± 10%	14	15	18
Within ± 25%	20	24	22

CONDITIONS IN THE EML RADON CALIBRATION ROOM DURING THE INTERCOMPARISON EXERCISES

Intercomparison No.	10	11	12
Date	3/3/86	8/18/86	2/26/87
Time (EST)	0800	0630	0745
B. P. (kPa)	101.3	100.6	9999.7
Temp. (°C)	23.6	24.0	25.5
R. H. (%)	46.5	60.9	34.0
Bq ^{222}Rn m^{-3}	2597 ± 30	1154 ± 19	2483 ± 26
Participants	24	21	23
Within ± 10%	14	18	18
Within ± 25%	23	19	23

Intercomparison No.	13	14	15
Date	7/20/87	2/8/88	8/8/88
Time (EST)	0645	0745	0645
B. P. (kPa)	101.5	102.1	101.1
Temp. (°C)	23.0	21.5	23.6
R. H. (%)	44.0	34.4	40.0
Bq ^{222}Rn m^{-3}	451 ± 15	463 ± 7	222 ± 4
Participants	23	28	24
Within ± 10%	19	24	18
Within ± 25%	23	28	24

Intercomparison No.	16	
	Day 1	Day 2
Date	6/19/89	6/20/89
Time (EST)	0645	0630
B.P. (kPa)	101.5	101.7
Temp. (°C)	22.0	23.5
R. H. (%)	60.0	55.0
Bq ^{222}Rn m^{-3}	709 ± 8	887 ± 21
Participants	24	19
Within ± 10%	20	13
Within ± 25%	23	19

APPENDIX 2 (Cont'd)

CONDITIONS IN THE EML RADON CALIBRATION ROOM DURING THE INTERCOMPARISON EXERCISES

Intercomparison No.	**17**	
	Day 1	**Day 2**
Date	4/23/90	4/24/90
Time (EST)	0630	0630
B.P. (kPa)	100.8	101.4
Temp. (°C)	24.1	24.1
R. H. (%)	40.2	40.0
Bq ^{222}Rn m^{-3}	200 ± 7	213 ± 8
Participants	20	20
Within ± 10%	11	15
Within ± 25%	17	18

Intercomparison No.	**18**	**19**
Date	11/5/90	4/15/91
Time (EST)	0730	0700
B. P. (kPa)	100.7	101.6
Temp. (°C)	22.0	22.0
R. H. (%)	42.0	36.0
Bq ^{222}Rn m^{-3}	862 ± 13	607 ± 19
Participants	26	34
Within ± 10%	21	27
Within ± 25%	25	33

Intercomparison No.	**20**		**21**
Date	11/4/91		4/13/92
Time (EST)	0730	1000	0630
B. P. (kPa)	101.8	101.7	102.8
Temp. (°C)	20.5	20.5	22.0
R. H. (%)	30.0	29.0	34.0
Bq ^{222}Rn m^{-3}	650 ± 14	827 ± 10	2075 ± 50
Participants	28	26	26
Within ± 10%	21	25	26
Within ± 25%	27	26	26

CONDITIONS IN THE EML RADON CALIBRATION ROOM DURING THE INTERCOMPARISON EXERCISES

Intercomparison No.	22	23	24
Date	11/9/92	4/26/93	11/15/93
Time (EST)	0730	0645	0730
B. P. (kPa)	102.8	100.7	100.6
Temp. (°C)	20.5	20.5	23.5
R. H. (%)	30.0	38.0	55.0
Bq ^{222}Rn m^{-3}	1650 ± 28	925 ± 22	675 ± 12
Participants	23	32	28
Within ± 10%	20	28	23
Within ± 25%	22	32	27

Intercomparison No.	25	26
Date	4/18/94	10/31/94
Time (EST)	0630	0715
B. P. (kPa)	101.4	101.5
Temp. (°C)	18.5	17.2
R. H. (%)	45.0	46.0
Bq ^{222}Rn m^{-3}	570 ± 12	945 ± 15
Participants	27	28
Within ± 10%	21	22
Within ± 25%	27	27

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