REVIEW OF QA/QC ASPECTS OF ELECTRET ION CHAMBERS- MANUFACTURING PRACTICES AND PERFORMANCE IN WORLDWIDE INTER-COMPARISON EXERCISES IN THE PAST EIGHT YEARS

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Rad Elec Inc., located in Frederick, MD, USA is the only commercial producer of electret ion chambers (EIC) systems. These are distributed under the brand name of E-PERM®, electret-passive environmental radon monitors. Different versions of these are used in various applications, which include: measurement of indoor/outdoor radon, thoron ($^{220}$Radium), radon flux, radon in water, radium in soil/building materials, environmental gamma radiation, tritium in air and on surfaces, alpha contamination on surfaces and in soil. The system consists of three major components: electrets, chambers and electret voltage readers. ISO 9002 listed Rad Elec vendors manufacture chambers and readers. Rad Elec manufactures and certifies the electrets for stability and performance. The strict ongoing QA/QC practices in the manufacturing and documentation of QA/QC data is the key that assures that all Rad Elec-certified electrets have the same stability and calibration characteristics, irrespective of when these were manufactured. The paper reviews the ongoing QA/QC practices in the manufacturing, the type of certificates issued to the customers and contents of 1997 USEPA QA audit report. Results of blind annual inter-comparison exercises conducted by Environmental Measurement Laboratory (U.S. Department of Energy) during 1990-1996 are reviewed.

Keywords: Quality control, Quality Assurance, electrets, Ion Chambers, Radon, E-PERM

E-PERM® ELECTRET ION CHAMBER RADON MONITOR

An electret ion chamber for monitoring radon (Kotrappa 1998 and Kotrappa 1990) consists of a stable electret (electrically charged Teflon® disc) mounted inside an electrically conducting chamber. The electret serves both as a source of the electric field and as a sensor. The ions produced inside the chamber are collected by the electret. The reduction in charge of the electret is related to total ionization during the period of exposure. This charge reduction is measured using a battery operated electret reader. Using appropriate calibration factors and the exposure time, the desired parameters such as airborne radon concentration in air is calculated. These low cost monitors require neither power nor battery and several hundreds of these can be used simultaneously and serviced by one reader. Fluctuations in temperature or humidity and mechanical shocks do not affect the performance of these monitors, making them robust for field use.

The standard E-PERM® radon monitor has a mechanical arrangement for opening and closing the electret from outside the monitor chamber. This feature allows transportation of these units, across the world if needed, without picking up any additional signal during shipment, and further minimizes handling of the electrets in the field. See Figure 1.

E-PERM® is a trade name for the Electret Ion Chambers manufactured by Rad Elec Inc., 5714-C Industry Lane, Frederick, MD 21704 USA
These have some similarity with alpha track detectors. In alpha track detectors, alpha particles from radon hit the special plastic and create a defect that will become visible when chemically processed. The number of tracks formed in the plastic over a time is related to integrated radon concentration over that period. In EIC, ions produced by alpha particles from radon are collected by electrets. The change in charge of the electret over a time is related to the integrated radon concentration over that time. Unlike alpha track detectors, no chemical processing is needed for EIC. Change in charge can be read rapidly, in seconds.

PROCEDURES FOR MEASURING RADON

Four components are needed for measuring radon: electrets, chambers, electret voltage readers and data analyzing pocket computer. See Figure 1.

These are the steps taken to measure radon with an E-PERM® detector:

1. Take initial voltage reading of the electret using electret reader.
2. Load the electret into the chamber in “off” position.
3. Turn the chamber to “on” position and locate it at a place where radon has to be measured.
4. Write down the start date and time of the measurement.
5. At the end of the exposure, turn the chamber to “off position”.
6. Write down the stop date and time of the measurement.
7. Take a final voltage reading of the electret using electret reader.
8. Enter initial voltage reading, final voltage reading and the exposure time into the pocket computer to calculate radon concentration.
9. Electret may be used repeatedly until the final reading is below certain voltage.

THE CONCEPT OF TOTAL QUALITY, QA/QC IN MANUFACTURING

Manufacturing quality control becomes very important because the same stability and calibration characteristics have to apply for each individual electret manufactured and supplied over the past eight years (more than 250,000 sold to date) and all electrets to be manufactured and sold in future years. The only way to achieve this is by following the concept of total quality control. This includes quality control on raw materials, components, manufacturing steps and finished products.

QA/QC on electret voltage readers

The following steps assure long and trouble free performance of electret voltage readers:

1. Manufactured by an ISO9002 (with CE compliance) listed
2. In order to assure highly reproducible quality, the manufacturer fully documents changes and improvements.
3. The same manufacturer provides servicing of the readers according to the same high quality standards.
4. Readers are calibrated using simulated voltage sources, traceable to NIST (U.S. National Institute of Standards and Technology).
5. As required by the certifying agencies in USA, the customer returns the reader to the manufacturer or authorized representative for annual calibration.

QA/QC on chambers
The following steps assure the quality of Rad Elec ion chambers:

1. Injection molds ensure highly reproducible dimensions of chambers.
2. Chambers are checked for electrical conductivity, matching of threads and several other critical dimensions. Such data is documented for each production batch and certified by QA inspector.

Qa/qc on electrets
This is a critical component. Standardization of electret quality is essential for accurate measurements. Following steps assure such performance:

1. Electret holders are manufactured using injection molds assuring reproducible dimensions and quality.
2. Statistical checks are made on the dimensions and data documented.
3. Reputed manufacturer manufactures the raw material, Teflon® sheets using specified resin, specified procedure and specified thickness.
4. Thickness, being a critical parameter, is checked and documented.
5. Manufacturing and stabilizing of electrets require large number of steps. A production control chart is maintained for each batch and production supervisor certifies that all the steps specified in production control charts are actually carried out.

Final quality and performance assurance
1. After taking an initial reading, all electrets undergo one week of 100% humidity exposure and a minimum of three months of storage on shelf. The final reading is compared with the initial reading to make sure that the stability specifications are complied. Such stability data for each electret is supplied to the customers.
2. A sample subset of electrets from each production batch is loaded into the chambers and exposed in radon test chamber. Accuracy and standard deviation are checked.
3. For each electret sold, a stability and performance certificate is supplied to the customers. These certificates are maintained by the users and satisfy the radon certification requirements of several States in USA.

RESULT OF TOTAL QUALITY
The efforts in assuring total quality are expensive and tedious, but the results are rewarding as demonstrated by the performance:
1. 97% of the electrets pass or exceed manufacturer’s specifications.
2. No electret batch has been rejected to date.
3. Calibration of E-PERM® radon monitors has not changed over the past five years.
4. USEPA does not require the users to perform a separate calibration.
5. E-PERM® radon detectors have the consistently highest pass rate in radon proficiency tests conducted by USEPA, over the past eight years (US EPA 1997).
6. Large number of E-PERM® users have participated in several blind tests conducted by the Environmental Measurement Laboratory of U.S. Department of Energy and results have always been in the range of 3 to 10% of the target value (EML 1995).

INTERCOMPARISONS CONDUCTED AT ENVIRONMENTAL MEASUREMENT LABORATORY OF U.S. DEPARTMENT OF ENERGY

EML conducted several inter-comparisons of monitoring devices for radon and radon progeny measurements as recommended by the Co-ordinated Research Program (CRP of the International Atomic Energy Agency (IAEA) in cooperation with the Commission of European Communities (CEC).

In the 1996 exercise, eight participants submitted 32 electret ion chamber detectors for exposure in the EML radon chamber. The mean ratio (target value to measured value) was 0.97 ± 0.03 (EML Oct 1996). In the 1995 exercise, nine participants submitted 36 electret ion chamber detectors. The mean ratio was 0.99 ± 0.14. (EML Dec 1995) In the 1994 exercise, nine participants submitted 36 E-PERM® detectors, with a mean ratio of 0.97± 0.03. (EML Feb 1995)

RESULTS OF NATIONAL RADIOLOGICAL PROTECTION BOARD (UK) EC RADON INTERCOMPARISON

Rad Elec submitted three groups of SLT E-PERM radon monitors. The average relative percent error was 3.8% and standard deviation was 2.3%. (NRPB 1998)

RELATIVE PERFORMANCE IN U.S. EPA RADON PROFICIENCY TESTS

Radon proficiency tests conducted by U.S. EPA requires that each laboratory to be certified send four detectors for testing. After exposing the detectors to known radon concentration for a known time, U.S.EPA sends detectors back to the laboratory for analyzing and reporting the results. If results are within 25% of the target value, the devices are declared as passed. Table-1 gives the results.

From the table, it can be seen that electret ion chambers constitute more than 50% of all the detectors sent for testing. Further, these have the highest pass rate. Alpha tracks have the poorest pass rate, attributable to difficulties in chemical processing and track reading.

Detector Type Expanded Name
ES  Electret Ion chambers - short term
EL  Electret Ion chambers - long term
AC  Activated Charcoal - short term
AT  Alpha Track - long term
CRM Continuos radon monitors

U.S. EPA QUALITY AUDIT REPORT

In December 1997, three scientists from the US EPA visited Rad Elec’s facility in Frederick, Maryland to observe and document company operations. The following is quoted from the conclusion to their report:

“The E-PERM system is so adequately documented and reliable that a user would have to exhibit systematic carelessness to produce consistently invalid results… A radon tester intent on quality would be well advised to look into E-PERM System to see how it fits their needs.” (US EPA, 1998).

CONCLUSIONS

Continued control on manufacturing QA/QC has assured products of reproducible characteristics over an extended period and the time to come. This is neither easy nor inexpensive, but rewarding in the long run. This minimizes the QA/QC for the users saving efforts and time in assuring quality measurements. The elements of QA/QC may be applied to the manufacturers of other detectors.

REFERENCES

[4] EML (Environmental Measurement Laboratory) Reports Department of Energy
Table 1: relative performance in U.S. EPA radon proficiency tests (1991 to 1997) EPA 402-F-93-003-I

<table>
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<th>Detector Type</th>
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<th>AC</th>
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<th>CRM</th>
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<td>1083</td>
<td>1164</td>
<td>113</td>
<td>670</td>
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<tr>
<td>Percent Pass</td>
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<td>89.0%</td>
<td>81%</td>
<td>64.2%</td>
<td>85.9%</td>
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Figure 1.
Components of electret ion chambers. From left to right: Radon Monitor in off position, Radon Monitor in on position, Electret Voltage Reader and Electret.