REVIEW OF E-PERM* PASSIVE INTEGRATING ELECTRET IONIZATION CHAMBERS FOR MEASURING RADON IN AIR, THORON IN AIR, RADON IN WATER AND RADON FLUX FROM SURFACES AND MILL TAILINGS

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ABSTRACT

E-PERM® (E-PERM® is a trade name for the Electret Ion Chambers manufactured by Rad Elec Inc., 5714-C Industry Lane, Frederick, MD 21704 USA) electret ion chambers are passive integrating ionization chambers requiring no batteries or power. The electret serves both as a source of high voltage and also as a sensor for quantitative measurement of ionizing gases and vapors. This technology is relatively new and is widely used in the past ten years. The technology provides a unique, single integrated solution for measuring short-term, long-term radon/thoron concentrations in air, radon in water, radon in soil and radon flux from surfaces and mill tailings. Paper reviews: Historic development of the technology, scientific basis, methodologies and published literature on the topic. Advantages and limitations of the methodology are also reviewed.

1. E-PERM® ELECTRET ION CHAMBER RADON MONITOR

Eventhough electrets and electret ion chambers were known from past 50 years, these remained scientific curiosity until a systematic research and development work was done in 1987-1990. Rad Elec Inc. did the initial research with funding from New York State and Department of Energy. The research was aimed at developing practical electret ion chamber system for measuring indoor radon. Practical electret ion chamber system was developed, patented and commercialized during 1989-1991. This invention was honored by American Nuclear Society by awarding International Radiation Industry Award for the year 1989. Additional applications relating radon were standardized during 1991-1995. With further funding from Department of Energy (DOE), new applications were developed and standardized for use in Decontamination and Deactivation programs of DOE.

E-PERM radon monitoring systems have been in use from the past 10 years and have become workhorse for most radon measuring laboratories in USA and many in Europe, Asia and South America.

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. Normally encountered temperatures, humidities and mechanical shocks do not affect the performance of these monitors, making them robust for field use.

A typical 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.

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. For more details, please refer to Rad Elec (1998).

2. E-PERM® THORON MONITOR

E-PERM® passive integrating electret ionization chamber for measuring radon in air has a restricted filtered passive access to radon (^{222}Rn). Area to volume ratio of access is designed to allow sufficient delay to effectively respond only to radon and not to thoron (^{220}Rn). A modified unit called thoron monitor, with unrestricted access to radon and thoron responds to both radon and thoron. Radon monitor and thoron monitor when used side by side allows measurement of both radon and thoron concentration in air. Such monitors were calibrated in a well-characterized thoron test chamber maintained by Canadian Mining Institute (CANMET). More details of this and the equations to be used for computing both radon and thoron concentrations are given by Kotrappa (1994). Figure 2 gives schematic of such chambers. For more details, please refer to Rad Elec (1998).

3. PERM® RADON MONITOR FOR MEASURING DISSOLVED RADON IN WATER

This method belongs to the general class of "de-emanation method" of measuring dissolved radon in water. A small water sample is placed in the bottom of a glass jar. An E-PERM® is suspended in the air phase above the water. The lid of the flask is closed and sealed to make it radon-tight. Radon reaches equilibrium between the water and air phase. At the end of the desired exposure period, the flask is opened and the E-PERM® removed. The average radon concentration in the air phase is calculated using the standard E-PERM® procedure. A calculation using this air concentration in conjunction with the other parameters gives the radon concentration of the water. Kotrappa and Jester (1993) give details on the theoretical basis for this method. Paper also evaluates the results of the measurements done with electret ion chambers and with liquid scintillation method on the same samples. Figure 3 gives a schematic of the measurement arrangement. Such arrangement can also be used for a quantitative measurement of radium in soil, by taking a soil sample in the place of water sample and measuring radon emanated from the soil or the building materials. For more details, please refer to Rad Elec (1998).

4. E-PERM® RADON MONITORS FOR MEASURING UNDISTURBED RADON FLUX

The Passive measurement of radon flux from the ground or other surfaces is useful for determining the (a) radon emanating potential of a building site, (b) to meet the regulatory requirements for uranium mill tailings or phosphate tailings or gypsum stacks, and to determine the radon flux from test materials such as bricks and other surfaces.

The H chamber (Rad Elec 1998) is modified to feature a large, carbon coated Tyvek(R) diffusion window. The chamber is vented by filtered outlets so that it will not accumulate radon. When the E-PERM® flux monitor is placed on radon emanating surface, the radon enters through the Tyvek(R) barrier and exits through the vents. The semi-equilibrium radon concentration established inside the chamber is representative of dynamic flux from the surface. Because of the equilibrium between the ground and outside environment through vents, the flux emanation from the ground is not disturbed. The electret discharge rate of the electret is a measure of the radon flux. E-PERM® flux monitors are calibrated on the well-characterized radon flux beds at CANMET (Canada). These flux beds consist of ^{226}Ra bearing material (well-characterized uranium tailings) 5.5 cm thick and 5 meter in diameter. The bed is precisely characterized by CANMET* to provide a radon flux of 7.7 pCi m^{-2} sec^{-1} (0.285 Bq m^{-2} sec^{-1}).

Details of the method are described in Rad Elec (1998) Manual and also published (Kotrappa 1996). Rechcigl (1996) describes the comparative evaluation of the flux measured by electret ion chamber method and by large area charcoal detector method on the same measurement area. Figure 4 gives a schematic of the measurement arrangement.

5. SCIENTIFIC BASIS

The scientific for these monitors to work, following facts have to be satisfied:

- Electret should be relatively stable even under 100 % relative humidity.
- Discharge of electret should occur only from the collection of ions of opposite sign and not by any other physical or chemical means.
- Method of measuring charge on the electret should be a non-destructive, non-contact, reproducible and accurate method.
- Being an ionization chamber, first approximate estimation of calibration factors should be possible.

Commercially available E-PERM® system (Kotrappa 1998 and Kotrappa 1990) satisfies all of these parameters.

6. COMPARATIVE FEATURES OF DIFFERENT RADON DETECTORS

Table-1 gives comparative features of different radon detectors. As can be seen E-PERM® radon monitors provide more versatility, robustness and cost competitiveness.

7. RELATIVE PERFORMANCE OF DIFFERENT DETECTORS IN USEPA RMP PROGRAM DURING 1991-1997 (EPA 402-F-93-003-I)

Table-2 gives relative performance of different detectors in USEPA RMP program during 1991-1997.
As can be seen, E-PERMs have highest pass rate and are also most used radon detectors in USEPA RMP program.

8. LIMITATIONS

A single E-PERM does not cover wide range of radon concentration.
An E-PERM is an ionization chamber and responds to all ionizing radiation.
An E-PERM radon monitor needs to be corrected for environmental cosmic and terrestrial radiation background.
Requires additional precautions, not to touch the surface of the electret and to keep the surface free of dust and fibers.

9. DISCUSSIONS AND CONCLUSIONS

The E-PERM® Electret ion chamber technology is an integrated method providing capability of measuring:
Radon in air (short and long term)
Thoron in air
Dissolved radon in water
Radon flux from the ground and building material

What makes this an inexpensive and attractive method is the ability to use the same electret reader and the same electret in all the applications

Because of ease with which, a building inspector can have his own laboratory with affordable investment has made E-PERM System very popular.

10. REFERENCES

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Table-1 Comparative Features of Different Radon Detectors

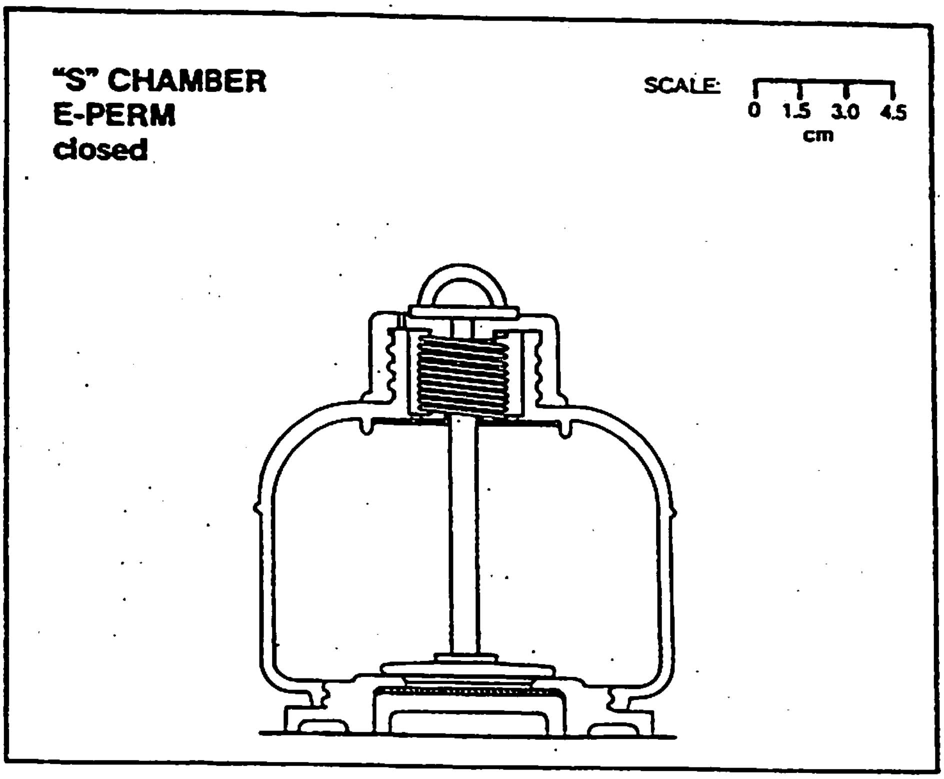
Detector	AC	AT	E-PERM	CRM
Features	Activated Charcoal	Alpha Track	Electret Ion Chambers	Continuous Radon Monitor
ST or LT	ST	LT	ST and LT	ST
True integration	No	Yes	Yes	Yes
Hourly Readings	No	No	No	Yes
Temperature Correction	Required	No	No	No
Humidity Correction	Required	No	No	No
Elevation Correction	Not known	Yes	Yes	May Require
Cost per Measurement	Low	Low	Low	High
Detector Cost	Low	Low	Low	High
Ruggedness	Good	Good	Good	Requires Careful handling
Analysis Equipment	High	Very high	Low	High

AC- Activated charcoal
AT- alpha Track
CRM-Continuous Radon Monitors
LS-AC- Liquid scintillation-Activated Charcoal

Table-2 Relative Performance of Different Detectors in USEPA RMP Program During 1991-1997 (EPA 402-F-93-003-I)

Detector	AC	AT	E-PERM-ES	E-PERM-EL	CRM	LS-AC
Number of detectors tested	1164	113	2206	1083	670	216
Device Pass Rate (%)	81.1	64.2	92.3	89.0	85.9	80.0
Program %	21	2.6	35	17.8	11.4	3.9

AC- Activated charcoal
AT- alpha track
CRM-Continuous radon monitors
LS-AC- Liquid scintillation-Activated Charcoal



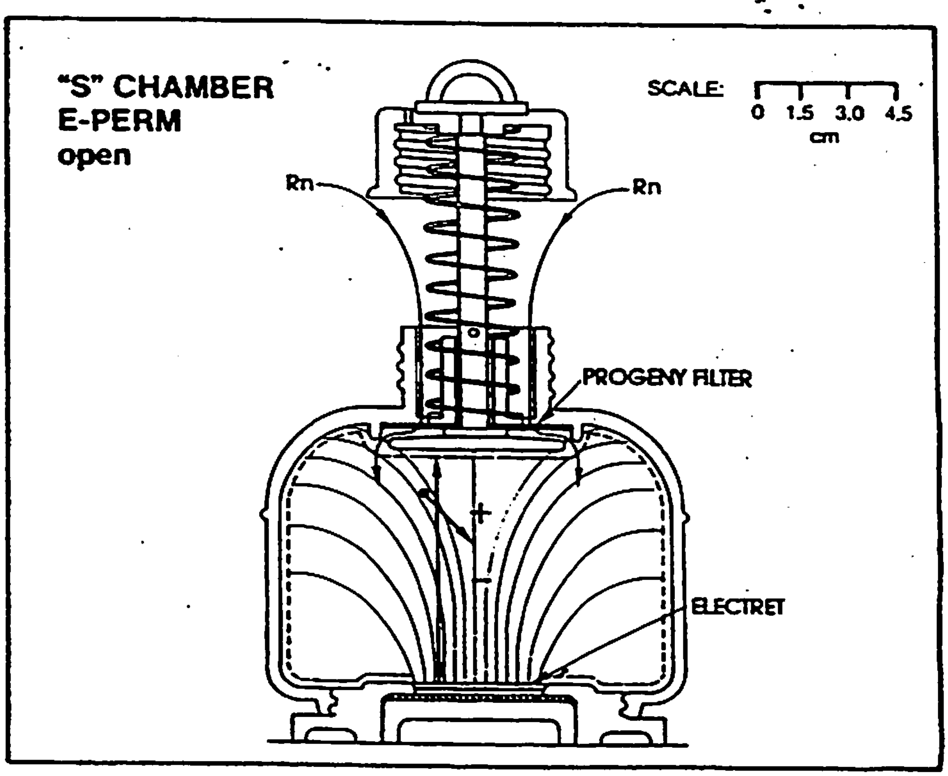


Figure-1
Schematic S Chamber E-PERM®

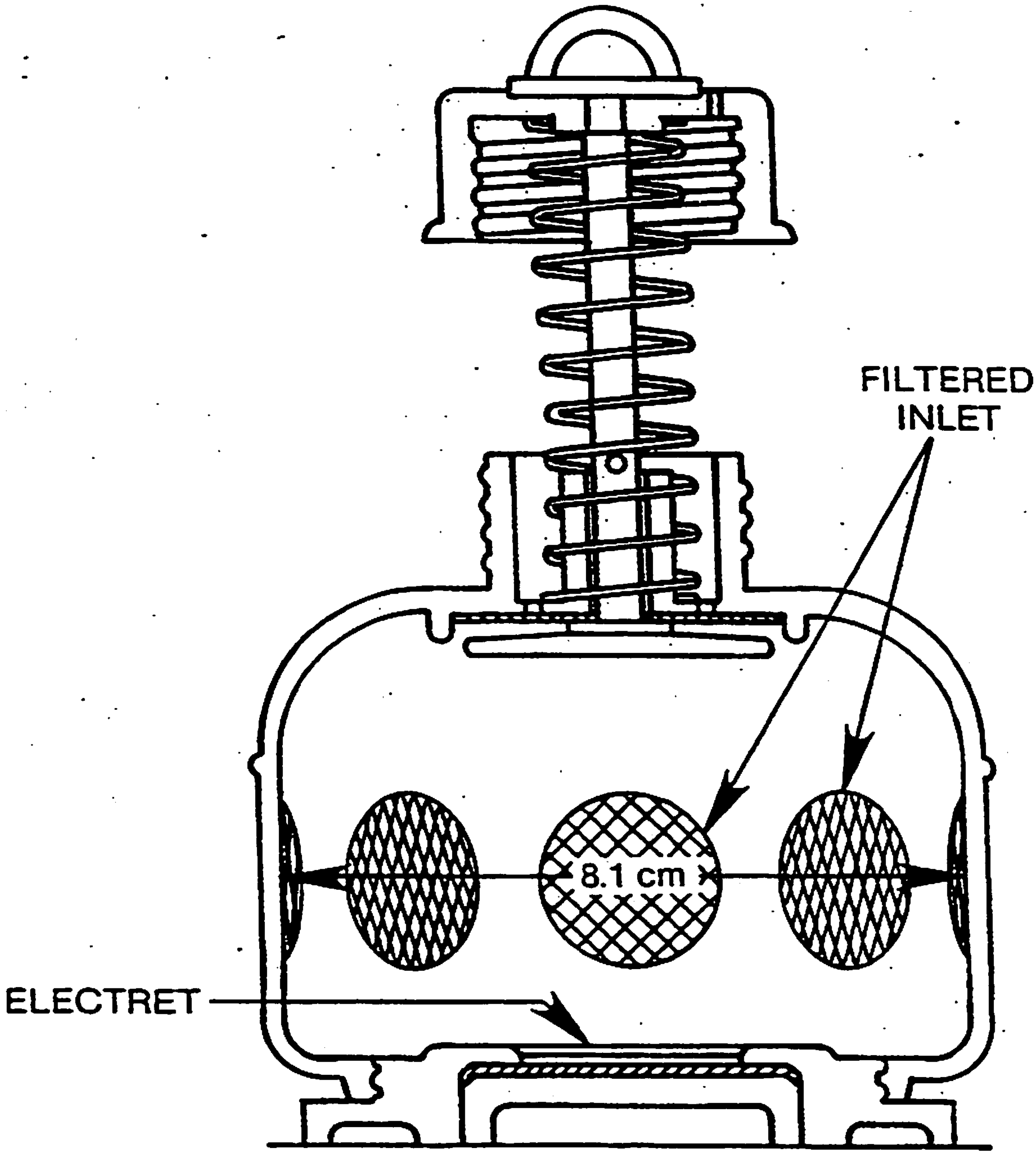


Figure-2
THORON E-PERM®

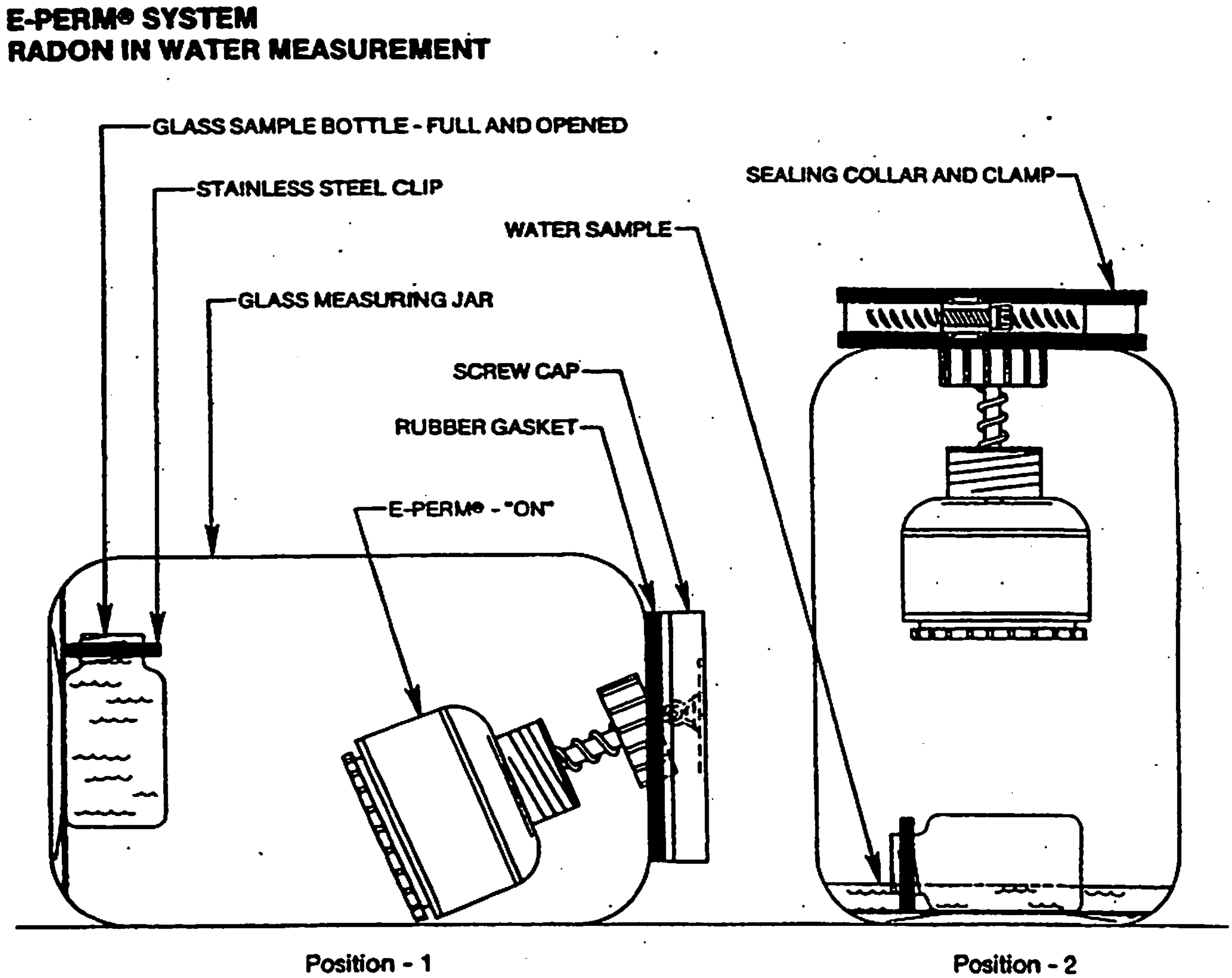
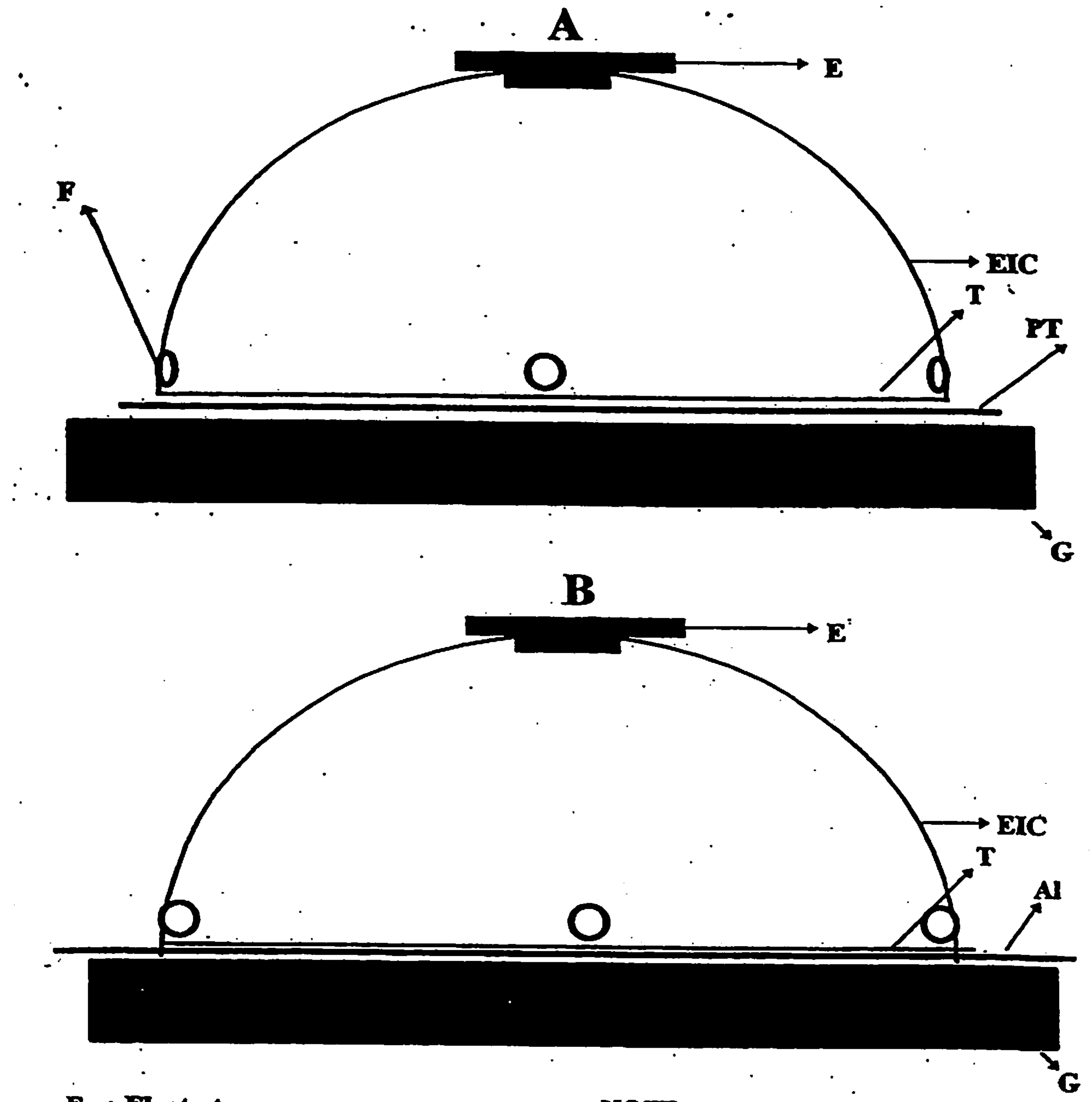


Figure-3
SCHEMATIC FOR MEASURING RADON IN WATER USING E-PERM®



E : Electret
G : Ground or tailings
PT : Paper Towel to allow radon to pass
T : Tyvek Window
EIC : Electret Ion Chamber
Al : Al sheet to stop radon
⬭ F : Filtered openings

NOTE
The Chamber A allows radon
The Chamber B stops radon

Figure-4
MEASURING RADON FLUX FROM GROUND USING E-PERM®