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ELECTRETS FOR MEASUREMENT OF BACK-GROUND RADIATION DOSE AND RADON CONCENTRATION IN AIR

by

S.D. Soman

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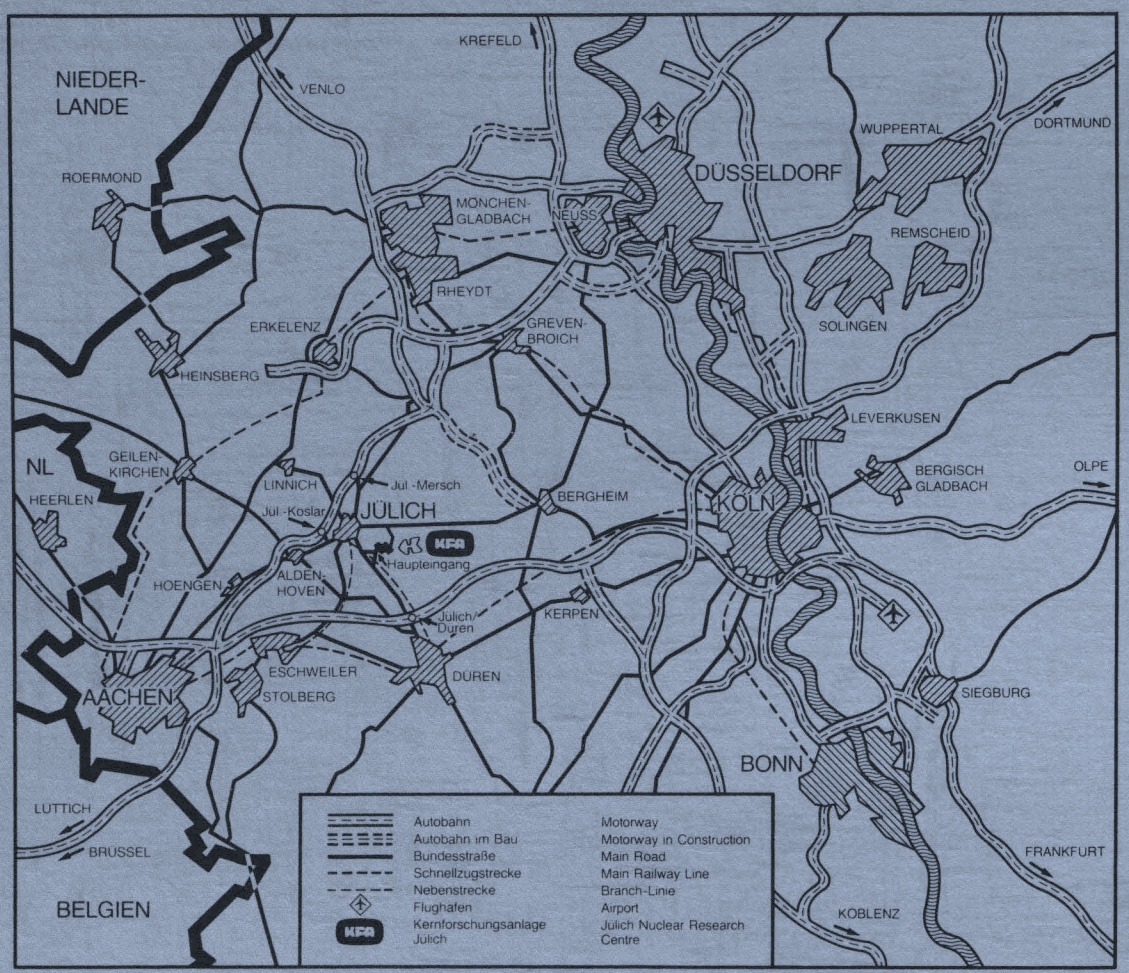

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ELECTRETS FOR MEASUREMENT OF BACK-GROUND RADIATION DOSE AND RADON CONCENTRATION IN AIR

by

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8th Communication within the Bilateral
Indo-German Scientific Agreement on
„Advanced Aspects of Trace and Ultratrace Analysis:
Trace Analysis of Radionuclides in the
Environment"

Table of Contents

page

Abstract 5

Preface 6

1. **Introduction** 7

2. **Preparation of Electrets** 8

3. **Handling of Electrets** 10

4. **Charge Reading** 10

5. **Background Radiation Dose Measurements** 13

6. **Measurement of Radon Concentration** 17

7. **References** 19

Abstract

A survey is given about investigations on electrets and their application in environmental radioactivity measurement, which has been performed for the last few years in the Health Physics Division of the Bhabha Atomic Research Centre, Bombay, India.

This survey includes preparation, handling, charge reading and application of electrets for background radiation dose as well as radon concentration measurement in air.

Zusammenfassung

Es wird eine Übersicht gegeben über Arbeiten der letzten Jahre in der Health Physics Division des Bhabha Atomic Research Centre in Bombay, Indien, über Elektrete und deren Anwendung zur Messung der Umweltradioaktivität.

Der Überblick enthält die Herstellung, Behandlung, Ladungsablesung und Anwendung der Elektrete für Messungen der Untergrund-Strahlendosis sowie Radonkonzentration in der Luft.

Preface

Electrets are a counterpart to permanent magnets in the field of electrostatics. They can be prepared by synthesizing special plastics such as teflon and its similar compounds under the influence of an electrostatic field. The molecular electrical dipols became straightend into one direction, which is fixed after solidifying of the resin. This electrets can be discharged by the uptake of electrical charges with opposite sign from the environment, which may e.g. be induced by ionizing radiation. On the reverse, this radiation can be measured by following the discharge of an electret.

This article was a lecture at the Seminar for Chemical Analysis of the KFA on the 25th November 1982 under the Bilateral Indo-German Scientific Agreement on "Advanced Aspects in Trace and Ultratrace Analysis: Trace Analysis of Radionuclides in the Environment" between the Health Physics Division of the Bhabha Atomic Research Centre (BARC) in Bombay, India, and the Central Department for Chemical Analysis of the Nuclear Research Establishment Jülich (KFA). This Project has been described in the preface to the previous JÜL-Spez-Report No. 161.

Mr. S.D. Soman is Head of the Health Physics Division of the BARC. He gives in the following a brief summary on investigations from his Division about the application of electrets for dose rate measurements of ionizing radiation.

Electrets are a new and promising tool for measuring environmental radioactivity as radiation doses and dose rates under extremely simple experimental conditions.

B. Sansoni

Jülich, 24th August 1982

1. Introduction

An electret is a piece of dielectric material exhibiting quasi-permanent electric charge. The charge of the electret produces a strong electrostatic field capable of collecting ions of opposite sign. Marvin [1] was the first to suggest that the reduction of charge on electret was due to collection of ions of opposite sign from the surrounding gas and proposed electret as a dosimeter. Wolfson and Dyment [2] noted that the reduction of charge was not stable for Carnauba wax electrets after the termination of irradiation. Until recently electrets were regarded merely as curious analogues of permanent magnets, worthly only of academic interest. However, with the advent of the development of fluoro-carbon polymers such as Teflon, electrets have finally become accepted as reliable electrostatic components capable of maintaining a constant electrostatic field even at high temperatures and severe humid conditions. Electrets made from Teflon show remarkable stability, with mean life of tens of years, and have ability to retain charge in the most adverse conditions likely to be encountered in the environment. Technology for making electrets is also fairly well understood and so also the techniques for measuring the surface charge of the electrets. Bauser and Ronge [3] made significant advancement in the use of electrets for radiation dosimetry. They used a pair of thin Teflon electrets of opposite charges to make an ionisation chamber. Such an ionisation chamber allows quick and repetitive read out linear to dose and measures the cumulative dose without loss of information. They claim a threshold dose of about 0.01 mGy. Electrets have also been used for measuring concentrations of radon and thoron [4] gases in air.

In the Health Physics Division at BARC, we have carried out the following programmes:

- Development and standardisation of techniques for making electrets;
- Design and fabrication of a portable unit for reading surface charge of the electrets;
- Design and development of a single electret dosemeter and study of its performance for external dose; and
- Development of a method for measurement of radon concentration using electrets.

2. Preparation of Electrets

Two methods have been standardised:

2.1 Preparation of Thermo-electrets [4]

A circular piece (6 cm in diameter and 0,08 cm thick) of Teflon coated with a thin layer of aluminium on either side was made into an electret. This sheet was sandwiched between two polished stainless steel discs, and lowered into an oven maintained at 240°C. A high voltage of about 4.5 kV was applied between the discs and the sandwich was allowed to cool to room temperature with the electric field still on. The high voltage was switched off, the sandwich was removed and held shorted (using metal clip) for about 10 days to remove unstable charges. The aluminium coating was removed and the Teflon sheet was washed, dried and retained shorted between the metal sheets for use as an electret. The Teflon electret thus prepared had a charge density of 7×10^{-9} coulomb/cm^2 as measured by a standard shutter method. The charge was equal and opposite on either side. This electret produced an electric field equivalent to that produced by a battery of nearly 3000 volts.

2.2 Liquid Contact Method [5]

In this method a filter paper F wetted with a few drops of electrolyte such as dilute HCl was sandwiched between the metal piston and Teflon sheet with its other side having conducting surface. The voltage of 3 to 5 kV was applied between the metal piston MP and the conducting side CS (Figure 1). After about five minutes the metal piston was removed out of the Teflon sheet with the high voltage still on to make the Teflon into an electret. Then the high voltage was switched off. To prepare good quality electrets it is necessary to pre-heat the Teflon sheet and also to give heat treatment after preparation.

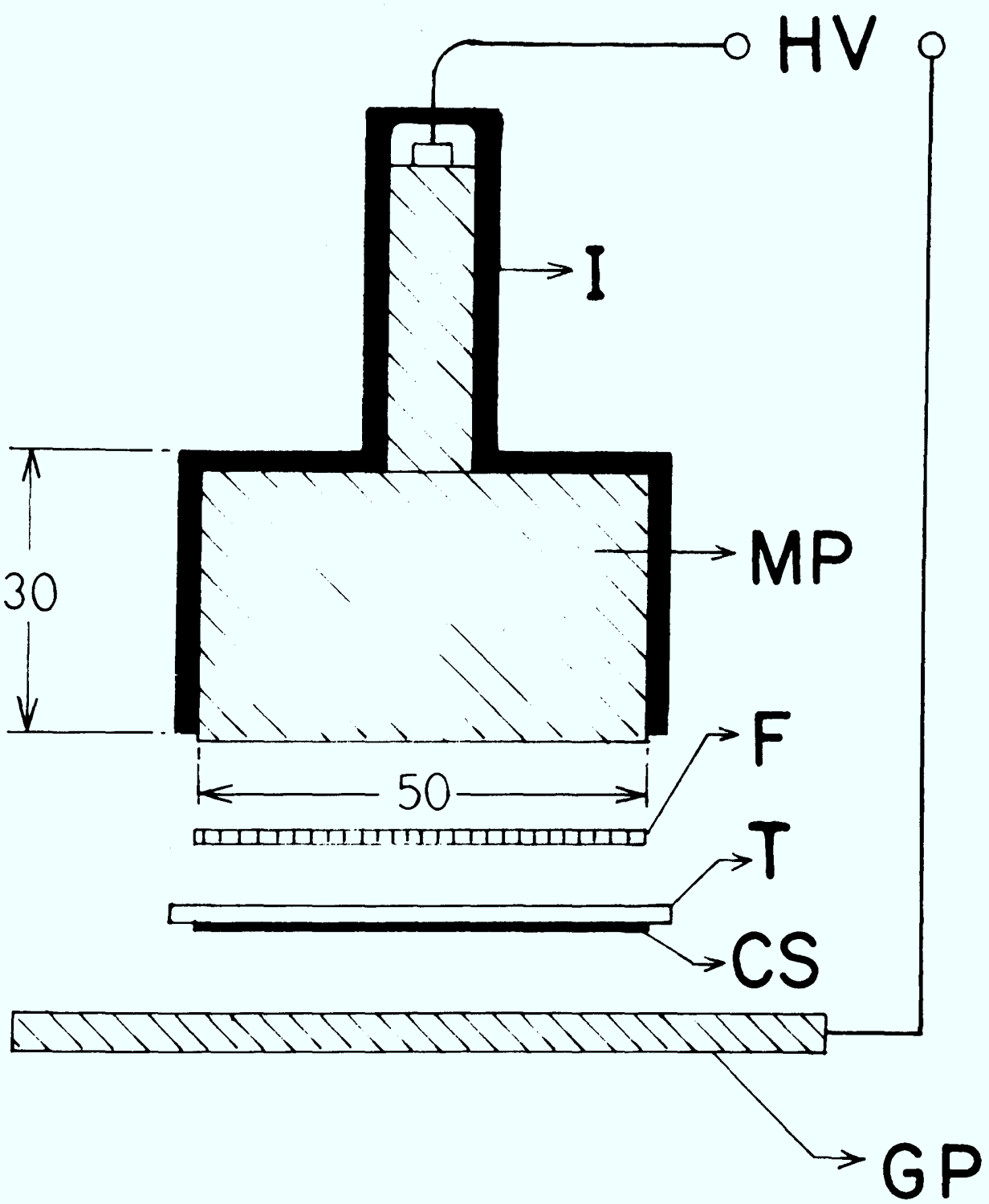

Figure 1:
Liquid Contact Method for Making Electrets (Exploded View)
Dimensions are in mm; MP metal piston; I insulating layer; HV high voltage unit; F electrolyte socked filter paper; T teflon sheet to be made into an electret; CS graphite coated conducting surface; GP grounding plate.

3. Handling of Electrets

In view of the inherent properties of electrets, certain handling problems arise. Due to large electrostatic fields, electrets attract dust as well as ions of opposite sign present in the environment. If an electret is left in dusty atmosphere, a thin layer of dust collects on its surface. This reduces the electric charge. The thermo-electret can be cleaned with soap and water to regain its original electric charge. The cleaning, however, should not be done with abrasive powders. The electrete prepared by liquid contact method should not be washed since these lose their charge. Electrets when not in use should be kept covered in small plastic containers to minimise collection of ions and dust.

4. Charge Reading

Capacitive probe method described by Sessler and West [6] (Figure 2), also known as the sutter method, was adopted for measuring the charge on electrets.

Electret E loaded in an electret holder (Figure 3) was positioned and the shutter pas pushed into the slot. The probe was momentarily shorted and the display zeroed. The shutter was pulled out and the maximum voltage recorded on the display was noted. Using various parameters of the system, the surface charge of the electret could be calculated [5]. The measuring system is small, battery operated and portable.

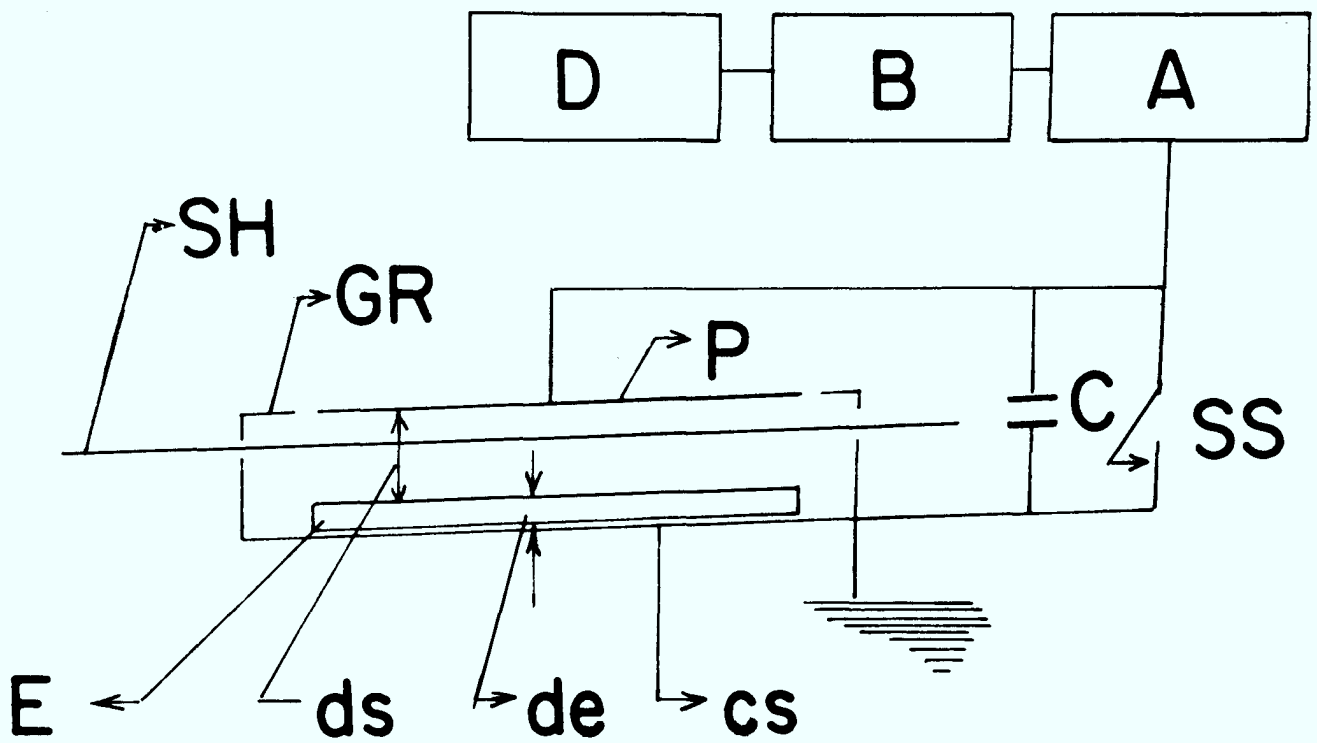

Figure 2: Schematic of Charge Measuring Unit

P	Probe
SH	Shutter that can be pushed or withdrawn through a slot
GR	Guard ring
E	Electret
CS	Conducting surface of electret
dS	Distance between the probe and the electret
de	Thickness of electret
C	Capacitance
SS	Shorting switch
A	High input impedance stage (MOSFET)
B	Differential amplifier using operational amplifier
D	LCD digital display

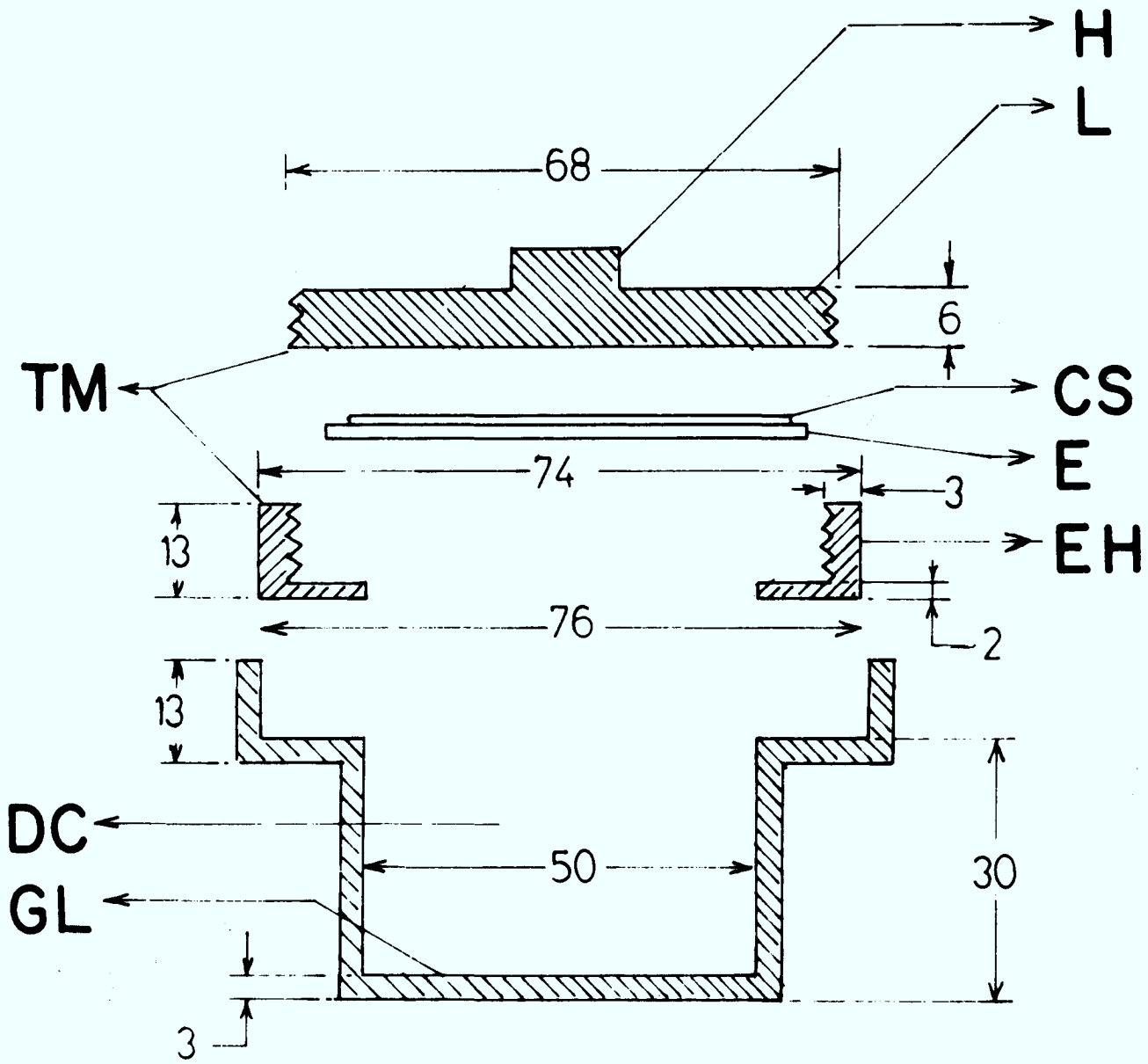

Figure 3: Exploded View of Dosemeter and Electret Holder.

Dimensions are in mm

H	Handle for lid
L	Perpex lid to screw into EH
CS	Graphite coated conducting surface of electret E
DC	Dosemeter chamber
GL	Thin graphite layer
TM	Threaded to mach

5. Background Radiation Dose Measurements

The dosemeter standardised in the laboratory is shown in Figure 3. Electret in an electret holder was read before loading into the perspec chamber. The assembled perspec chamber is called dosemeter, and the reading of the electret involved is called the dosemeter reading.

The system is very nearly air equivalent. The dosemeter was given doses in steps of 1 mGy, and the reading after each successive dose was taken. The response of the dosemeter in terms of volts per mGy over a range of dosemeter reading was like a typical ionisation chamber response with a saturation region between 5 and 20 volts (Figure 4). The saturation region corresponds to a response of about 0.8 volts per mGy for an electret of 0.08 cm thickness.

It is seen that the experimentally measured response per milli Gray agrees fairly well with the calculated response based on instrument parameters. It is also independent of dose rate and photon energy. The response of dosemeter of electrets of different thicknesses was also studied. Useful range, minimum resolvable dose and the response for different electret thicknesses are given in Table 1.

Table 1: Characteristics of Dosemeter

Electret Thickness (cm)	Response (volt/MGy)	Minimum Dose Resolvable (mGy)	Useful range of Dosemeter Readings (volts)	Maximum Measurable Dose (mGy)
0.0127	0.1341	0.0751	5.2 to 20.8	116
0.0794	0.7981	0.013	5 to 20	18.8
0.3084	2.6615	0.0038	4.5 to 17.8	5.0

It is seen that for an electret of 0.3 cm thickness, the minimum resolvable dose is 0.0038 mGy. This corresponds to a value of 0.01 volt background radiation measurements.

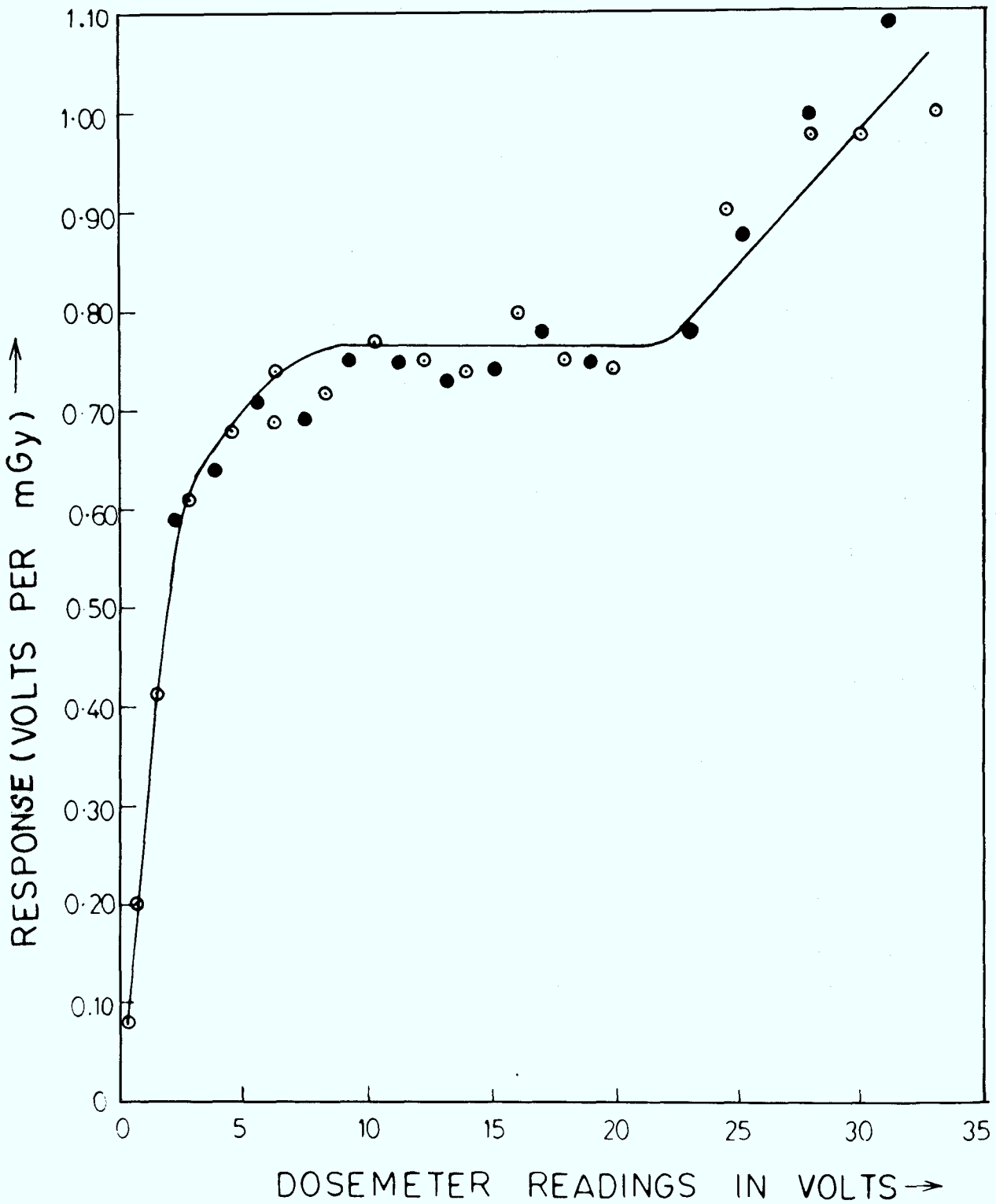

Figure 4:
Experimentally Determined Response (volts/mGy) of Measuring System for Various Dosemeter Readings (volts).

Electret thickness: 0.0794 cm
Dosemeter exposed to 192 Ir Photons
Dose rate: 45 mGy/hr

6. Measurement of Radon Concentration

The decay products of radon carry positive charge immediately after their formation. These daugther products can, therefore, be quantitatively collected on metal electrodes maintained at high negative potential. The Teflon electrets by virtue of their high charge density can be used to collect these daugther products. Figure 5 shows the 10 l chamber used for measurement of radon concentration.

The decay products formed inside the chamber were collected on to the surface of the mylar foil covering the elctret. After a known sampling time, the mylar sheet was alpha counted. The theory analogous to the theory of double filter was used to calculate the concentration of radon in air. In case of radon in about 8 minutes, 90 % of equilibrium is attained between the volume inside the chamber and the environment outside whereas in about 20 minutes full equilibrium is established. Thus for a few hours of sampling time this effect is negligible. However, due to short half time of thoron a gradient of concentration is established between the wall and the centre of the chamber and concentration in the chamber is lower than the outside concentration by a factor which depends on the area of the chamber available for thoron to diffuse in.

The relative humidity (RH) has a considerable effect on the collection efficiency of radon decay products [4]. As RH increases from 10 % to 75 %, the collection efficiency decreases from 70 to 40 %. This effect is less pronounced for thoron decay products. These observations are similar to those of Cowper and Davenport [7] for radon daughters and of Porstendörfer and Mercer [8] for thoron daughters.

It is possible to calculate both radon and thoron concentrations by programmed alpha counting of collected decay products. For three hour sampling and subsequent counting the minimum detectable limit works out to about 30 pCi/m^3 for radon and 300 pCi/m^3 for thoron.

Table 2 shows that the method is capable of measuring the levels encountered in the environment and the results agree fairly well with measurements carried out using large 150 litre double filter system.

Long term cumulative concentrations of radon or thoron can also be measured by collecting decay products directly on to the surface of TLD or SSNTD[9]. The arrangement for using an electret for such purposes needs some modifications. These configurations are shown in Fig. 6. It is seen that the TLDs registered nearly 0.0137 mGy per pCi/l.hr for radon and 0.0007 mGy per pCi/l.hr for thoron. In the case of SSNTD using CR-39 the detector recorded 90 $\pm$ 10 tracks/cm^2 per pCi/l.hr for radon and 6 $\pm$ 0.06 track/cm^2 per pCi/l.hr for thoron. Simultaneous measurements of radon and thoron by this technique is possible if one uses two chambers with different thicknesses of foam and hence different responses.

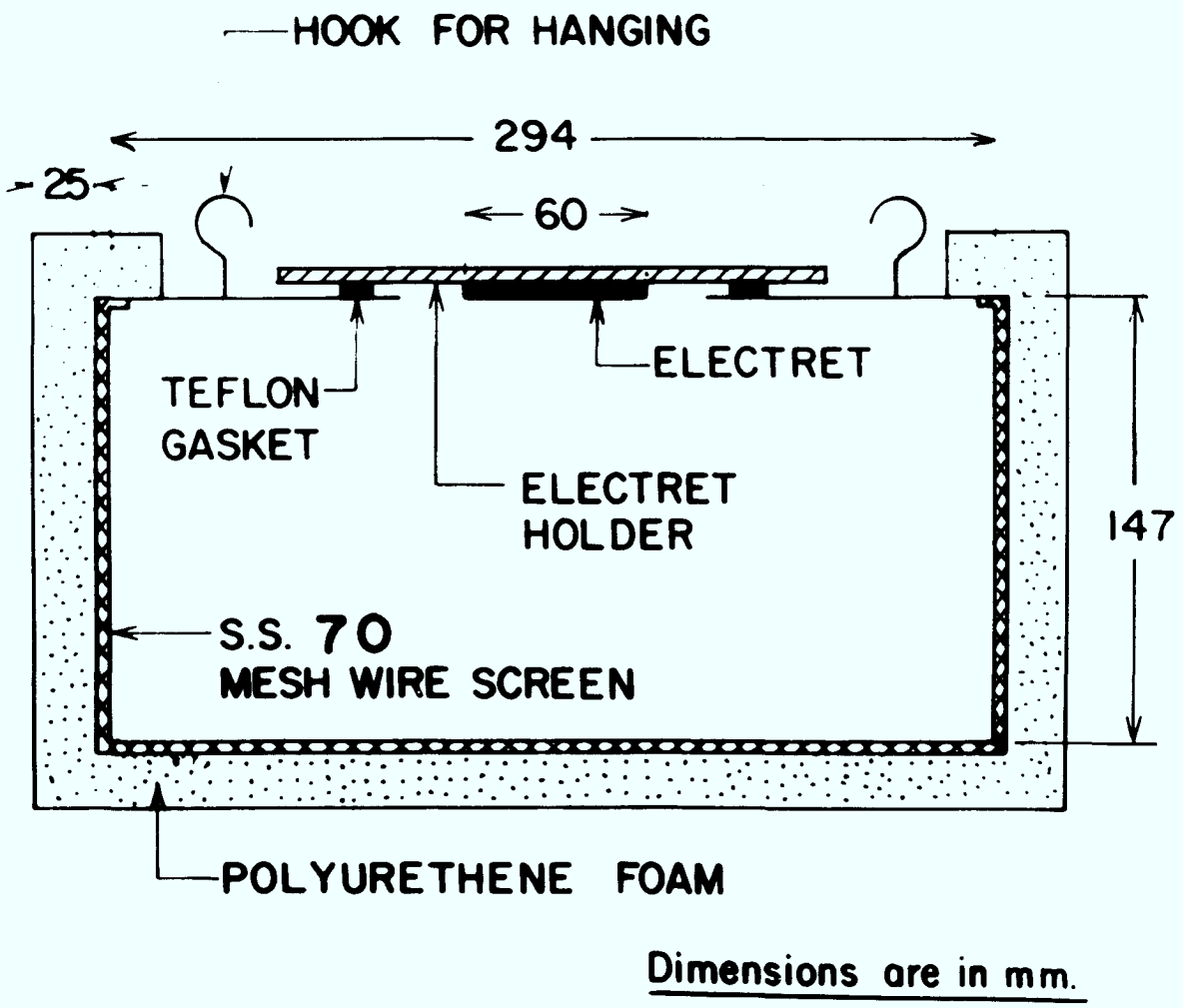

Figure 5:
Electret Chamber System for Measuring Concentration of Radon and Thoron

Table 2:
Measurements of Concentration of Radon and Thoron in Unventilated Laboratory Room by Electret Chamber System and Double Filter System

Date	Radon (pCi/m^3)			Thoron (pCi/m^3)		
	Electret System C_e	Double Filter System C_d	$\frac{C_d}{C_e}$	Electret System C_e	Double Filter System C_d	$\frac{C_d}{C_e}$
Feb 11	486	333	0.69	1371	1261	0.92
Feb 12	454	480	1.06	586	498	0.85
Feb 13	469	539	1.15	640	618	0.97
Feb 14	371	268	0.72	–	–	–
Mar 11	366	245	0.67	1954	2605	1.33
Mar 12	314	327	1.04	2651	3000	1.13
Mar 13	460	391	0.85	1042	1968	1.89
Mar 14	507	410	0.81	1542	909	0.59
Mar 15	464	447	0.97	769	979	1.27
Mar 18	274	240	0.88	1029	767	0.75
Mar 19	182	182	1.00	1449	2412	1.66
Mar 20	221	257	1.16	1146	1537	1.34
Mar 21	438	258	0.59	1605	1607	1.00
	Mean and standard deviation of $C_d/C_e = 0.89 \pm 0.19$			Mean and standard deviation of $C_d/C_e = 1.14 \pm 0.38$		

Note: Errors due to counting statistics were in the range of 5 to 10 % in all the measurements. Relative humidities were in the range of 50 to 60 % and a corresponding value for F_e was used in the calculations.

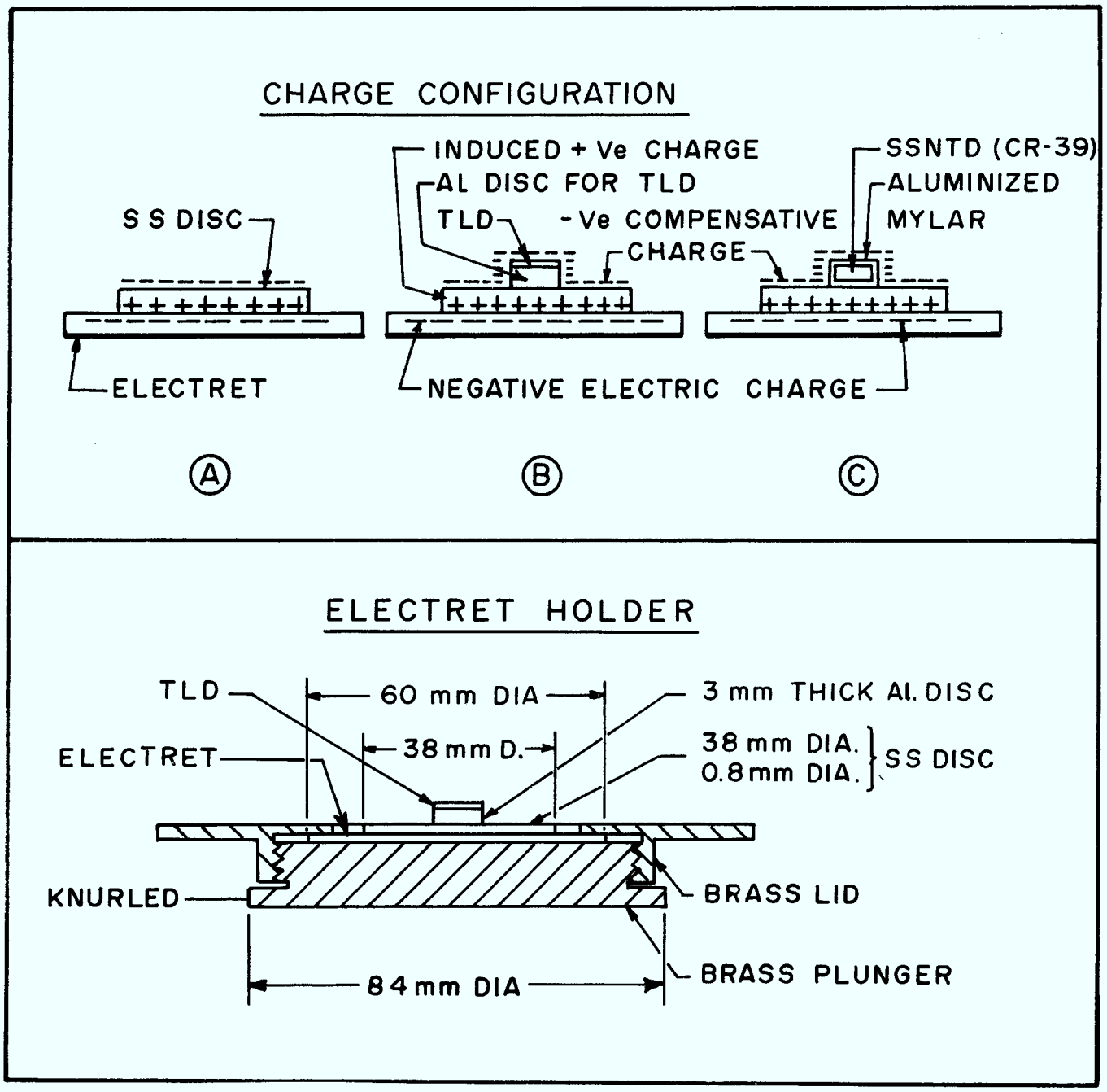

Figure 6:
TLD or SSNTD on Electret: Electret Charge Configuration and Electret Holder

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