

36824

RECORDS ADMINISTRATION
R0061766

DISPU 58-30-8
August 1958

1114-1-1
739914 ✓

PORTABLE MONITOR FOR TRITIUM IN AIR

J. D. Anthony
Savannah River Plant
E. I. du Pont de Nemours and Company
Aiken, South Carolina

To be offered for publication in a journal such as
"Review of Scientific Instruments" or "Nucleonics."

The information contained in this paper was developed during the course of work under Contract AT(07-2)-1 with the Atomic Energy Commission, whose permission to publish is gratefully acknowledged.

This document was prepared in conjunction with work accomplished under Contract No. AT(07-2)-1 with the U. S. Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

**Available for sale to the public, in paper, from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161,
phone: (800) 553-6847,
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/help/index.asp>**

**Available electronically at <http://www.osti.gov/bridge>
Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from: U.S. Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831-0062,
phone: (865)576-8401,
fax: (865)576-5728
email: reports@adonis.osti.gov**

Abstract

A portable air sampler was developed which will monitor concentrations of tritium in air between 4×10^{-5} and 1600×10^{-5} microcurie per cubic centimeter.

Introduction

In the handling of the tritium associated with heavy water moderator there is a possibility that some of it, in the form of tritiated hydrogen or water vapor, may become airborne. An instrument is needed which will quantitatively measure tritium in air in order to protect personnel from the radiation hazard associated with tritium.

Desirable requirements for such an instrument are that it be:

- Portable.
- Sensitive to 5×10^{-5} microcurie per cubic centimeter ($\mu\text{c}/\text{cc}$) of tritium in air.
- Linear on all scales.
- Insensitive to *gamma* radiation.
- Insensitive to all ionization not occurring within the ionization chamber.
- Equipped with an ion chamber which is easily decontaminated or replaced.

This paper describes an instrument developed to meet these requirements.

Summary

A portable tritium air sampler was developed which accurately detects concentrations of tritium in air between 4×10^{-5} and 1600×10^{-5} $\mu\text{c}/\text{cc}$. The instrument consists of a DC amplifier circuit, two ionization chambers, a deionizer, and a battery-operated motor and blower. The total weight of the unit is 18 pounds.

Gamma compensation is used to permit measuring low levels of tritium activity in a gamma field. Air is drawn through a sample chamber which passes a current proportional to the gamma field and the tritium in the air sample. The compensating chamber is adjusted to have the same gamma sensitivity as the sample chamber and is connected in the circuit so that its current subtracts from the sample chamber current. The difference current, which is proportional to tritium activity alone, is amplified and displayed on the meter indicator.

A deionizer is used to trap ions formed before the sample air enters the ion chamber.

The instrument was evaluated under varying levels of air activity and showed good agreement with nonportable instruments used for tritium air monitoring.

Discussion

General

The portable tritium air sampler operates on the same principle as the model 101 Sniffer (reference 1), a tritium alarm device developed at Los Alamos Scientific Laboratory. The air being sampled is continuously drawn through an ion chamber by a blower. Ions caused by tritium beta radiation are collected, and the resulting current flow is amplified and read on a microammeter.

Because it was desired to use the portable tritium air sampler as a health physics monitoring instrument, three additional requirements not necessary to an alarm device were considered. These were:

- The instrument reading should not be affected by gamma radiation.
- Only ions formed within the ion chamber should be collected.
- The amplifier should be linear.

The above requirements were met by using a gamma-compensating ion chamber, a deionizer, and a three-stage DC amplifier.

The over-all dimensions of the instrument are 5 x 10 x 16 inches long. The total weight including batteries and blower is 16 pounds. The assembled unit is shown in figure 1.

Gamma Compensation

A compensating chamber is used to minimize the sensitivity of the instrument to gamma radiation. The sampling chamber has an opening at each end through which an air stream is drawn. Ion pairs are formed in this chamber as a result of both gamma and tritium beta radiation. The compensating chamber has a volume equal to the sampling chamber; however, it is closed and measures only gamma radiation. The collecting electrodes of each chamber are connected to the grid of the electrometer tube. The conductive walls are equally and oppositely polarized. Any radiation common to both chambers (as would be the case in a uniform gamma field) results in the cancellation of current flow across the high-megohm input resistor.

Ionization Chambers

Construction. The ionization chambers (figure 2) are constructed of Flexiglas, and each has a volume of approximately 1800 cc. Chamber (a) is the compensating chamber, and since it will not become contaminated, it need not be removed once it has been installed. Chamber (b) has an opening at each end for passage of the air being sampled. The chamber is expected to become contaminated and therefore is removable for cleaning or replacement. Chamber (c) is a spare and is shown without the black conductive coating which is applied before use.

The ion chambers are plugged into banana jacks mounted on the chassis (to connect the conductive walls into the circuit). The three holes in the top of the ion chambers are for the collecting electrodes. Figure 3 shows the chassis compartment into which the ion chambers are inserted.

The collecting electrodes, mounted in "Teflon", have guard rings to reduce leakage across the "Teflon" insulation. Each chamber has three collecting electrodes to give a uniform electric field. They are permanently attached to the chassis and are not disturbed when the chambers are removed or inserted.

Adjustable Ionization Chamber Volume. Small differences in effective volumes are to be expected in ion chambers designed to avoid costly machining operations. A small volume difference results in an erroneous reading when the instrument is placed in a high gamma flux because of the incomplete cancellation of current. The magnitude of this error is directly proportional to the gamma flux. In order to correct for this difference, the compensating chamber has an inside false wall made of a thin sheet of brass. Moving the brass wall changes the effective volume of the ion chamber. The compensating chamber is slightly larger than the sampling chamber to insure that the volume difference will be within the range of adjustment. The adjustment is made at the time of calibration without removing either chamber from the instrument.

Deionizer

Since it is desirable to collect only those ions which are caused by tritium beta radiation within the chamber, a deionizer is provided to remove as many ions as possible from the air before it enters the chamber. Ions may be present in the atmosphere being sampled because of smoke, ionizing radiation, etc. The deionizer efficiently removes free ions from the air sample. However, large charged particles, such as those in cigarette smoke, are not efficiently collected by either the deionizer or the measuring chamber. Therefore, the instrument reading is not seriously affected by smoke unless it is present in such large concentrations that it is easily visible.

The deionizer is housed in an aluminum cylinder attached to the front of the instrument. It consists of positive and negative electrodes supplied by eight 22 $\frac{1}{2}$ -volt batteries connected in series. Figure 4 shows the construction of the deionizer.

Electronics

The amplifier is the same as that used in the Samson alpha survey meter (reference 2) with minor modifications. This amplifier was chosen because of its stability, linearity, and high current gain. It is a three-stage DC amplifier in which the input tube serves as an electrometer. The circuit employs 100% negative feedback for stability and has a current gain of approximately 1×10^6 . The amplifier is linear over the range that is used and has a drift rate of 8% of the $\times 10$ scale in the first hour, after three minutes warmup. The circuit diagram is shown in figure 5.

AC noise, developed in the amplifier is reduced by capacitor C-101 in parallel with the input resistor. The capacitor counteracts the shunting effect of the input capacity on AC feedback. C-101 is a coating of conductive paint on the glass case of the input resistor. When this capacitor is not present, circuit noise causes meter fluctuations as high as 40 microamperes. These fluctuations are reduced to less than 3 microamperes when C-101 is in the circuit.

Motor and Blower

The motor and blower are housed in the bottom of the instrument (figure 3). The motor is operated from two 6-volt batteries in parallel and has a continuous operation time of about 20 hours on one set of batteries. Battery life is actually much greater in ordinary use because the motor is not normally run continuously. Air flow through the chamber is between 0.75 and 3.3 cfm.

For ease of replacement, the batteries are accessible through a plate at the rear of the instrument.

Calibration

Initial. In order to determine whether or not the instrument would respond to tritium as expected, an experimental arrangement was set up in the laboratory as shown in figure 6. The portable tritium air sampler was connected in series with a 60-liter box in a closed system. Tritium was introduced into the box in the form of vaporized HTO by first drying the air in the box with silica gel and then placing a tray containing a solution of liquid HTO in the box. After sufficient tritium oxide had evaporated to give the desired concentration of tritium, the tray was removed. The air was then circulated continually by the instrument blower to give a uniform concentration throughout the system. A standard Applied Physics Corporation chamber connected to a calibrated vibrating reed electrometer was used to measure the amount of tritium in the sample.

Meter readings of the portable tritium air sampler and of the vibrating reed electrometer when sampling the same tritium atmosphere taken on two different test runs are compared in the table on page 7. Lower levels of tritium concentration were obtained by disconnecting the tubing at one point for a short time to allow contaminated air in the system to become diluted.

All of the readings of the portable tritium air sampler and the vibrating reed electrometer agree within $\pm 25\%$, which is estimated to be the accuracy of the air sampling method used.

<u>Run</u>	<u>Sample No.</u>	<u>Portable Tritium Air Sampler, $\times 10^{-5}$ $\mu\text{c}/\text{cc}$</u>	<u>Vibrating Reed Electrometer, $\times 10^{-5}$ $\mu\text{c}/\text{cc}$</u>
First	1	1050	820
	2	950	1037
	3	430	411
	4	155	151
	5	105	110
	6	70	92
Second	1	350	260
	2	210	164
	3	152	121
	4	105	88
	5	85	66
	6	55	47
	7	35	30
	8	25	25

Some residual contamination was noted after the chamber had been exposed to relatively high concentrations of tritium. In one instance, after exposure to $1500 \times 10^{-5} \mu\text{c}/\text{cc}$ concentration for 15 minutes, approximately 30 minutes were required for complete evacuation. Apparent evacuation was noted in a much shorter period of time, but the meter indication slowly increased after the blower was turned off. This drift was probably due to release into the chamber of tritium oxide which had been adsorbed on the chamber walls.

Routine. Provision is included in the portable tritium air sampler to use a gamma source for calibration, since routine calibration using tritium is impractical. A switch is provided which eliminates the gamma-compensating feature during calibration and places the two chambers in parallel.

The following calculation is used to determine the gamma equivalent of tritium beta radiation.

For air containing a tritium concentration of 1×10^{-5} $\mu\text{c}/\text{cc}$, the current flow due to ionization within the chamber is

$$I = \frac{(1600 \text{ cc})(1 \times 10^{-5} \mu\text{c}/\text{cc})(3.7 \times 10^4 \text{ d/s})(5690 \text{ ev})(1.6 \times 10^{-19} \text{ coulomb})}{35 \text{ ev}}$$

$$= 1.54 \times 10^{-14} \text{ ampere}$$

where: 1600 cc = volume of ionization chamber

3.7×10^4 d/s = disintegrations per second for 1 microcurie

5690 ev = average energy of tritium beta in electron volts

1.6×10^{-19} = charge of an electron in coulombs

35 ev = energy in electron volts, given up by tritium beta forming an ion pair in air (reference 3)

By a similar calculation, it can be shown that for a field of one milliroentgen per hour of gamma radiation, 14.8×10^{-14} ampere will flow in the same circuit.

$$\text{Therefore, } \frac{14.8 \times 10^{-14} \text{ amp}}{1 \text{ mr/hr}} \times \frac{1 \times 10^{-5} \mu\text{c}/\text{cc}}{1.54 \times 10^{-14} \text{ amp}} = 9.61 \times 10^{-5} \frac{\mu\text{c}/\text{cc}}{\text{mr/hr}}$$

It can be seen from the above calculation that a field of 1 mr/hr causes the same current to flow as 9.61×10^{-5} $\mu\text{c}/\text{cc}$ tritium. Because two chambers are used in calibrating and only one in detecting tritium, 1 mr/hr of gamma radiation gives a reading equal to 2 (9.61×10^{-5}) or 19.22×10^{-5} $\mu\text{c}/\text{cc}$ tritium.

Because the characteristics of some of the circuit components may change with use the sampler should be recalibrated every 2 weeks.

References

1. Eutsler, B. C. et al. Instruments for the Monitoring of Tritium in the Atmosphere. Los Alamos Scientific Laboratory, LA-1909, April 1955.
2. "Operating Instructions - Samson Alpha Survey Meter," Radioactive Products, Inc., Ferndale, Michigan.
3. Valentine, J. M. and Curran, S. C., "Energy Expenditure Per Ion Pair for Electrons and α -Particles." Philosophical Magazine, 43, 964-767 (1952).

AEC RESEARCH AND DEVELOPMENT REPORTS ON TRITIUM INSTRUMENTATION

These reports, although not used as references for this report, contain allied information.

Colvin, D. W., "A Simple Monitor for Tritium Contamination on Surfaces," DP-242.

Ryder, F. D., "An Explosion-Resistant Ion Chamber for the Measurement of Tritium," DP-150.

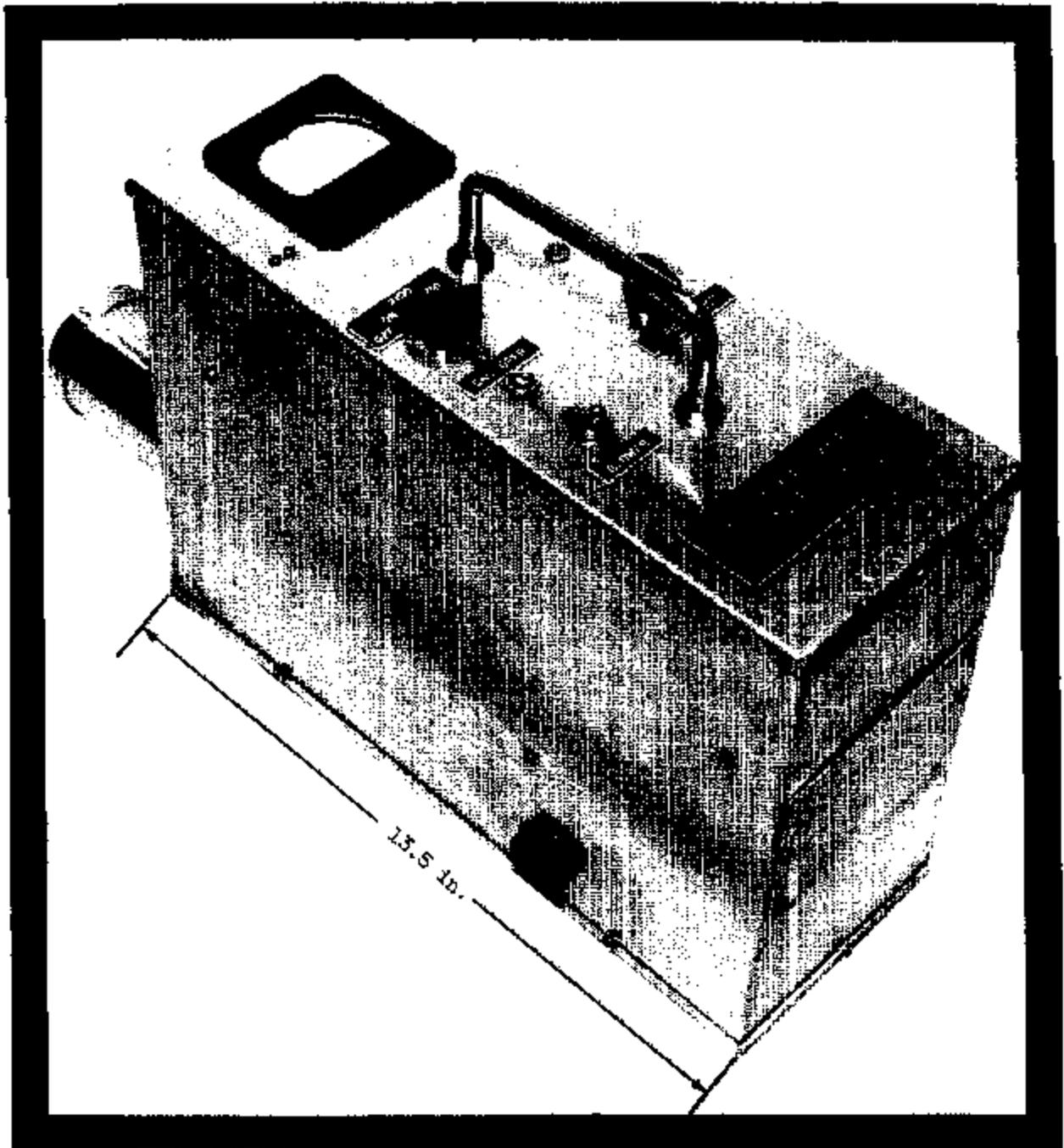


Figure 1. Portable Tritium Air Sampler

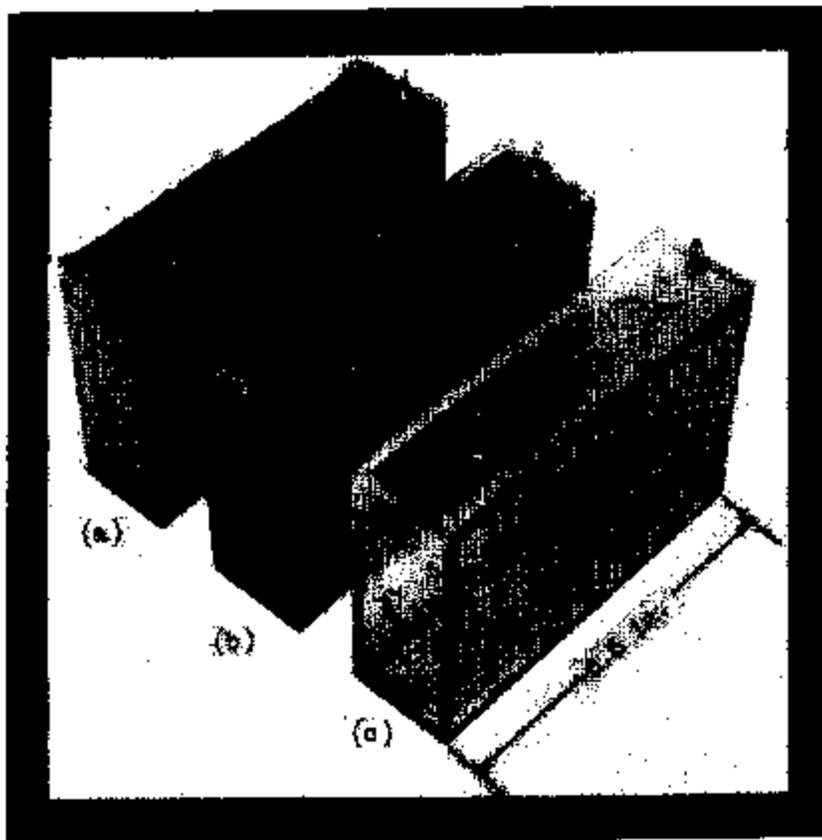


Figure 2. Ion Chambers

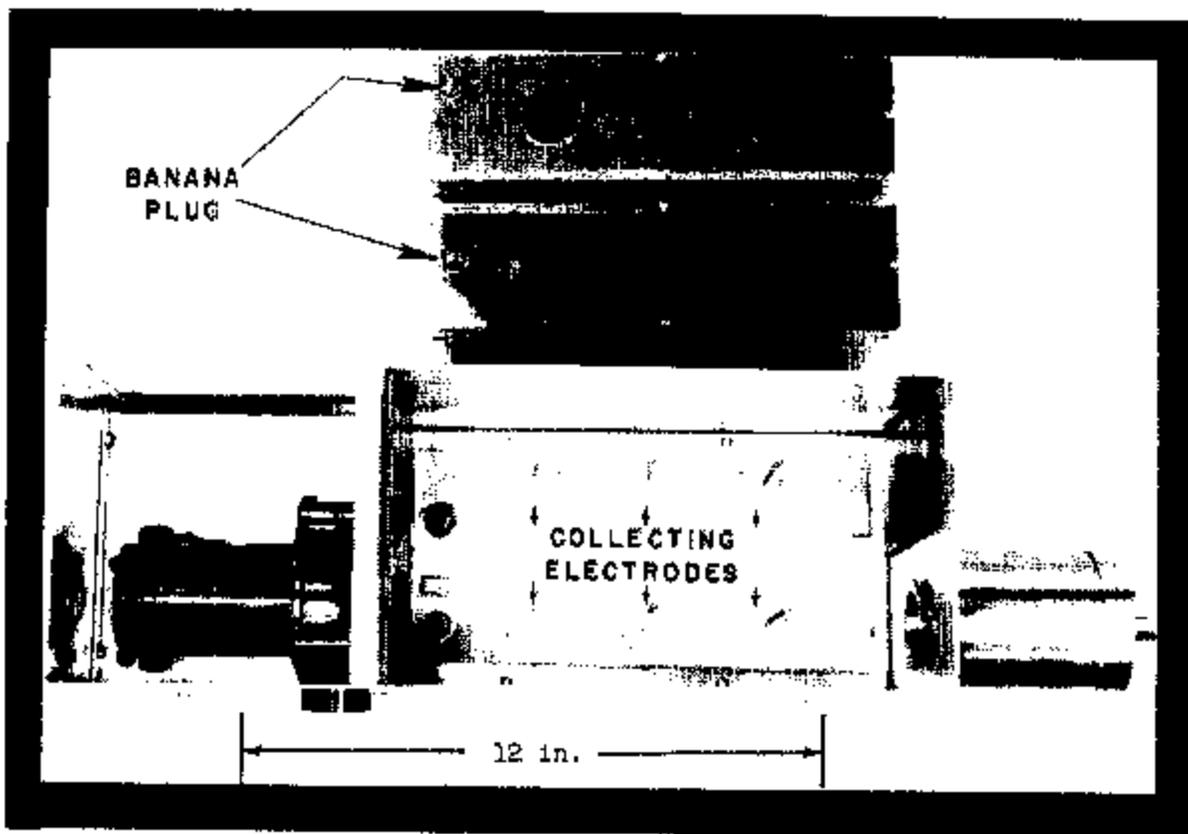


Figure 3. Motor and Ionization Chamber Compartments

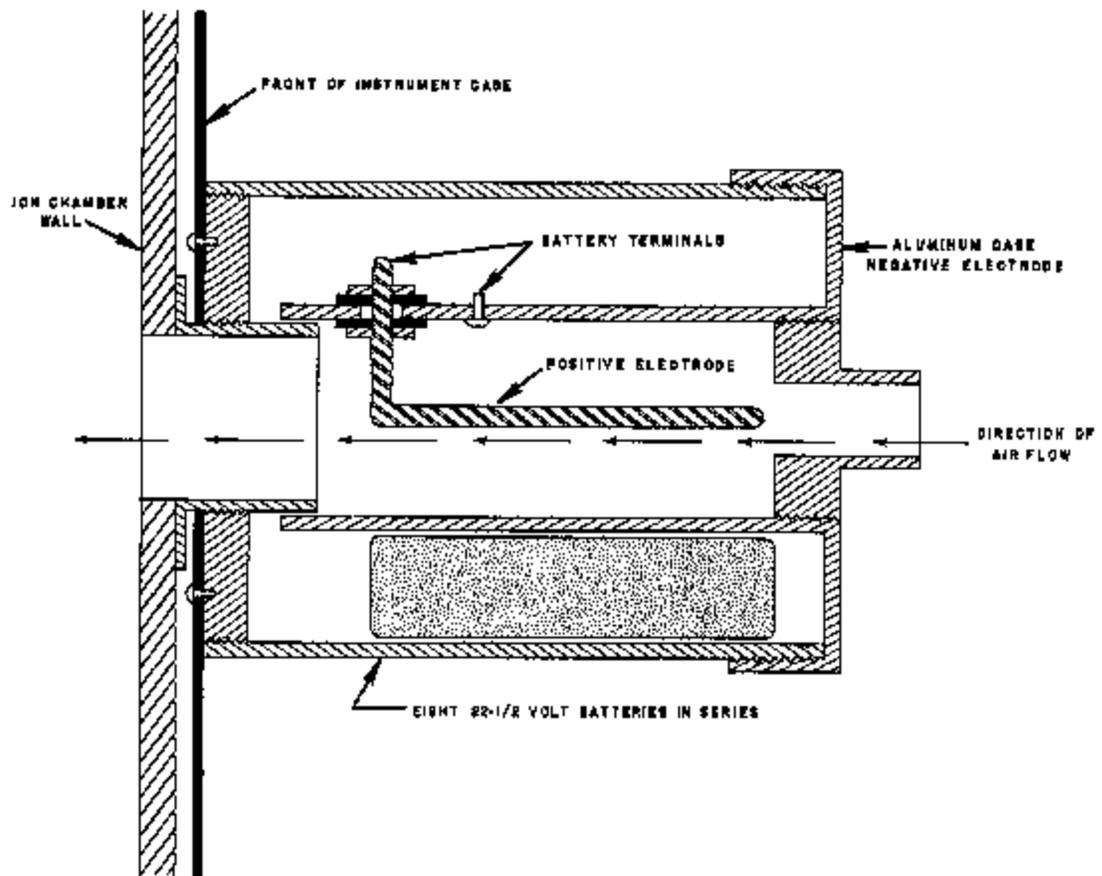


Figure 4. Cross-Section of the Deionizer

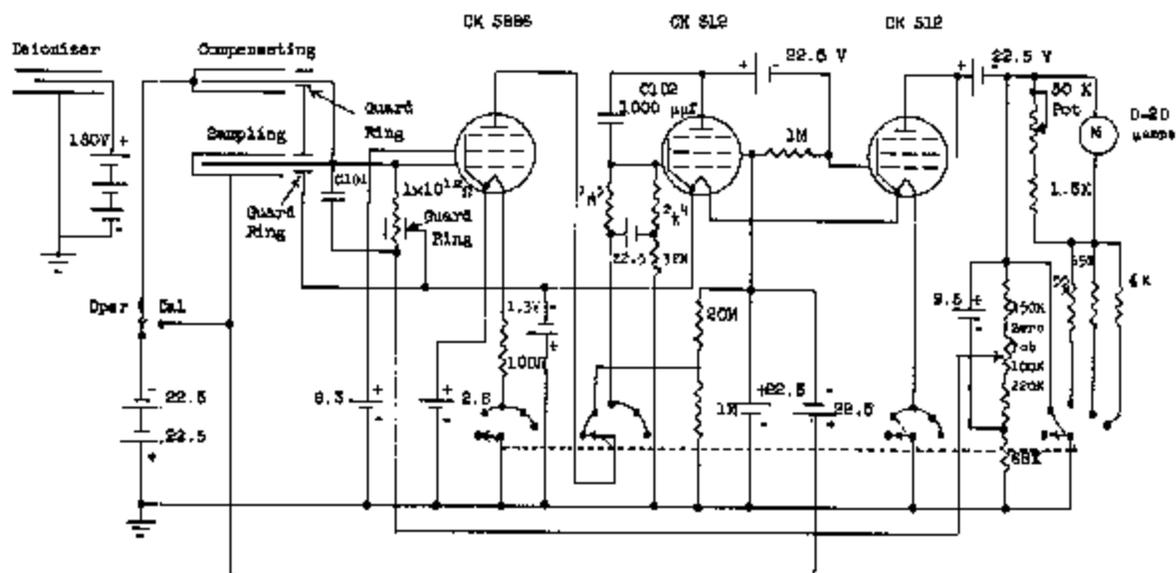
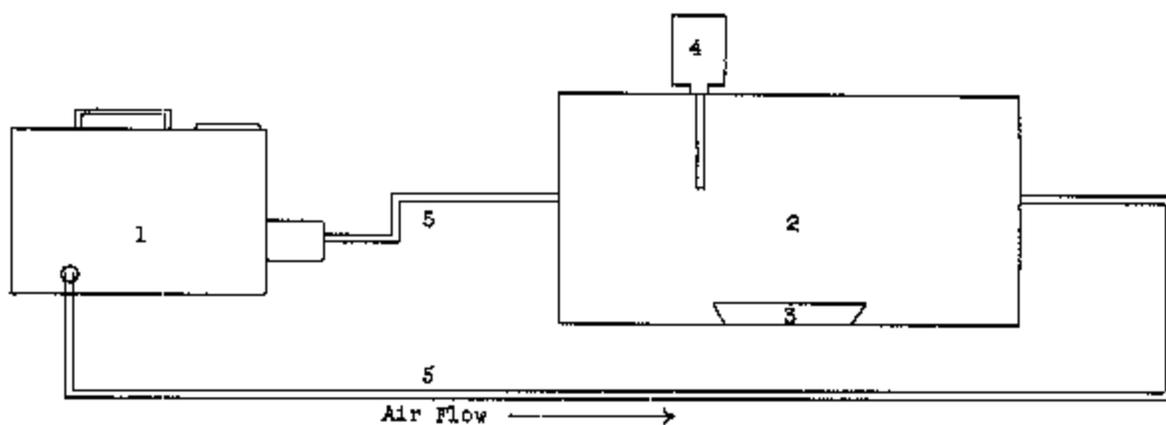


Figure 5. Circuit Diagram



1. Portable Tritium Air Sampler
2. Sealed Box
3. Tray Containing ETO
4. Vibrating Reed Electrometer Chamber
5. Tygon Tube Forming Closed System

Figure 6. Tritium Response Test Setup

M419-8322-1
NC4-01-01