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Instrumentation

AEC Research and Development Report

AN EXPLOSION-RESISTANT ION CHAMBER FOR THE MEASUREMENT OF TRITIUM

by
F. D. Ryder
Instrument Development Division

March 1956

E. I. du Pont de Nemours & Co.
Explosives Department - Atomic Energy Division
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ABSTRACT

An ion chamber was constructed to monitor gaseous tritium in hydrogen-oxygen mixtures that have a high relative humidity and that might fall within the explosive limits. In calibration tests the ion chamber responded linearly to tritiated water vapor in air, at concentrations from 10^{-5} to 10^{-4} microcurie per cubic centimeter. The chamber withstood deliberate internal explosions without detectable damage.

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AN EXPLOSION-RESISTANT ION CHAMBER FOR THE MEASUREMENT OF TRITIUM

INTRODUCTION

An explosion-resistant ion chamber was needed for the continuous measurement of tritium in gaseous mixtures. The tritium was present with hydrogen and oxygen in a gaseous mixture that might occasionally fall within the explosive limits.

It was necessary to solve two problems in chamber design:

1. The chamber was required to withstand explosions of the gas mixture.

2. The chamber was required to operate satisfactorily under humid conditions, when the incoming gas had a dew point as high as 15°C.

This report describes the construction of the ion chamber and measurements of its sensitivity.

SUMMARY

An ion chamber was constructed with heavy-walled pipe to withstand possible internal explosions. Automobile spark plugs were used as explosion-resistant electrical lead-ins.

In calibration tests, the ion chamber responded linearly to tritiated water vapor in air at concentrations from 0.8 to 13.3 x 10^{-5} microcurie per cubic centimeter.

The walls of the chamber could be heated to prevent the condensation of moisture at high humidities. As a result, satisfactory operation was obtained with the incoming air saturated at 21°C.

DISCUSSION

CONSTRUCTION OF THE CHAMBER

A sketch and photograph of the ion chamber are shown in Figures 1 and 2. The sketch of Figure 1 shows the assembly of the electrodes and their connectors. Figure 2 shows the ion chamber with the connector caps removed and a heating tape wrapped around the chamber walls. The chamber is 25 inches long and has a sensitive volume 2 inches in diameter.

The chamber was designed to withstand explosions of the incoming gas. Schedule 40 stainless steel pipe and 1/2-inch thick end caps were used for the body of the chamber. Spark plugs were used for the electrode connections. The chamber withstood ten deliberate internal explosions without suffering any detectable damage.

CALIBRATION SETUP

For the purpose of calibration, the ion chamber was connected into a closed system in which air containing water vapor or tritiated water vapor was circulated. A diagram of this system is shown in Figure 3.

The water and tritiated water samples were introduced into the system by way of a closed vessel, which was heated slightly to evaporate the sample. A diaphragm pump circulated the vaporized sample and air through the system. A 90-liter tank was included in the system to mix the vapor and air. A hygrothermograph in the system measured the relative humidity and temperature of the circulating gas.

Before a sample was introduced into the system, the air in the system was circulated through a "Drierite" bypass until the hygrothermograph showed zero relative humidity. The sample was then introduced into the system with the "Drierite" bypass closed and the main line opened.

The ionization current from the chamber was measured with a Beckman Model V micromicroammeter (Figure 4) and recorded by a 50-millivolt Brown recorder.

EFFECT OF HUMIDITY ON ION CHAMBER CURRENT

The background current of the chamber was affected by the humidity in the chamber. The average background ion current of the chamber with dry air was 2.6×10^{-13} ampere, with current fluctuations covering a range of approximately 0.4×10^{-13} ampere. After a water sample was introduced the average ion current increased to 3.0×10^{-13} ampere, at a relative humidity of 40 per cent. Fluctuations remained at approximately 0.4×10^{-13} ampere.

Between 40 and 80 per cent relative humidity the current fluctuations increased abruptly to as much as 3×10^{-13} ampere, which prevented a successful determination of the average ion current. Above 80 per cent relative humidity the ion current dropped to zero. Presumably, water vapor in the chamber had condensed on the insulators and shorted the electrodes to the body of the chamber.

To improve the performance of the chamber under conditions of high humidity, a heating tape was wrapped around the chamber and the temperature of the chamber walls was raised to approximately 200°C. After the chamber was heated, the ion current was reasonably stable for humidities up to saturation at 21°C, which was the temperature of the air entering the chamber. The current fluctuations were again approximately 0.4 to 10^{-13} ampere. However, the average background current was increased to 4.8×10^{-13} ampere at a relative humidity of 100 per cent.

When the circulating air was kept below 40 per cent relative humidity, the average chamber current did not vary as the chamber walls were heated. The chamber background current was therefore a function of the humidity, but was not a function of the temperature of the air.

CHAMBER CURRENT RESPONSE TO TRITIUM

Five one cubic centimeter samples of tritiated water were used in calibrating the ion chamber. Their activity ranged from 0.7 to 12.9 microcuries. Under the assumption that the tritiated water was completely evaporated and distributed equally throughout the circulating air, the tritium activity in the system ranged from 0.8 to 13.3×10^{-5} microcurie per cubic centimeter of air. The tritium sample was allowed to circulate through the system for four hours before the current response of the chamber was recorded. After the chamber current was recorded, the air in the system was routed through the "Drierite" bypass for 17 hours. This procedure removed the tritiated water vapor from the air in preparation for the next sample.

The current response to each sample is recorded in Table I and is designated "actual current response." The "actual current response" is the difference between the average background current of 2.9×10^{-13} ampere, obtained by introducing one milliliter of normal water into the volume of the system, and the average total current for each tritiated sample. The chamber was not heated during the tritium calibrations. The temperature of the chamber and the circulating air was 21°C, and the relative humidity of the air was 30 per cent.

The ion current was calculated as shown in the Appendix. For the system in question the equation representing this calculated current response is

$$I = 1.18 \times 10^{-9}\ C_S \text{ ampere}$$

where C_S is the tritium concentration in the system, expressed in microcuries per cubic centimeter of air. The calculated current response for each sample is also shown in Table I.

Calculated and actual response curves are shown in Figure 5.

At tritium concentrations above 2×10^{-5} microcurie per cubic centimeter of air the actual current response of the chamber was greater than that calculated. The equation derived in the Appendix took into account only the ionization produced in the sensitive volume of the chamber, and was useful only to show the order of magnitude of the expected currents.

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APPENDIX

CALCULATION OF ION CHAMBER CURRENT

If the ion chamber current is assumed to be due only to the ionization produced in the sensitive volume of the chamber, then

$$I = \frac{3.7 \times 10^4 \, eE}{32.5} \times C_S \, V_C$$

I = ion chamber current, amperes

e = charge on electron = 1.6×10^{-19} coulomb

E = average energy of the tritium beta particles = 6000 ev

32.5 = average energy to form ion pair, ev

3.7×10^4 = disintegrations per second per microcurie

C_S = concentration of tritium sample in the system, microcuries per cubic centimeter of air

V_C = sensitive volume of the ion chamber = 1.08×10^3 cubic centimeters

Therefore

$$I = 1.18 \times 10^{-9} \, C_S \text{ ampere}$$

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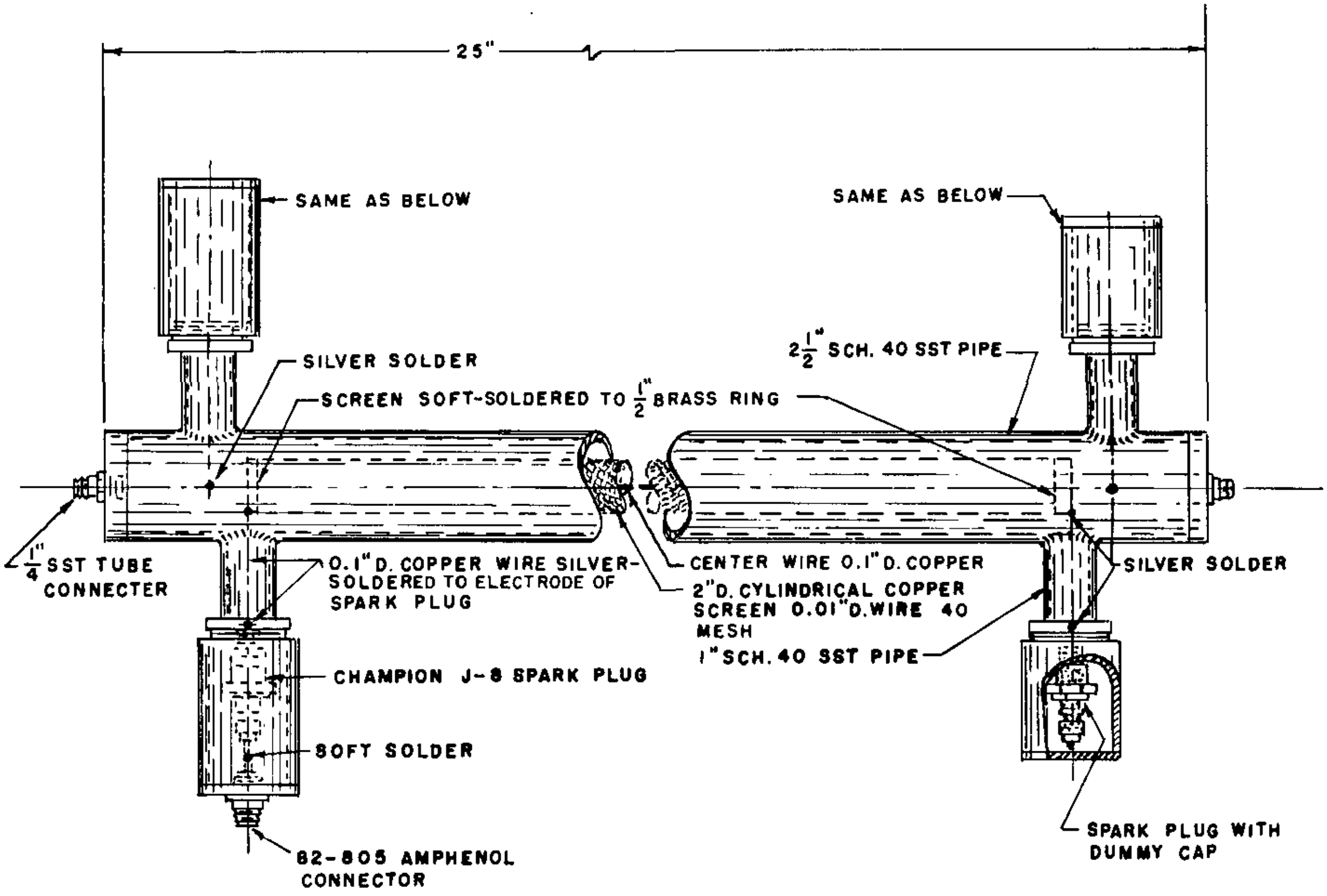
TABLE I

ION CHAMBER CURRENT RESPONSE TO TRITIUM SAMPLES

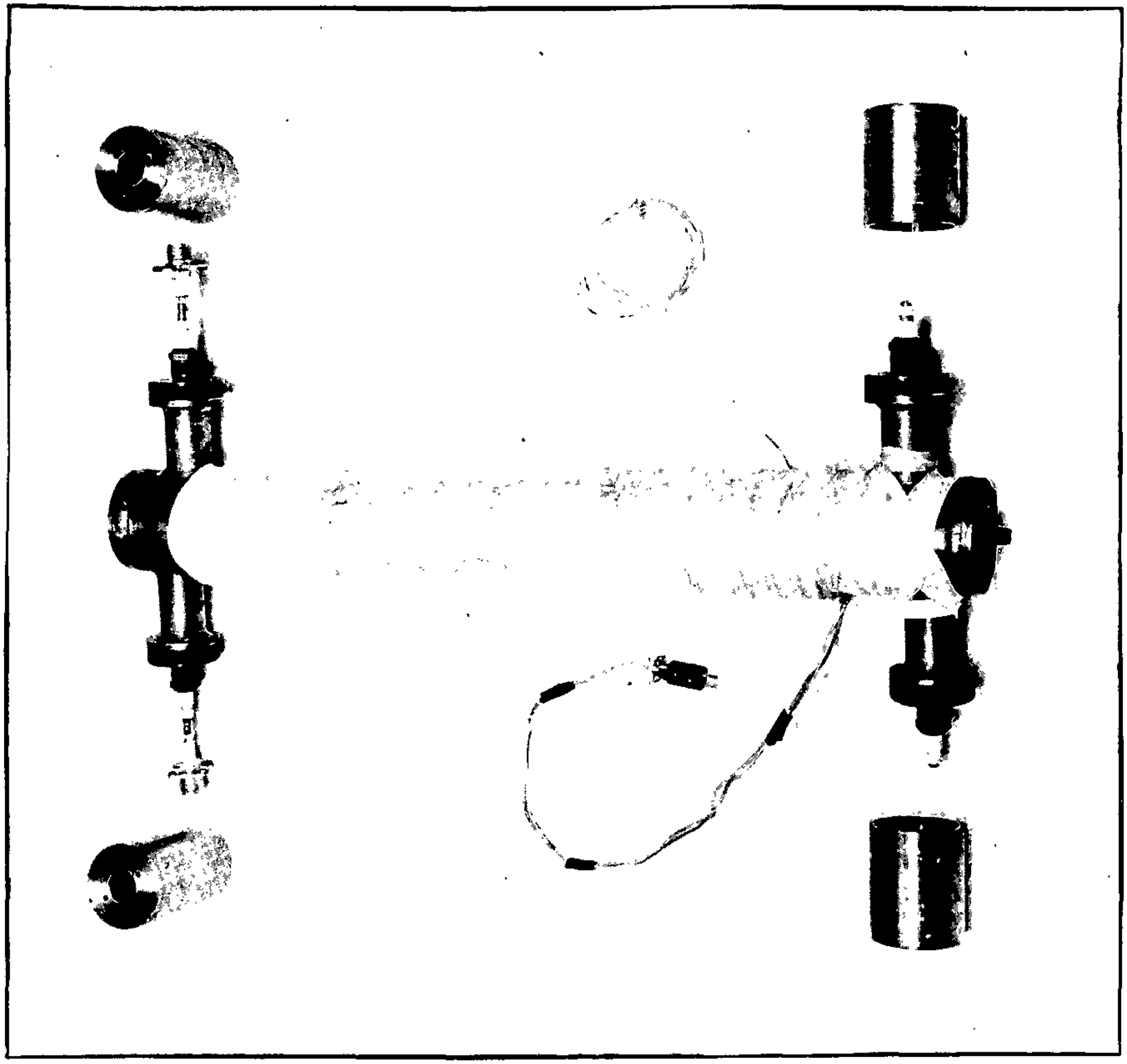
mple No.	Tritium Concentration in the System, Microcurie per Cubic Centimeter of Air	Calculated Current Response, Ampere	Actual Current Response, Ampere
1	0.8×10^{-5}	0.1×10^{-13}	0.1×10^{-13}
2	1.5×10^{-5}	0.2×10^{-13}	0.2×10^{-13}
3	2.6×10^{-5}	0.3×10^{-13}	0.7×10^{-13}
4	6.7×10^{-5}	0.8×10^{-13}	1.6×10^{-13}
5	13.3×10^{-5}	1.6×10^{-13}	3.5×10^{-13}

FIGURE 1



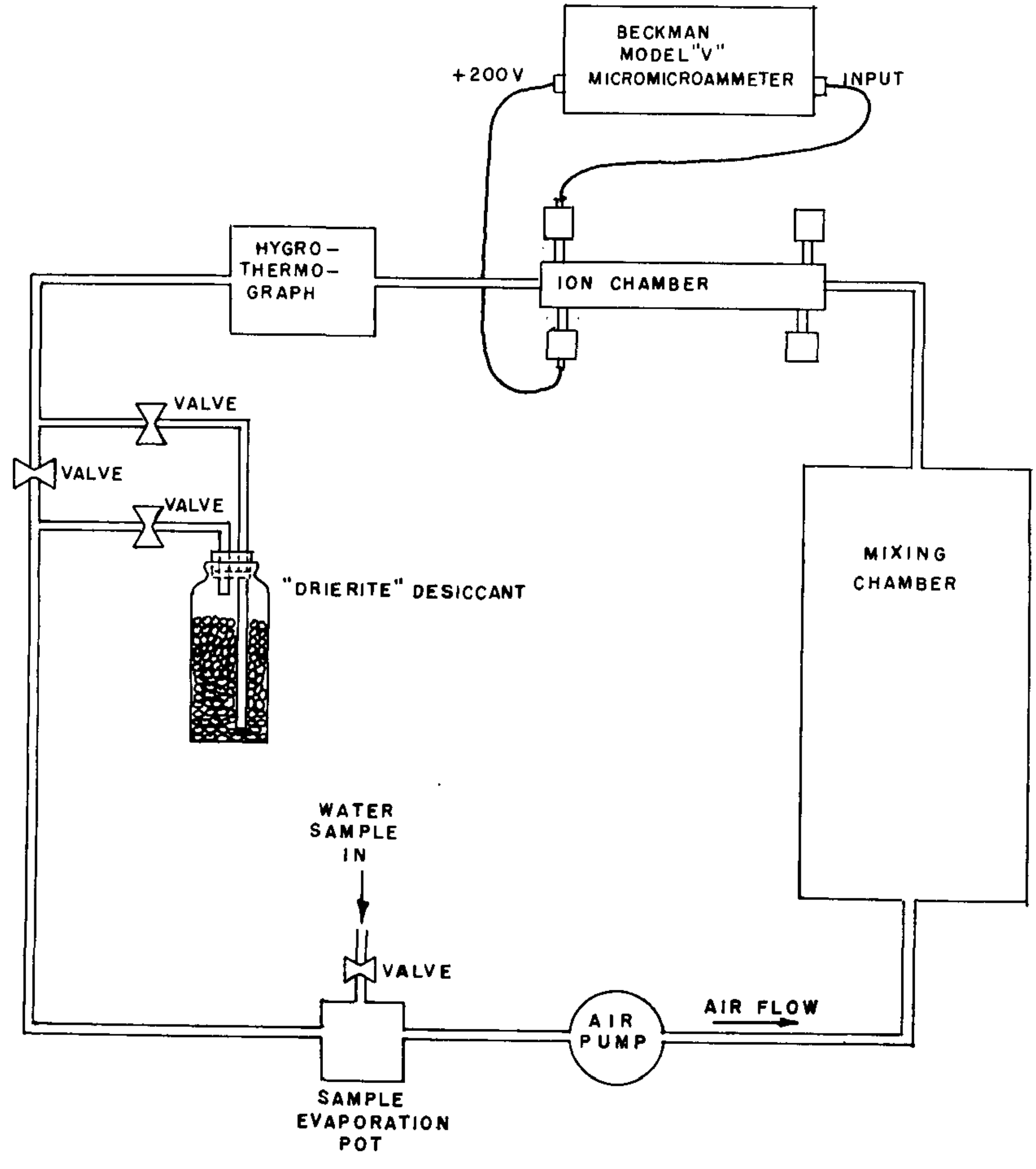
EXPLOSION–RESISTANT ION CHAMBER

FIGURE 2



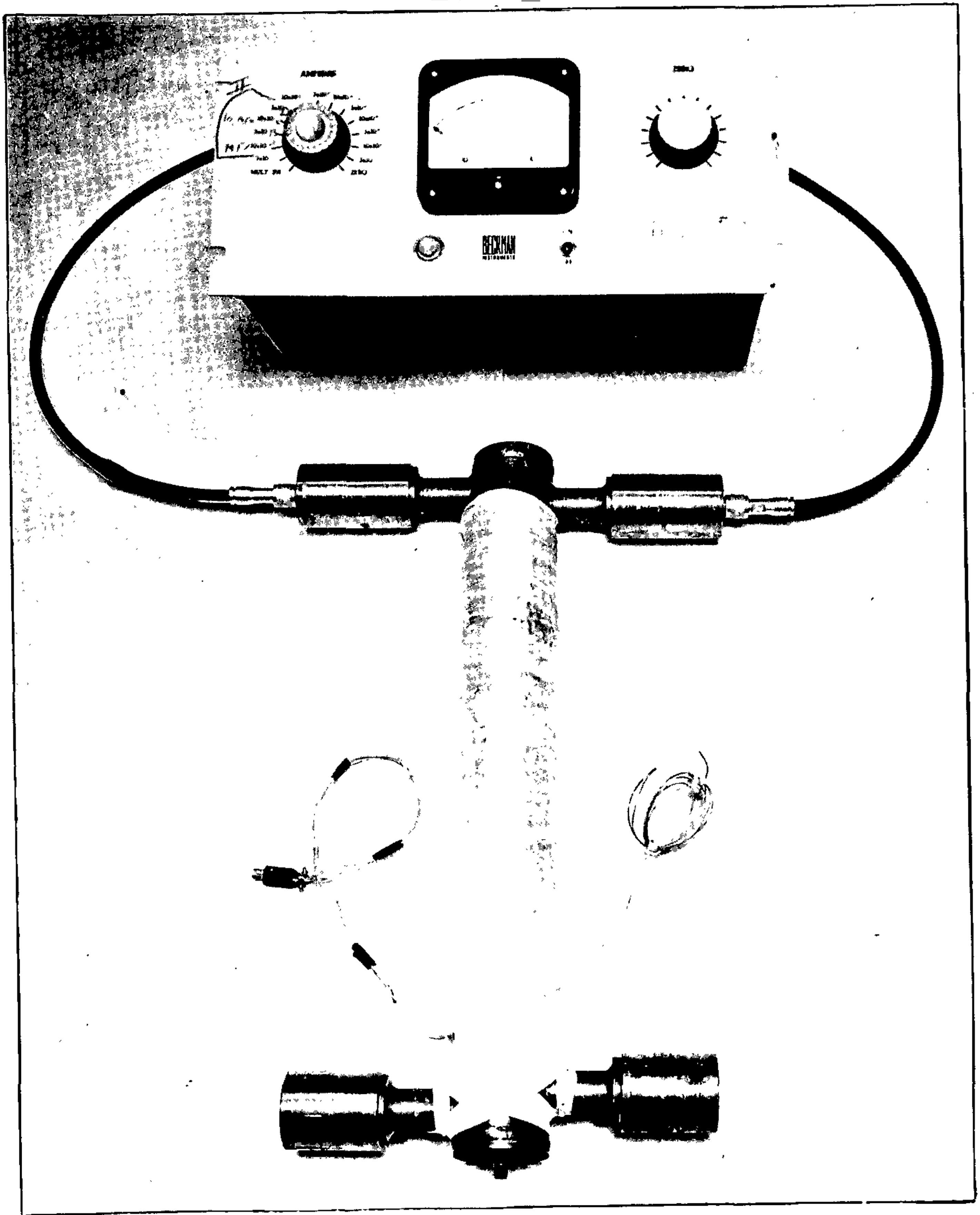
EXPLOSION-RESISTANT ION CHAMBER WITH THE CONNECTOR CAPS REMOVED

FIGURE 3



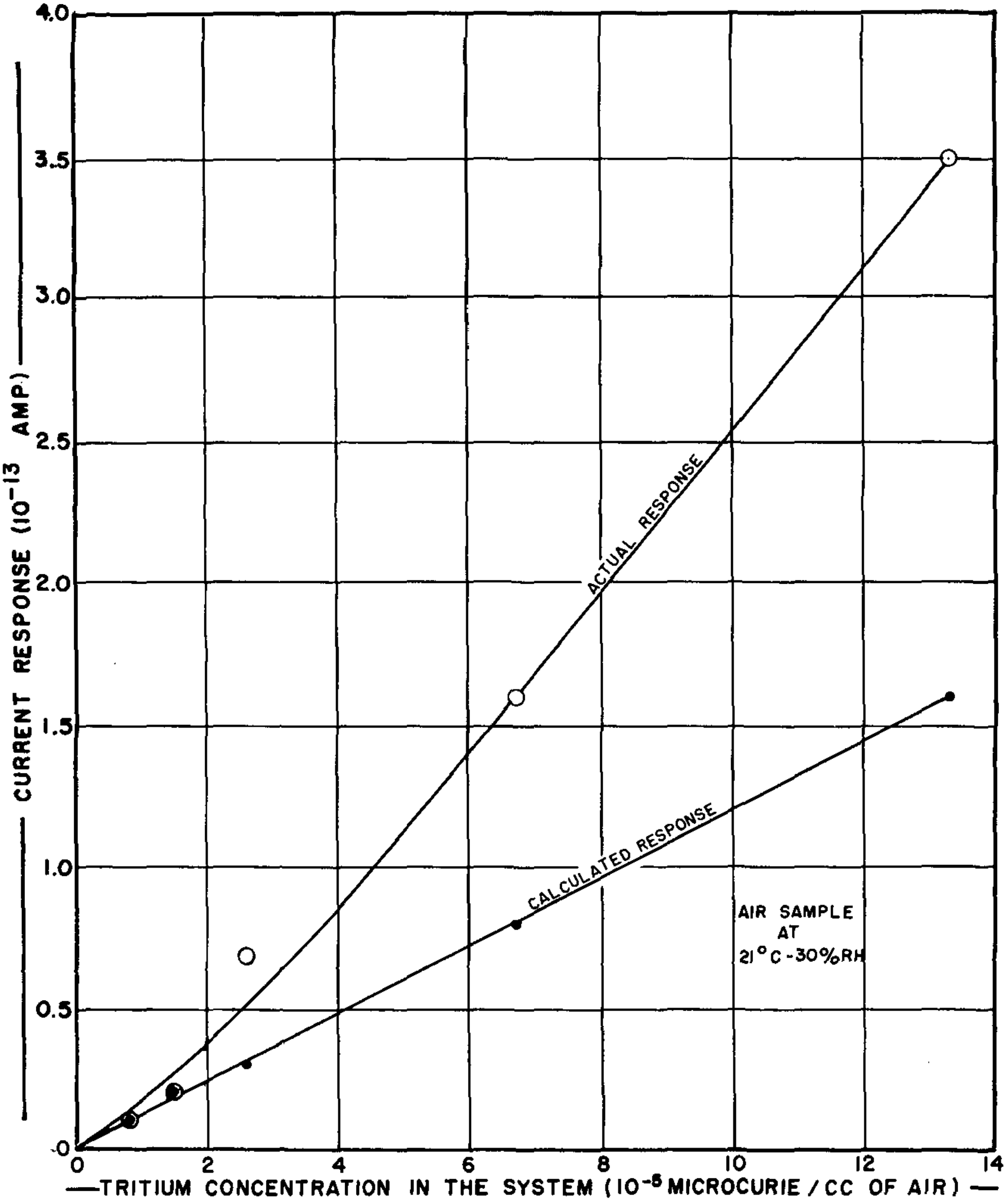
CALIBRATION SETUP FOR THE EXPLOSION-RESISTANT ION CHAMBER

FIGURE 4



EXPLOSION-RESISTANT ION CHAMBER WITH BECKMAN MICROMICROAMMETER

FIGURE 5



EXPLOSION-RESISTANT ION CHAMBER CALIBRATION