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A METHOD OF PRODUCING AN ELECTRIC CURRENT FROM RADIOACTIVITY

By
P. E. Ohmart

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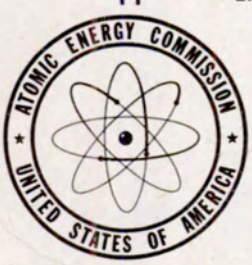

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MIAMISBURG, OHIO

A METHOD OF PRODUCING AN ELECTRIC CURRENT FROM RADIOACTIVITY

Date: September 11, 1950
Written By: P. E. Ohmart

Approved By: R. A. Staniforth
Research Division Director

Experiments have shown that if a cell, made up of two electrochemically dissimilar materials separated by a gas, is connected to a current measuring device, a small continuous current will be caused to flow from the more noble to the more active electrode without an external source of voltage when the separating gas is forcibly ionized by exposure to nuclear radiation. The current thus produced has been found to be dependent upon the nature of the electrodes and their surfaces, the type and flux density of the energizing radiation, the type and pressure of the filling gas, and (when excited by gamma-radiation) the gamma-stopping power of the electrodes.

It has been found, for example, that if a cell with one electrode made of gold and the other of lead with air as the filling gas is energized by gamma-radiation, a small, continuous current will flow from the gold to the lead. If a copper electrode is substituted for the gold, the current is smaller but the polarity is the same. When the surface of the copper is oxidized the current increases and is greater than that originally obtained with the gold. When a lead electrode having a surface that is identical with the other lead electrode is substituted for the gold electrode, no current flows. When an aluminum electrode is substituted for the gold, the current is weaker and is reversed in polarity.

By connecting a potentiometer with such a polarity that increasing the voltage of the potentiometer caused a reduction in the current flow and adjusting it until the current dropped to zero, it was found to be possible to measure the open-circuit voltage of the cell. By carrying out a number of measurements with various types of filling gases at different pressures, with various types of energizing radiation on a number of different electrode combinations, it was found that the open-circuit voltage of the cell is apparently dependent upon the character of the surfaces of the electrodes only and is essentially independent of the type and pressure of the filling gas, the geometry of the cell, and the type of energizing radiation. A list of open-circuit voltages of cells with aluminum negative electrodes (Al_2O_3 surfaces) and different positive electrodes is given in Table I. It will be noted that these fall in the same general position as they appear in the electrochemical series.

TABLE I

OPEN-CIRCUIT VOLTAGES OF CELLS WITH ALUMINUM (Al_2O_3) NEGATIVE ELECTRODES

POSITIVE ELECTRODES	CHARACTERISTIC POTENTIAL *(volts)*
PbO_2 PLATED ON GOLD	1.34
OXIDIZED COPPER	0.975
GOLD PLATED ON COPPER	0.95
SILVER	0.67
COPPER	0.64
BRASS	0.64
LEAD	0.2
CHROMIUM	0.18
ZINC	-0.01

The current, on the other hand, was found to increase as the flux density increased, to increase as the molecular weight of the filling gas increased (ionization potential of the gas also seems to be an influencing factor), to approach zero as the gas pressure approached zero, and to depend on the type of energizing radiation. Also, when a cell was energized by gamma-radiation, it was found that the gamma-stopping power of the electrodes was an important factor since some ionization of the filling gas is produced by secondary electrons emitted from the surfaces of the electrodes. For example, a gold:lead cell gives greater current flow from gamma-radiation than a copper oxide:aluminum oxide cell even though its open-circuit voltage is lower.

The fact that the current approaches zero as the pressure of the gas approaches zero and an experiment carried out with alpha-activity in which the cell was so arranged that current flow was caused by ionization of the gas alone (since none of the alpha-particles could strike either electrode) indicate that practically none of the total current is produced by selective secondary electron emission from the electrodes. Also it should be noted that when a light metal is employed as the positive electrode and a heavy metal as the negative electrode, tendencies for current flow caused by secondary electron emission from the electrodes will be in opposition to the direction that the current actually has been observed to flow.

From the foregoing it appears as if these cells are essentially constant-voltage generators with variable internal impedances and that there is a close analogy between these and the ordinary electrolytic cells. The voltage in both types of cells is dependent upon the nature of the electrodes, and the current is dependent upon the concentration of ions between the electrodes as well as the external load resistance. Also there is an analogy to the behavior of an ordinary ionization chamber. In the ionization chamber the electrodes may be identical, and an external potential is required to make the radiation-produced gas ions move and thus produce a current. Whereas, in this cell the inherent potential difference between the electrodes produces the necessary potential.

Also it is interesting to note the similarity of the method of measuring the open-circuit voltages of the cells and the Kelvin Null method of measuring contact differences of potential. In the Kelvin Null method contact potentials are made to produce a current flow by vibrating a reed in the electrostatic field produced by the contact potential of the electrodes. In these cells, the current flow is produced by ionizing the gas in the field between the electrodes.

Initial efficiencies of conversion of radioactive energy to electrical energy that were achieved were only of the order of 1×10^{-11} percent when an air cell was excited by gamma-radiation from a 24.8 milligram radium source. In order to improve these efficiencies the co-axial type cell, shown in Figures 1 and 2, was constructed. In this cell the negative electrode was prepared by first plating the brass case with lead and then coating the lead with magnesium by metal evaporation. Thus, since no efforts were made to protect it from oxygen, the negative electrode had a magnesium oxide surface. The positive electrode was made by plating brass shim stock first with gold and then with lead-dioxide. The characteristic potential of the cell was 1.24 volts. The cell was filled with argon gas at 70 pounds per square inch gauge. The sample was mounted in the center of the cylinder so that greater than 50 percent geometry was obtained.

When this cell was connected to the simple electrometer circuit shown in Figure 3 and was checked for sensitivity and linearity with several calibrated Co^{60} sources the curve shown in Figure 4 resulted.

When the cell was excited with approximately 11 microcuries of Ag^{110}, 0.86 volt was developed across 1×10^{11} ohms, thus the electrical power that was received from the cell was 7.3×10^{-12} watt. If the assumption is made that the gamma-radiation from Ag^{110} has an average energy of 1.0 million electron volts, then the power that would be available from the source would be (number of disintegrations per second) x (the energy of the gamma-photons) x (charge on an electron). In numerical values this would give

$$(11.0 \times 10^{-6} \times 3.7 \times 10^{10}) \times (1.0 \times 10^{6}) \times (1.59 \times 10^{-19}) = 6.49 \times 10^{-8} \text{ watt.}$$

So the over-all efficiency would be

$$(7.3 \times 10^{-12}) / (6.49 \times 10^{-8}) \times 10^{2} = 0.011 \text{ percent.}$$

If this is corrected by a geometry factor so that only the gamma-energy that is available for conversion to electrical energy is considered, then the efficiency would be about 0.02 percent.

For recoil-proton or alpha-detection where it is desirable to discriminate against gamma-radiation, it has been found desirable to make electrodes of light materials such as aluminum for the negative electrode and copper-oxide-on-copper or carbon for the positive electrode to reduce the number of secondary electrons emitted from the electrodes.

Although this effect may be found to have many uses, so far its applications mainly have been confined to the measurement of electrode potentials, to the measurement of the rate of growth of oxide films, and to the measurement of gamma-radiation in a portable gamma-monitor. It has been possible to build a gamma-monitor that has an over-all size of 3 1/8 inches by 3 1/8 inches by 7 1/4 inches. Compared with the well-known "Cutie Pie," it is smaller, more sensitive, and simpler in that no high voltage battery is required. It should be pointed out however that the energy-sensitivity of the detector is not, as yet, known. A complete description of this device will appear later in the literature.

Experiments performed to date in this work have been of a preliminary and exploratory nature. It is planned to repeat all experiments discussed here with greater attention to detail and control so that greater precision will result.

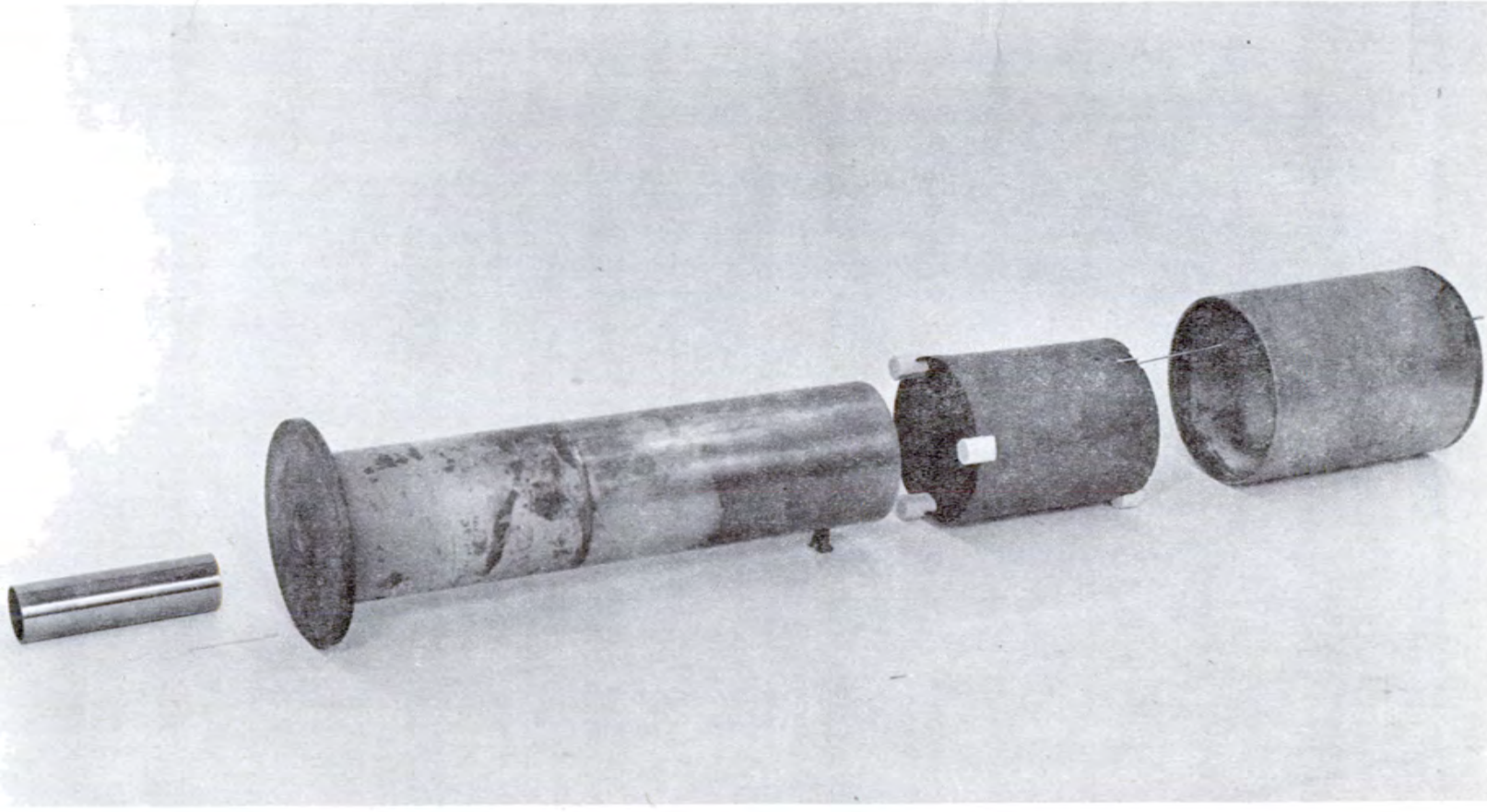


Fig. 1--Coaxial Type Cell, Disassembled

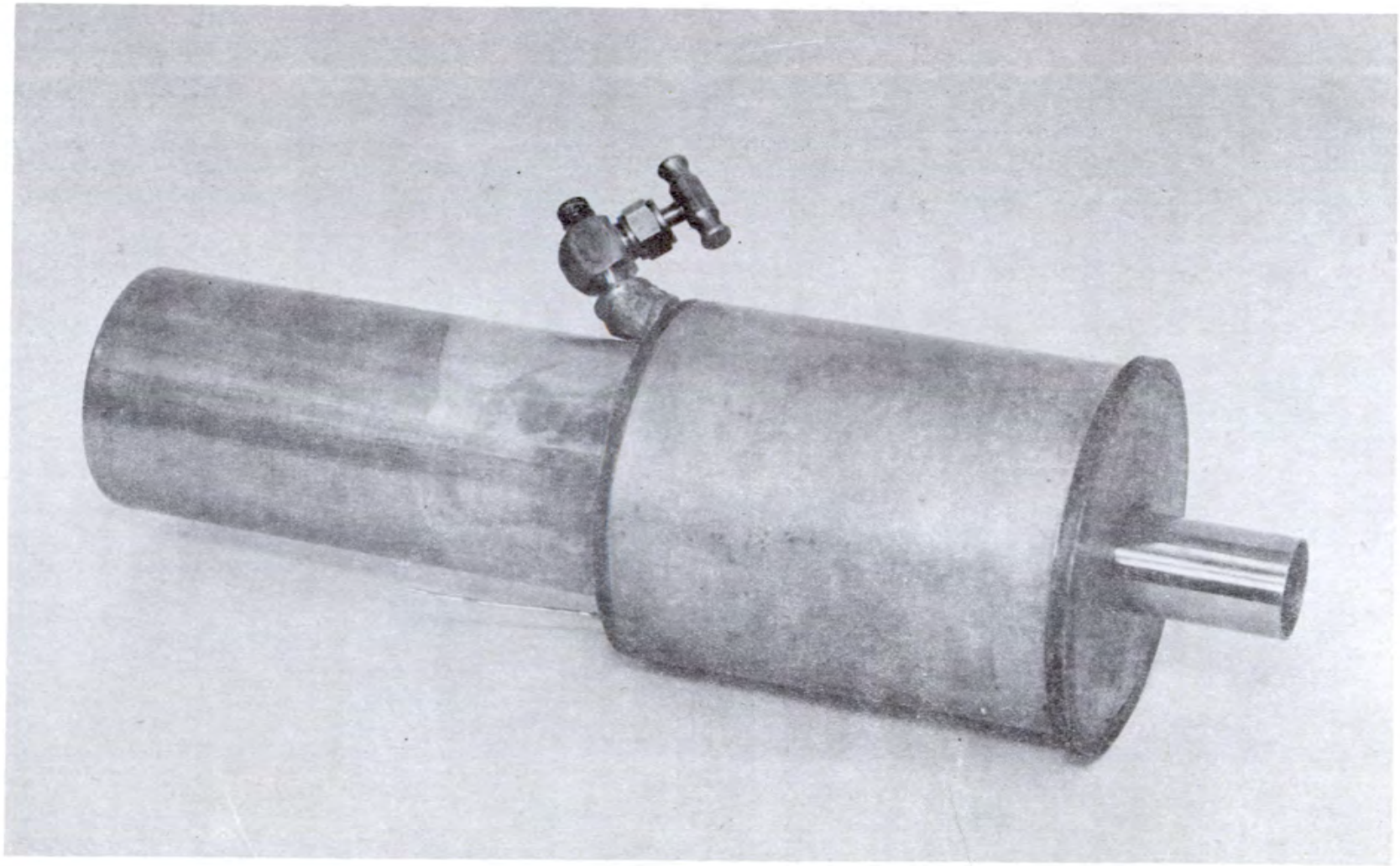


Fig. 2--Coaxial Type Cell, Assembled

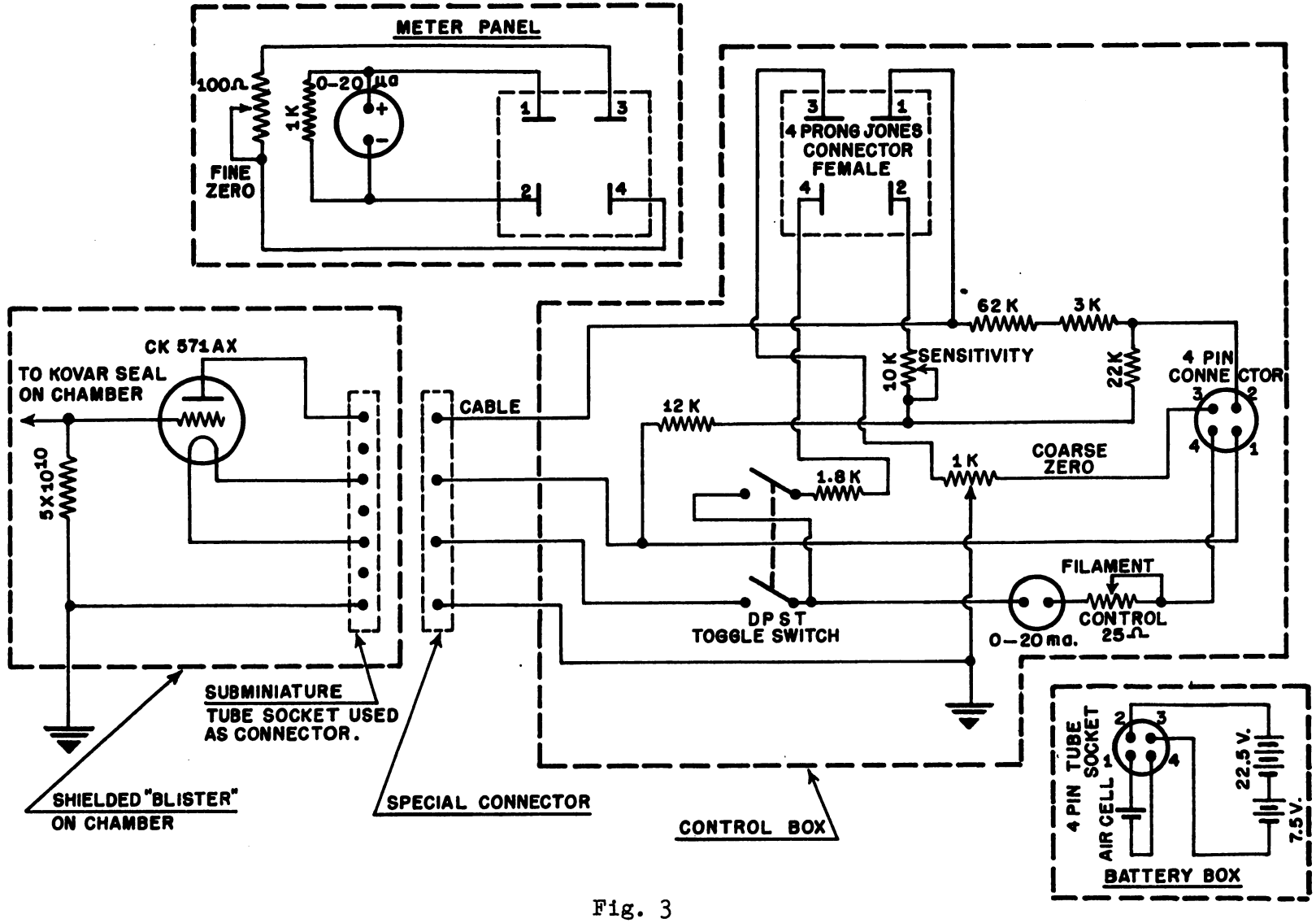
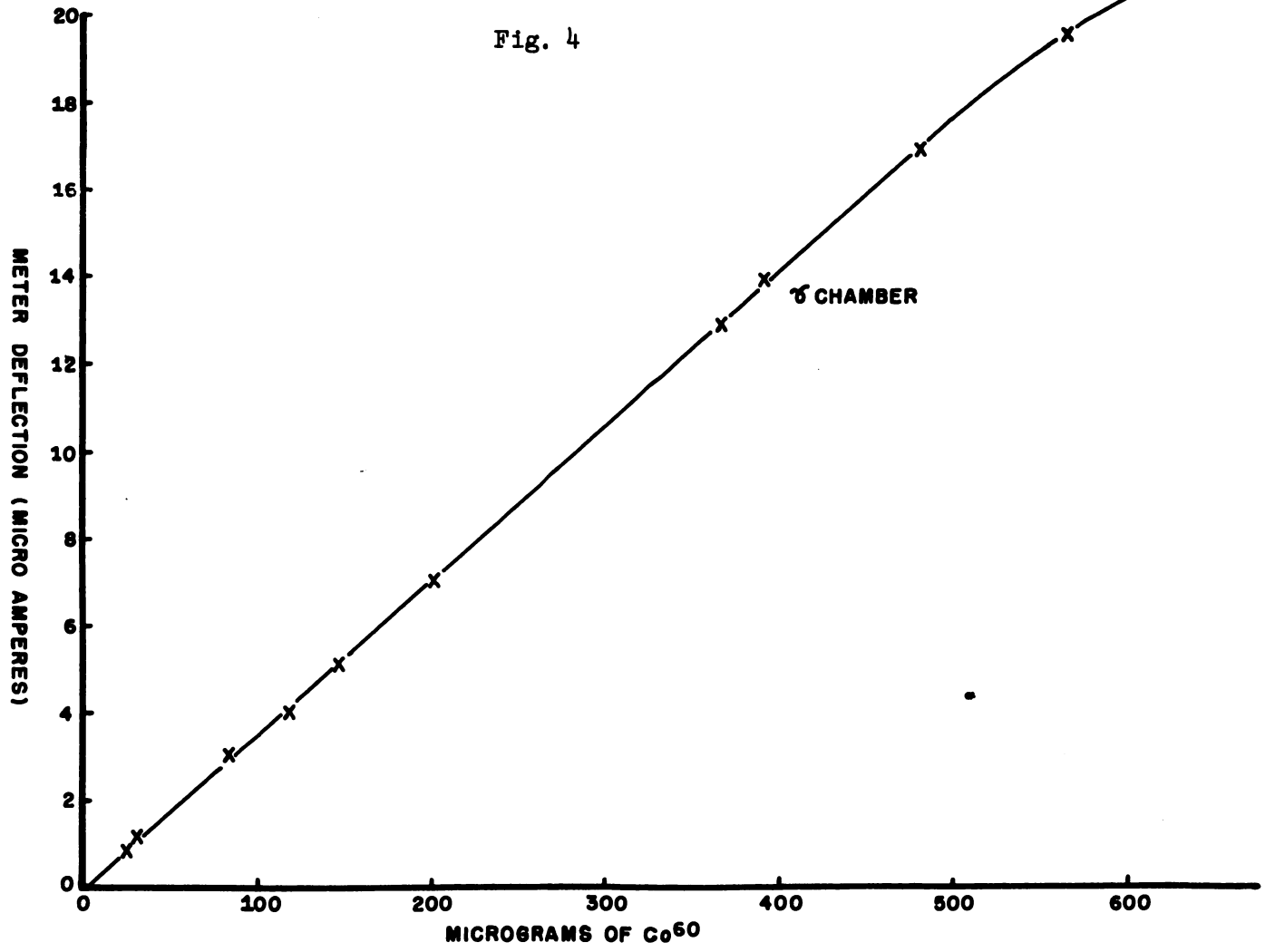


Fig. 3

ELECTROMETER CIRCUIT USED WITH CO-AXIAL CELL.

Fig. 4



CALIBRATION CURVE OF CO-AXIAL CELL.

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