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MINIATURE ION CHAMBER FOR HIGH GAMMA FIELDS

by

A. C. Lapsley
Instrument Development Division

March 1955

E. I. du Pont de Nemours & Co.
Explosives Department — Atomic Energy Division
Technical Division — Savannah River Laboratory

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Printed for
The United States Atomic Energy Commission
Contract AT(07-2)-1

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ABSTRACT

A miniature ion chamber was developed to measure gamma fields from 10^4 r/hr to 10^9 r/hr. Its sensitivity is 10^{-13} amps per r/hr. It may be operated under water and in high-flux nuclear reactors at temperatures up to 500°C.

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INTRODUCTION

Higher power levels in a nuclear reactor may often be achieved by improving the power density distribution. To do this, a method is needed for measuring the power densities during high-level operation.

A power-density monitor for use at high neutron fluxes must maintain its accuracy under the intense radiation fields existing within the reactor. A gamma-sensitive ion chamber is a promising candidate for a monitor, and a device of this type was previously built by R. L. McCarthy[1]. His model did not saturate completely above 5×10^7 r/hr, and improvements were needed to permit measurements in gamma fields as high as 10^9 r/hr.

SUMMARY

A gamma-sensitive ion chamber was developed, which saturates satisfactorily in gamma fields up to 10^9 r/hr. In a reactor such as the MTR, this gamma field corresponds roughly to a neutron flux of 10^{15} nv.

The useful life of the chamber is estimated to exceed 10^{14} r, on the basis of life tests of its components. A complete chamber has not been life-tested.

The chamber's small size (0.5 inch in diameter and 2.0 inches in length) makes it effectively a "point" detector. The chamber, which is waterproof, is welded to a 0.3-inch O.D. "triaxial" cable made of aluminum tubing.

The gamma sensitivity is 10^{-13} amperes per r/hr at 20°C, and is inversely proportional to the absolute temperature. The chamber is expected to operate satisfactorily up to 500°C.

DISCUSSION

BACKGROUND

Maximum power may be obtained from a nuclear reactor by establishing an optimum neutron flux distribution. This is a distribution which maintains the largest possible volume at a neutron flux level that is limited only by the maximum safe operating temperature.

One method of determining the optimum flux distribution is to place power density monitors inside the reactor. There may be several of these at various locations, or a single movable monitor may be used.

Ideally, the response of such a monitor should be a linear function of the thermal neutron flux. Neutron detectors, however, are relatively impractical in high flux. For example, a fission chamber has too high an ionization density for complete ion collection [(1)]. Also, a boron-coated thermopile is burned out very quickly[(2)].

In many reactors, and particularly in the Savannah River reactors, a monitor that has a linear response to gamma flux will make a satisfactory power density detector. In such reactors, the mean free path of the gamma rays is insufficient to distort the gamma flux distribution seriously with respect to the power density distribution. Neither is the contribution of fission-product gammas to the total gamma flux serious. The activity of fission products does cause some lag in the response of the gamma detector, but the lag produces an estimated error of only 2.5 per cent ten minutes after a change in power level of 20 per cent.

A gamma-sensitive ion chamber for use in reactors was previously developed by R. L. McCarthy[(1)] of the du Pont Company. Tests on his chamber indicated that in the range 10^7 - 10^8 r/hr, there was incomplete ion collection.

CHAMBER DESIGN

To improve the saturation properties, the chamber was redesigned so as to reduce the electrode separation sufficiently to double the electric field. The gas filling, as with McCarthy's chamber, was air at atmospheric pressure.

Drawings of the redesigned chamber are given in Figure 1. The metal parts are 2S aluminum and the insulators are synthetic sapphire. Components of the same materials were used in the original chamber. Sapphire is used because of its outstanding resistance to radiation damage.

The chamber is welded to a "triaxial" cable, also shown in Figure 1. This is a special cable having a single central conductor and two individually insulated concentric shields. The central wire carries the signal current. The inner shield is operated at the same voltage as the signal lead so that ions produced in the cable are not collected. Voltage applied between the outer shield and signal lead collects the ions formed in the chamber. This cable was developed for the original chambers, and it is described in greater detail by McCarthy(1).

A special amplifier measures the output current of the chamber. It allows the signal lead to operate at the chamber collecting voltage from ground so that the outer cable shield may be grounded. The wiring diagram of this amplifier, which was developed for use with the original chamber(1), is shown in Figure 2.

RESULTS

The original and redesigned chambers were tested side-by-side in the MTR at neutron fluxes up to 2×10^{14} nv, which corresponded to an estimated gamma intensity of 2×10^{8} r/hr. Logarithmic plots of the measured currents as a function of the neutron flux are shown in Figure 3. The current in the redesigned chamber is directly proportional to reactor power, as would be expected if collection of ions were complete at all power levels. The original chamber showed incomplete saturation above 5×10^{7} r/hr, with only 80 per cent collection at 2×10^{8} r/hr.

In the MTR tests the redesigned chamber saturated at 200 volts with a gamma field of 2×10^{8} r/hr (see Figure 4). At 600 volts, which is the maximum usable potential, the redesigned chamber should saturate completely to at least 10^{9} r/hr.

The redesigned chamber has not been life-tested, but its component parts withstood 10^{11} r in an MTR test(1). All the chamber materials are highly resistant to radiation and a much longer life than 10^{11} r is expected, perhaps on the order of 10^{14} r.

The sensitivity of the chamber is 10^{-13} amperes per r/hr at 20°C, and is inversely proportional to the absolute temperature. The sensitivity varies with temperature because the air-filled chamber is open to the atmosphere through the "triaxial" cable. By operating the chamber at a fixed or a known temperature, accurate data on relative power levels can be obtained.

Temperatures up to 500°C do not affect the performance of the chamber except for the change in sensitivity. Higher temperature operation is not recommended, as aluminum may fail above 500°C.

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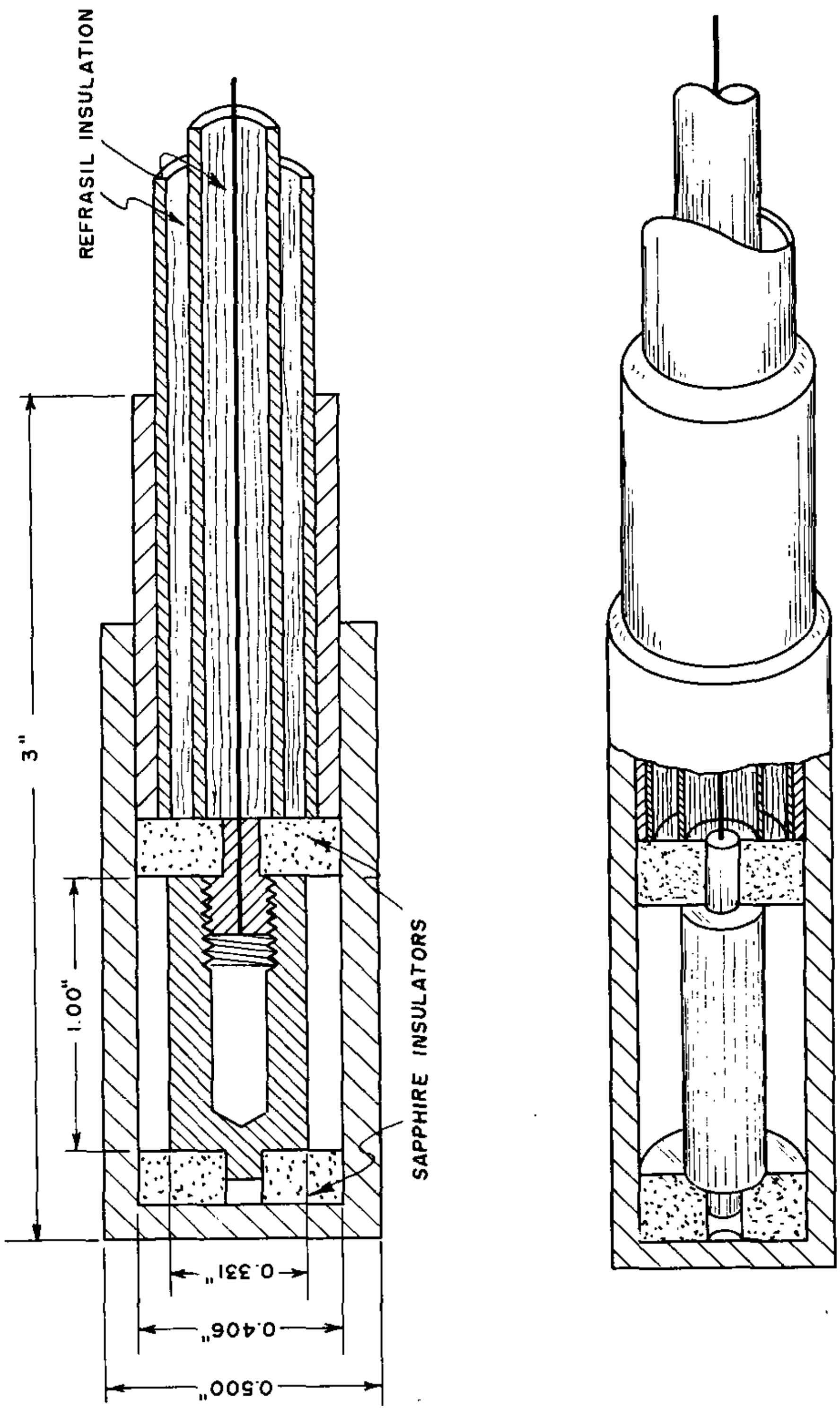
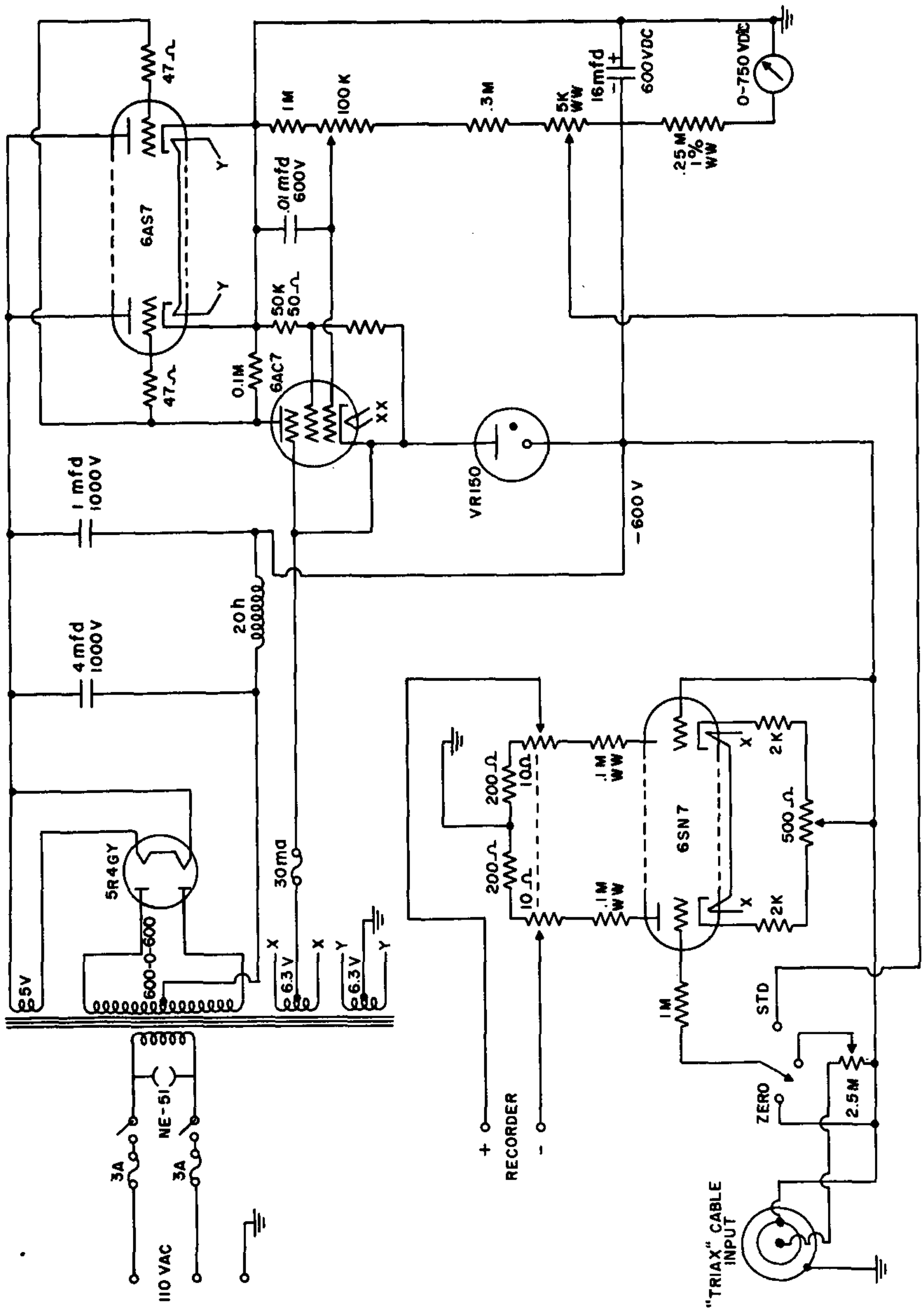
2. Lapsley, A. C. "Neutron Flux Measurement with Thermopiles," _Nucleonics_, _11_, (No. 5), 62. (May 1953).

FIGURE 1

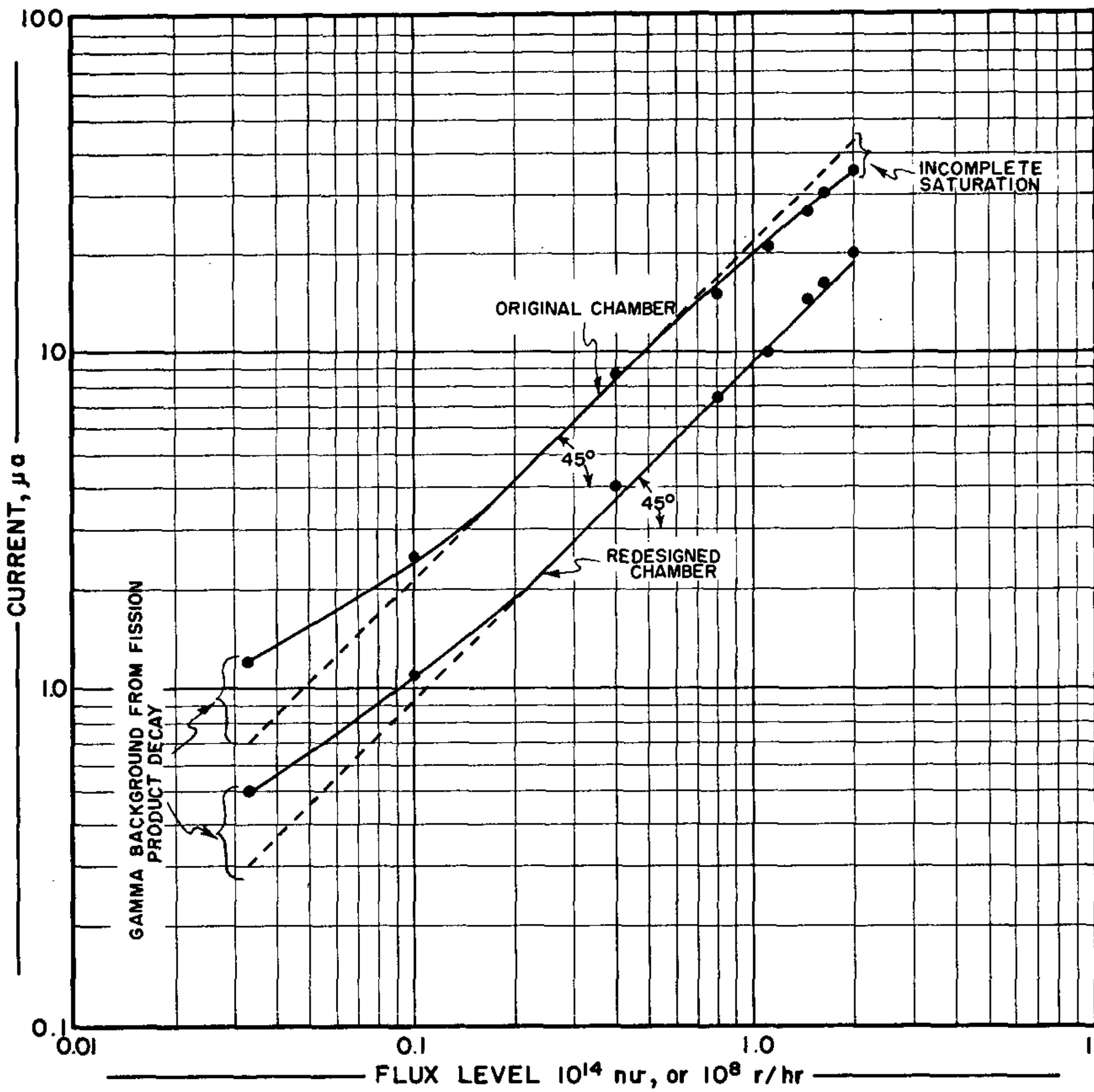


REDESIGNED CHAMBER

FIGURE 2

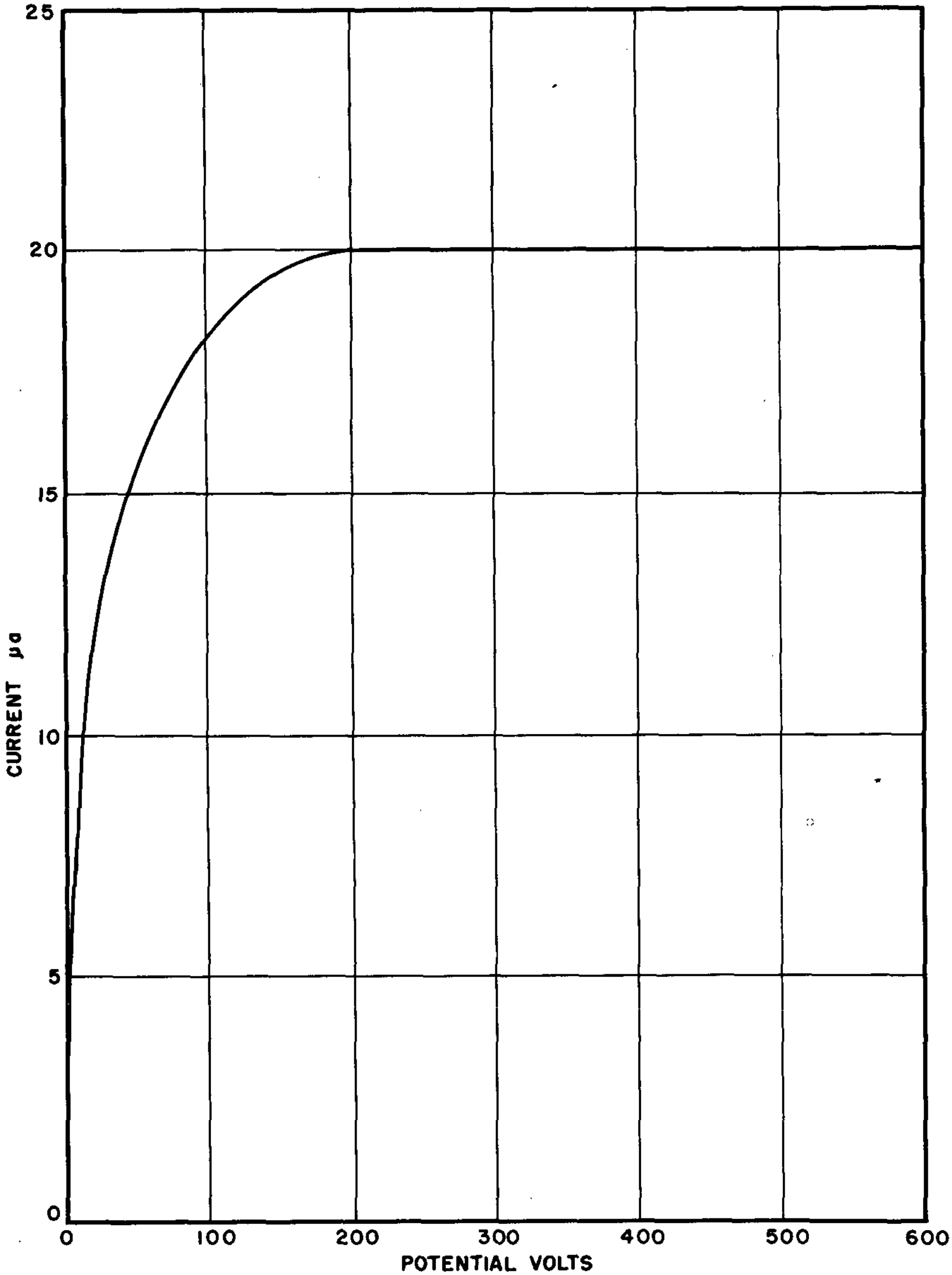


ION CHAMBER POWER SUPPLY AND AMPLIFIER - AFTER McCARTHY(1)



ION CHAMBER CURRENTS vs NEUTRON AND GAMMA FLUXES
(TESTED IN THE MTR)

FIGURE 4



SATURATION CURVE OF REDESIGNED ION CHAMBER
(MTR TESTS AT 2×10^{14} nv FLUX)