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# A SURVEY METER FOR URANIUM AND PLUTONIUM

by

A. H. Dexter
Instrument Development Division

November 1954



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

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## ABSTRACT

A portable instrument is described that can distinguish between plutonium and uranium contaminants by detecting the difference in range of their respective alpha particles in air.

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# A SURVEY METER FOR URANIUM AND PLUTONIUM

## INTRODUCTION

When alpha radioactive contamination is found in installations handling both uranium and plutonium, it is often desirable to determine which element is the contaminant, since there is a greater physiological hazard associated with plutonium. If a smear with sufficient activity can be obtained, the contaminant can usually be identified with a special alpha-particle analyzer. However, a direct and rapid determination of the contaminant at the source is much preferred. No portable survey instrument was known which was capable of making such a determination.

This report describes the development and construction of an instrument to fill the need for an improved survey meter.

## SUMMARY

A survey meter was developed to distinguish plutonium contamination from uranium. The instrument consists of an alpha counter with a very "shallow" sensitive depth and a means for accurately positioning the alpha counter relative to the source of contamination. Since the alpha particles emitted by plutonium have a greater range in air (by 0.78 cm) than those emitted by uranium, the instrument can identify the contaminant by measuring the range of alpha particles which are emitted. The survey meter is a self-contained portable instrument which operates on 110 volts A.C.

## DISCUSSION

The instrument distinguishes between plutonium and uranium on the basis of the difference in range of the alpha particles emitted by the substances.

The most energetic alpha-emitting isotope of uranium is $U^{234}$ which emits alpha particles with an energy of 4.76 Mev(1). About 49% of the alpha particles emitted by natural uranium and almost all of the alpha particles emitted by enriched uranium are due to $U^{234}$. The most energetic plutonium alpha emitter is $Pu^{238}$ which emits alphas of 5.49 Mev(2)(3). Since the $Pu^{238}$ content of plutonium is a function of the exposure of uranium in a pile, it is not possible to set a definite value for the percentage of alpha emissions due to $Pu^{238}$ in plutonium.

The range (4) in air of the 4.76 Mev alpha particle is 3.24 cm, and that of the 5.49 Mev alpha particle is 4.02 cm.

Any alpha activity registered by an appropriate counter, placed at a distance slightly greater than 3.24 cm but less than 4.02 cm from a known source of contamination, identifies the contaminant as plutonium. Conversely, the absence of any detectable alpha activity at this distance indicates uranium.

The two most promising alpha counters for this application were the scintillation counter and the spark counter. The former was rejected because the necessary light-tight window would confuse the difference in the alpha track lengths. An investigation was therefore made of the spark counter (5-8).

## THE SPARK COUNTER

In its simplest form, the spark counter consists of a tungsten wire, approximately 0.003 inch in diameter, stretched parallel to and about 1 mm distant from an aluminum plate. When a potential of 3,000 to 5,000 volts is impressed between the wire and plate, a visible corona appears around the wire. If an alpha particle passes near the wire, it ionizes the air and a spark discharge occurs. The sparks are both visible and audible. Since the sensitive region of the counter is closely limited to the small region of corona surrounding the wire, the spark counter has a very "shallow depth", a requisite for the measurement of small differences in range of alphas. The counter is windowless and operates in air.

A simple, four-wire, "guitar-type" counter was constructed. The instrument is shown in Figure 1 and the circuitry in Figure 2.

The variation of count rate with applied voltage was determined with the counter placed over an $Am^{241}$ source; the alphas were normally incident to the plate of the spark counter. The curve obtained (Figure 3) was extremely irregular, probably because the wires were not properly parallel to the plate. The counter was subsequently restrung with more care and a fifth wire was added. The curve obtained (Figure 4) shows a reasonable plateau, approximately 200 volts in length (4400 - 4600 volts) with a slope of about 0.02% change in counts per volt. These results are in excellent agreement with those of R. D. Connor (7), who obtained 250-volt plateaus with a slope of 0.06% change in count per volt, but in disagreement with those of G. G. Eichholz(8) who did not obtain a plateau for normal incidence of the alpha particle.

The $Am^{241}$ source was next mounted on the end of a screw so that the variation of count rate could be obtained as the source was moved away from the counter (see Figure 5).

Range curves of alpha particles from enriched uranium and plutonium were taken in a similar manner (Figure 6). The apparent range of alphas from plutonium is approximately 0.64 cm greater than for enriched uranium. This is true whether one uses the extrapolated range or the end point range. The experimental difference in range is within 20% of the predicted difference in range. These measurements established the principle of utilizing the range of the alpha particles to distinguish plutonium from uranium.

The spark counter has a background of 1 count per hour and is insensitive to beta and gamma radiation.

## THE URANIUM - PLUTONIUM SURVEY METER

The prototype survey meter and associated high-voltage supply are shown in Figure 7. The instrument is portable, but operates on 110 volts A.C. The survey meter consists of a spark counter that is enclosed in an aluminum housing. The wire-to-plate spacing is about 1 mm. The spark counter is mounted on a lucite block which can be raised or lowered by means of a screw with 20 threads/inch. The knob that turns the screw is a 15 turn "Duodial" located on the top of the survey meter. These features may be seen in Figure 8 which is a view of the meter with one of the side covers removed. Some of the associated capacitors and resistors of the survey meter circuit can also be seen in this view.

The alpha particles enter through a screened opening in the bottom of the instrument (Figure 9). The screen is positioned above the bottom surface of the instrument to avoid contamination of the screen.

The spark counter is entirely enclosed and inaccessible to the operator; thus, there is no possibility of his coming in contact with the high voltage.

The two electrical connectors on the end of the survey meter are used for the high voltage input and signal output. The latter is provided in the event that it is desired to connect the survey meter to a scaler in order to obtain a range curve. The spark counter and high voltage circuits are shown in Figure 10. Note that the high voltage output is negative. Satisfactory operation is obtained only with a negative high voltage. The operating voltage is approximately 4500 volts. An exterior "stop" on the rheostat of the high voltage supply assures correct setting of the voltage.

## OPERATION

To start the instrument, turn the HIGH VOLTAGE control on top of the high voltage supply fully clockwise, plug the high voltage supply into a convenient 110 volt - 60 cycle outlet, and throw the POWER switch to "ON". After a minute or two of warm up, turn the HIGH VOLTAGE control counterclockwise until it reaches the limiting stop.

To standardize the survey meter, place it over a uranium source and adjust the "Duodial" until no count is indicated by the indicator light on top of the survey meter. Next place it over a plutonium source to make certain that the spark counter has not been raised beyond the range of the plutonium alpha particles. Once this optimum setting has been obtained, the instrument is ready for survey work. Care should be taken that the top surfaces of the uranium and plutonium standards are flush with the bottom of the instrument when the standarization is made. Moreover, the standardization should be performed under conditions of room temperature and pressure that are appropriate to the site where the survey is to be made, since the range of the alpha particles is a function of air temperature and pressure.

To examine unknown sources of contamination, place the survey meter on the surface to be examined and note the indicator light. If the light flashes at a rate significantly greater than the background of one count per hour, the presence of plutonium is indicated.

On occasion, it may be desirable to plot a Bragg range curve of the alpha particles from an unknown source of contamination for comparison with a known alpha source. This is accomplished by connecting the output of the survey meter to a scaler. The count per unit time as a function of "Duodial" setting is then plotted. Curves taken in this manner with the survey meter, for uranium and plutonium, are shown in Figures 11 and 12.

## SENSITIVITY

An estimation of the sensitivity of the instrument is obtained by considering Figure 11. For the optimum "Duodial" setting of 17, the two elements (U and Pu) are easily differentiated, and the plutonium count rate is 70 c/m. The Pu source was actually emitting 27,300 alphas/minute in the $2\pi$ space above its surface. Accordingly, a source of 400 alphas/minute will give about 1 c/m at this range.

By way of comparison, one of the best available alpha survey instruments, the scintillation AC Poppy (9), has a threshold of detection of approximately 100 alphas/minute in the same $2\pi$ space. It should be emphasized, however, that the uranium-plutonium survey meter was not developed for routine survey work. It is intended for the identification of contamination once it has been found in the course of routine survey work with a scintillation AC Poppy or a similar instrument.

Measurements of sensitivity were made for standard survey instruments used at SRL to determine how long the uranium-plutonium survey meter should be left over the source of contamination for proper identification. These "rule of thumb" measurements indicate that if the meter reading (c/s) of the scintillation AC Poppy is divided into 10, the approximate number of minutes required is given. For example, if the AC Poppy reads 5 c/s, the time required for the identification will be 10/5 or 2 minutes.

For the Samson alpha-survey meter (10), the rule is: 1000 divided by the meter reading (counts/minute) gives the time required in minutes. For example, if the reading on the Samson meter is 500 c/m, the time required for the identification will be 1000/500 or 2 minutes.

## PERFORMANCE

The instrument accurately identified small evaporated sources of uranium and plutonium in the laboratory. Inexperienced personnel were able to standardize and use the instrument after only a few minutes instruction.

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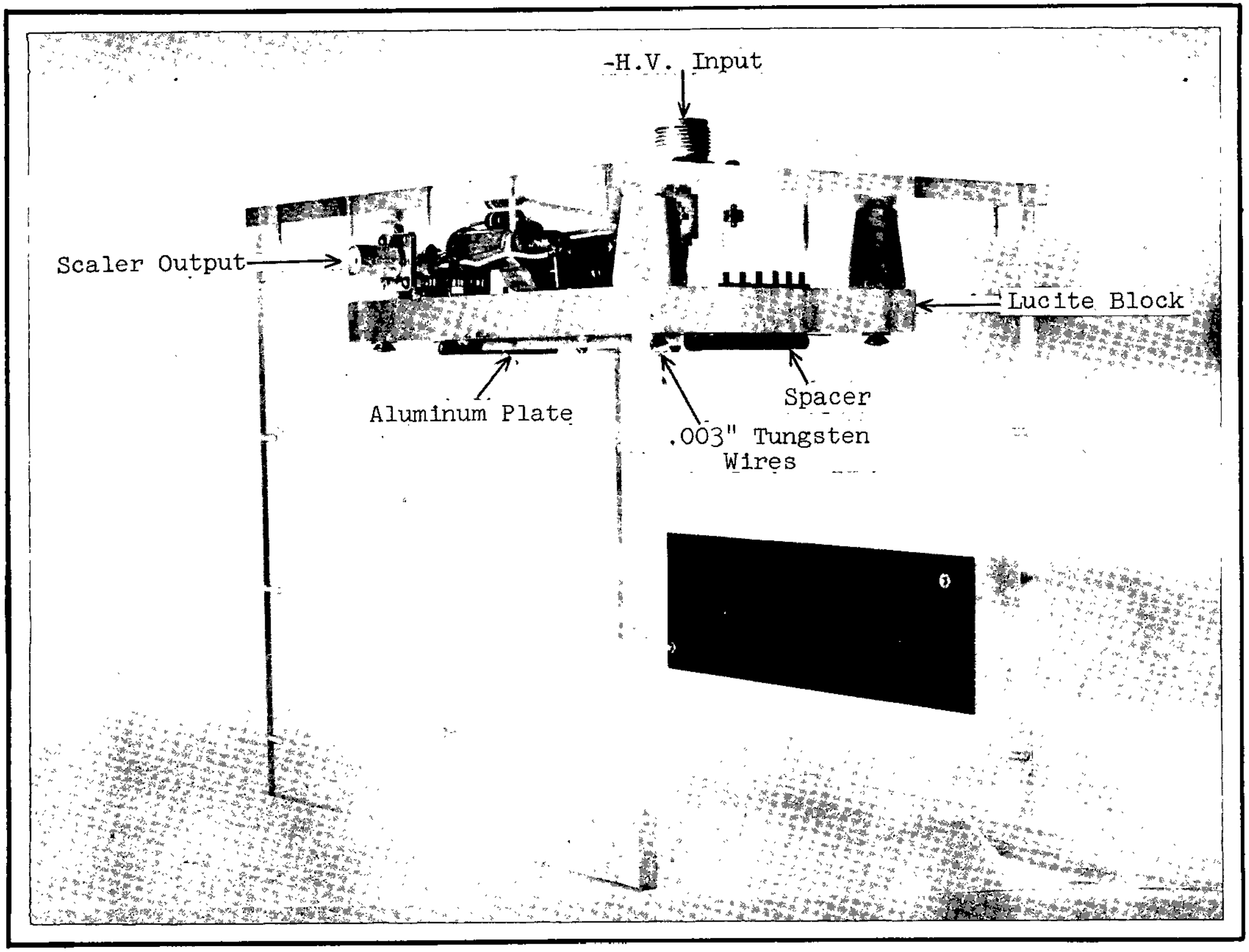
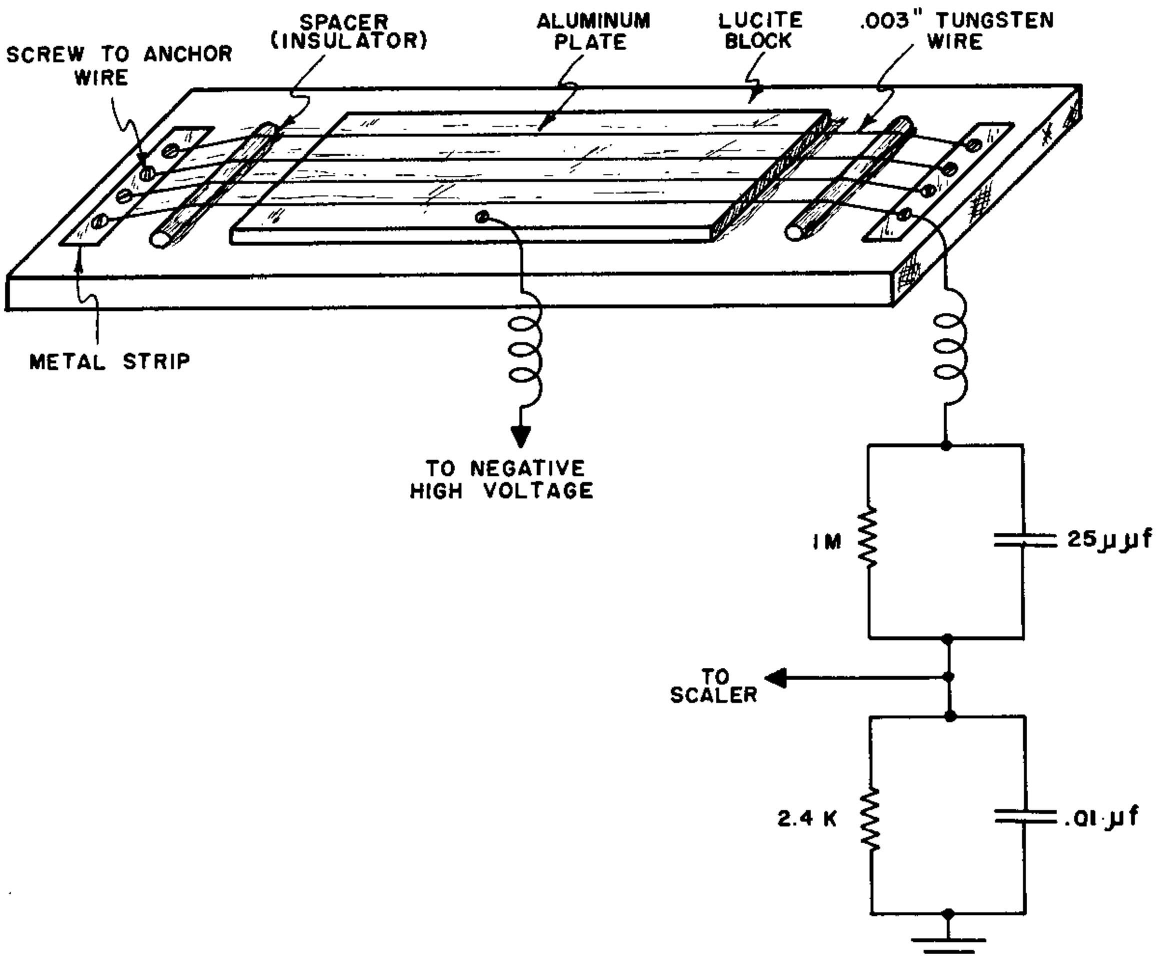



FIGURE 1

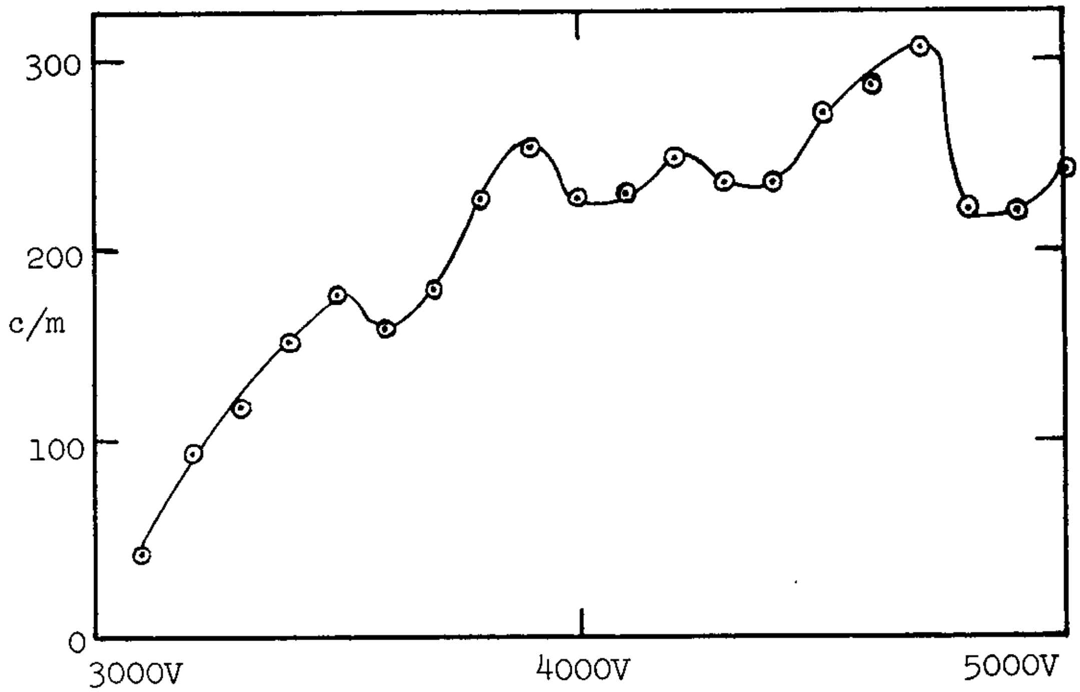
RESEARCH MODEL OF THE SPARK COUNTER

FIGURE 2



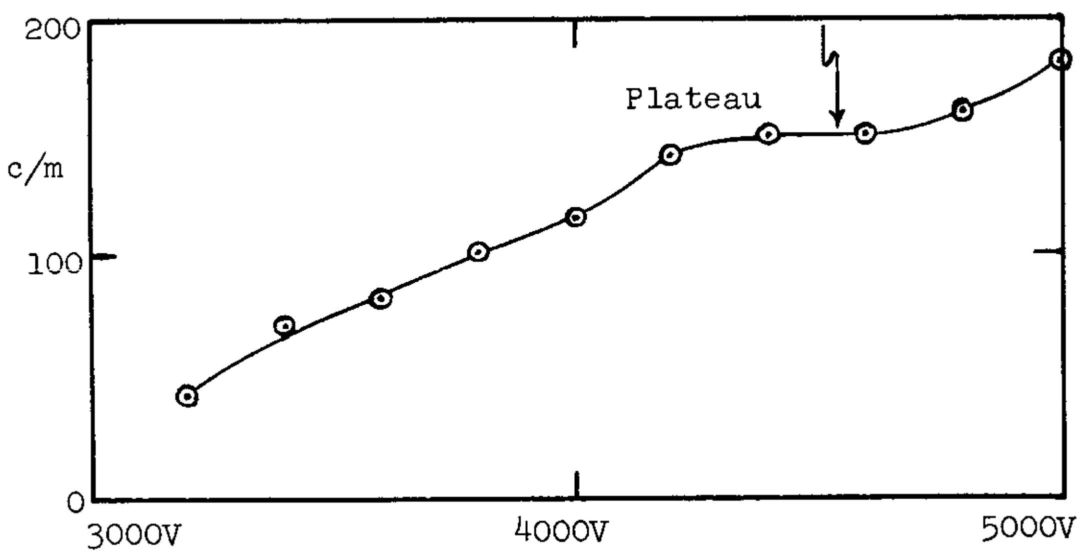

SPARK COUNTER CIRCUIT

FIGURE 3



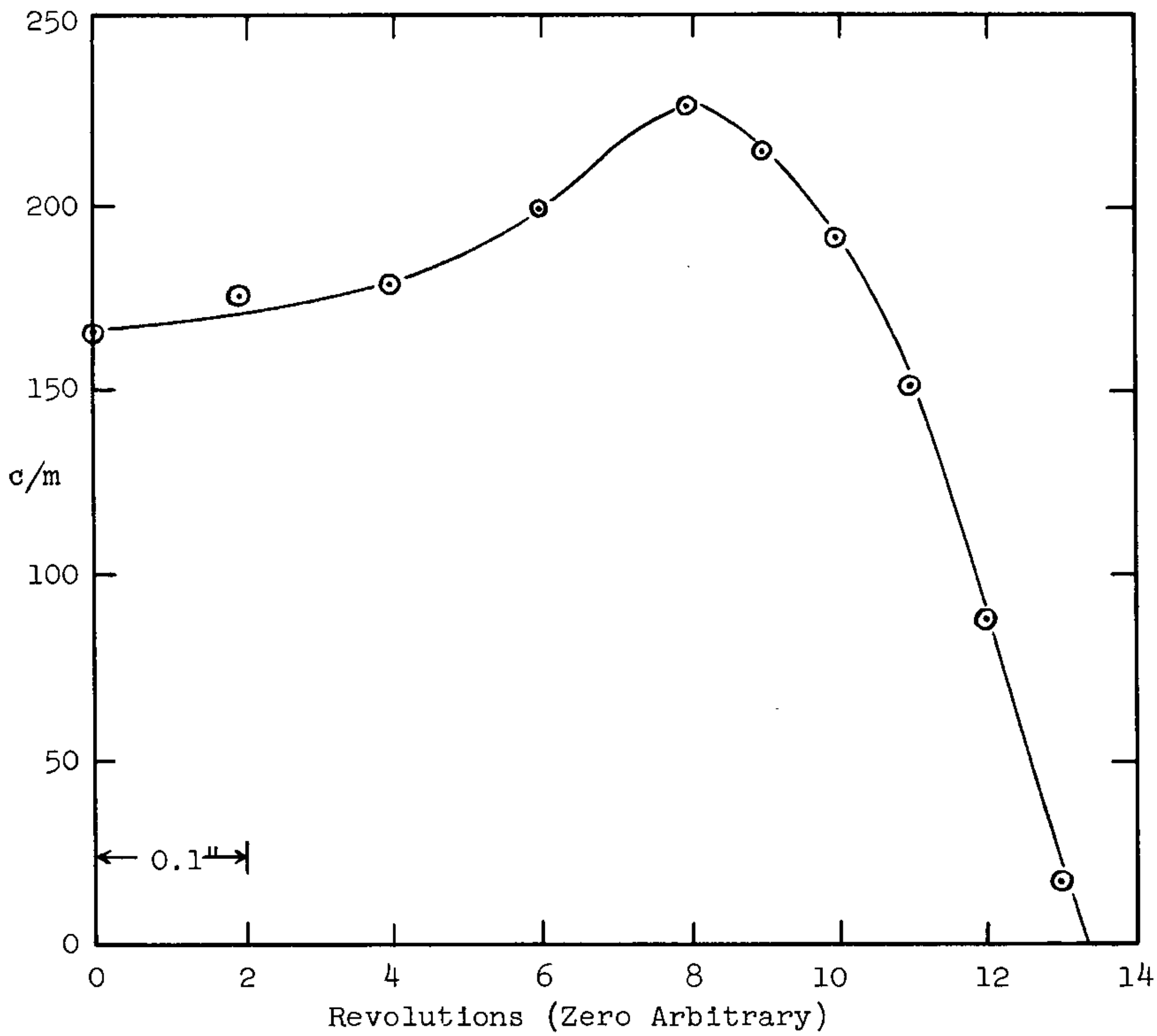

COUNT RATE vs. VOLTAGE
(Unevenly Spaced Wires)

FIGURE 4



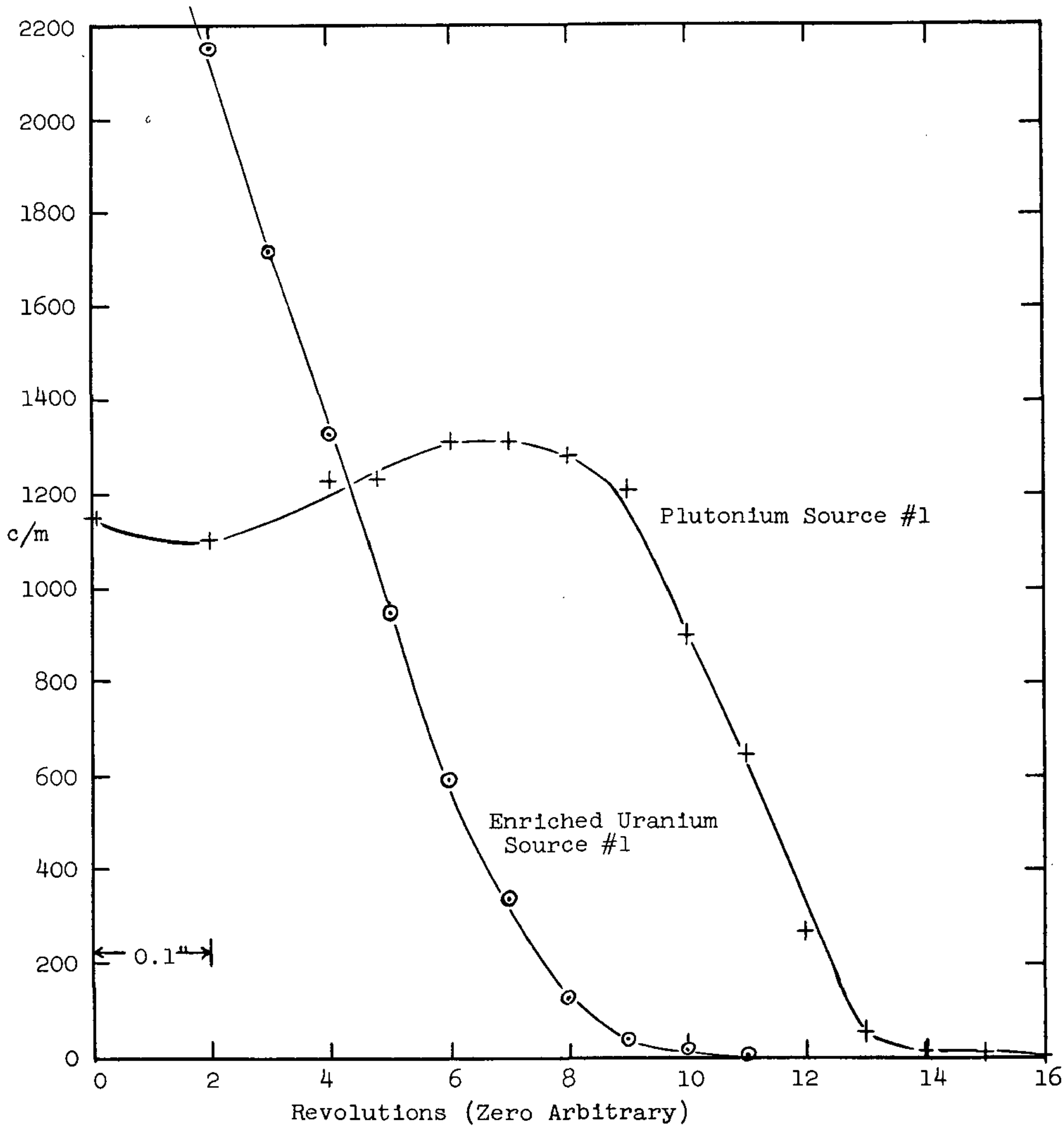

COUNT RATE vs. VOLTAGE
( Evenly Spaced Wires )

FIGURE 5



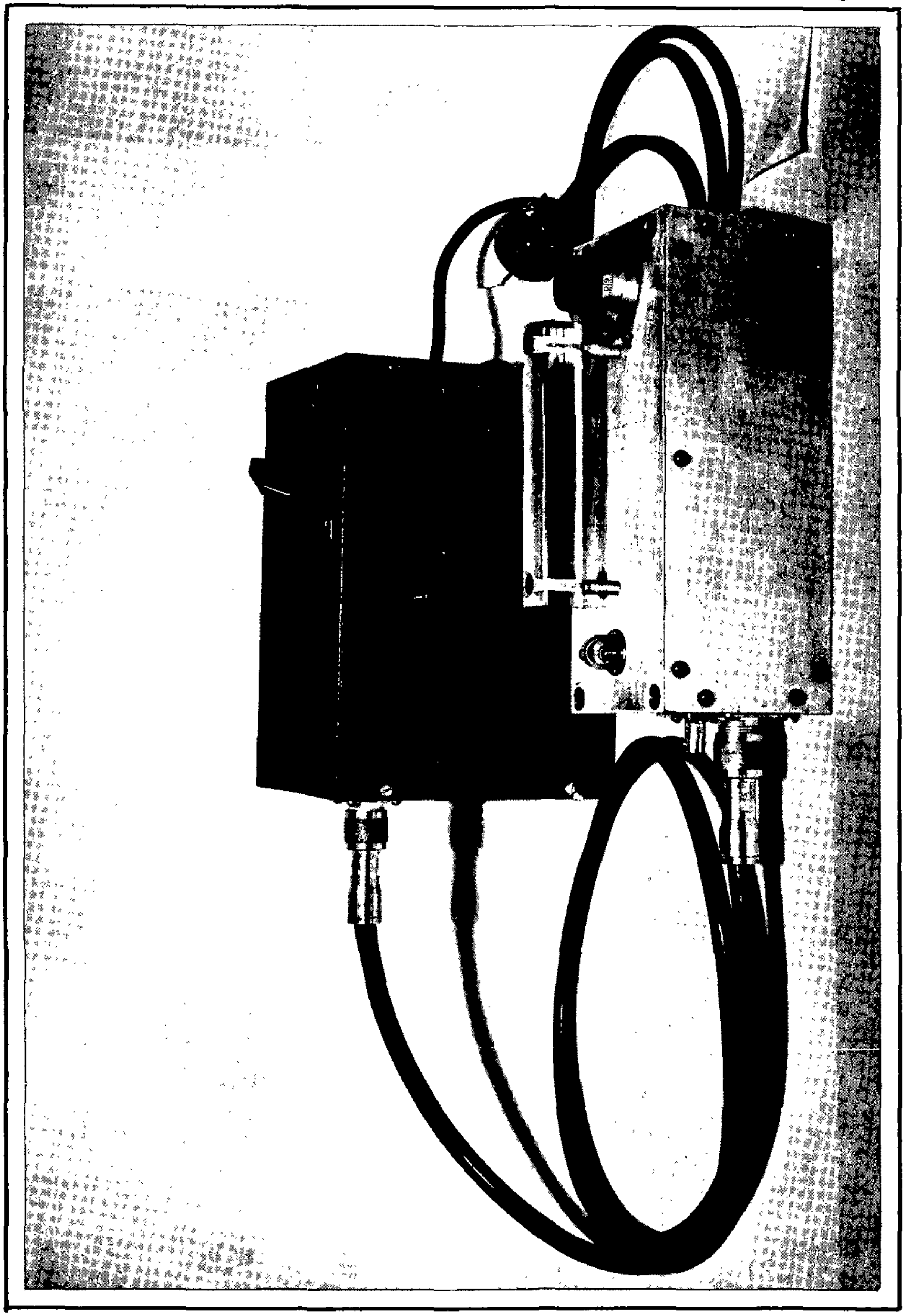

BRAGG RANGE CURVE OF $Am^{241}$
OBTAINED WITH RESEARCH MODEL

FIGURE 6

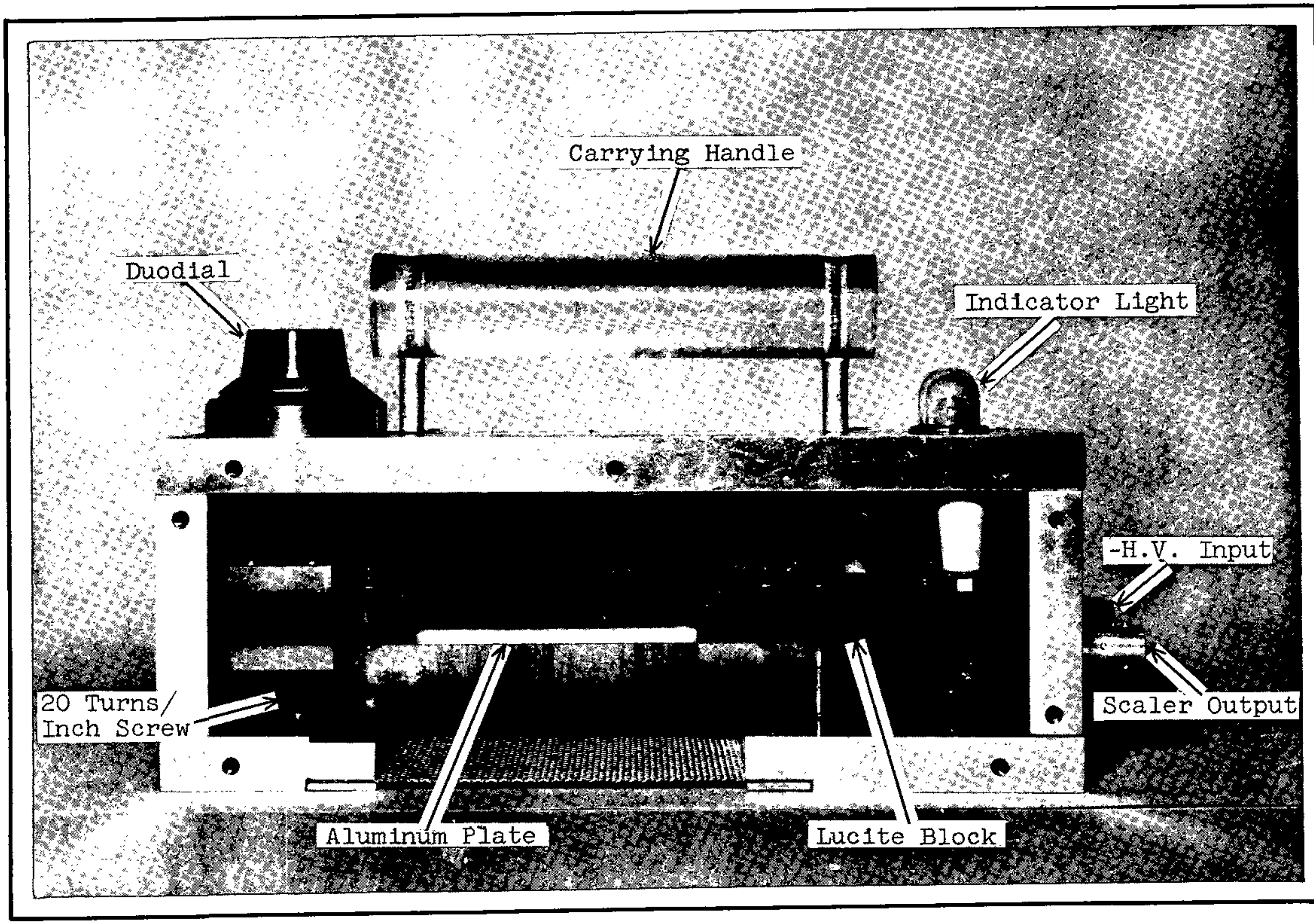



BRAGG RANGE CURVES OF ENRICHED U and Pu
OBTAINED WITH RESEARCH MODEL

FIGURE 7



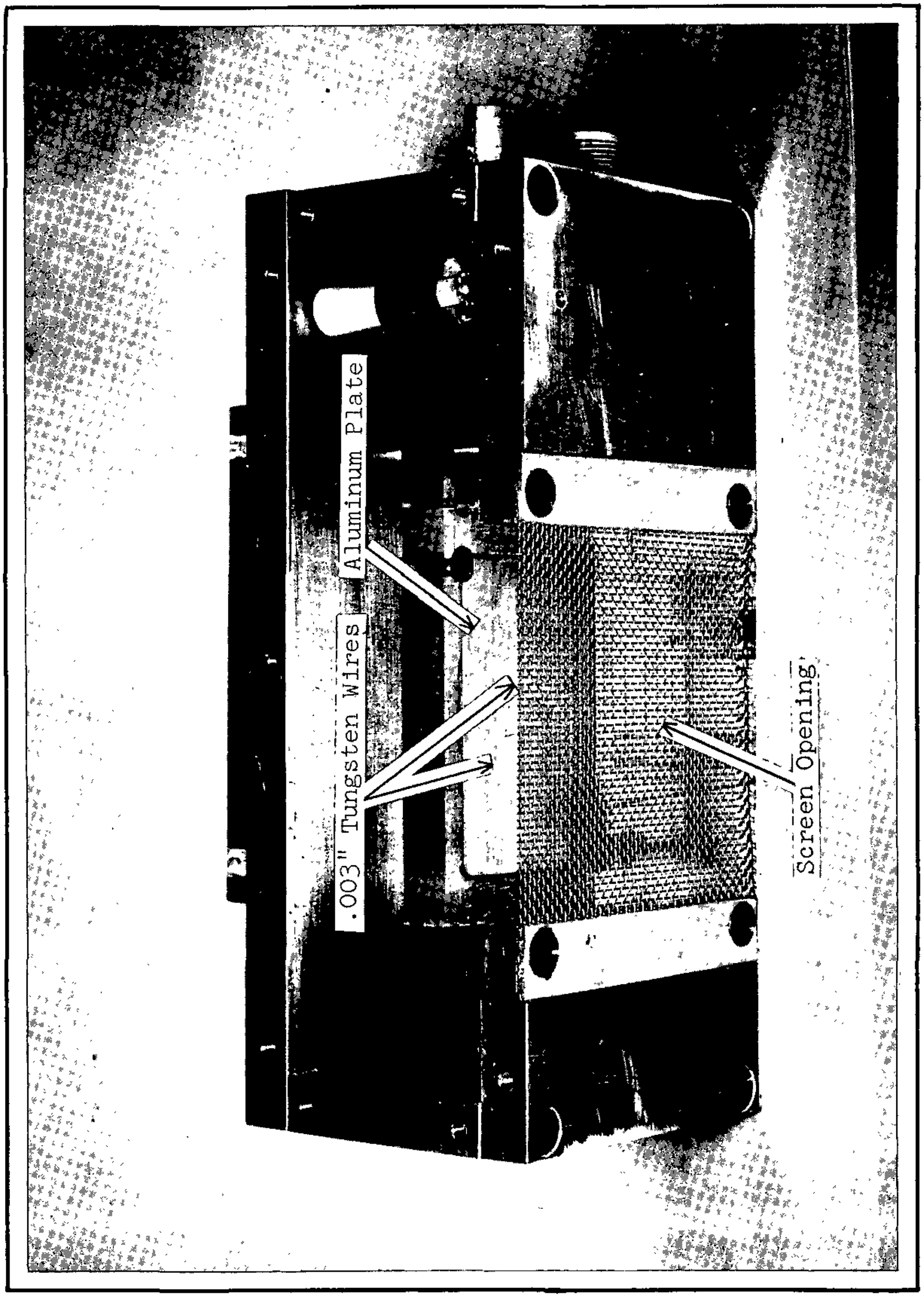
SURVEY METER AND HIGH VOLTAGE SUPPLY




INTERIOR VIEW OF SURVEY METER

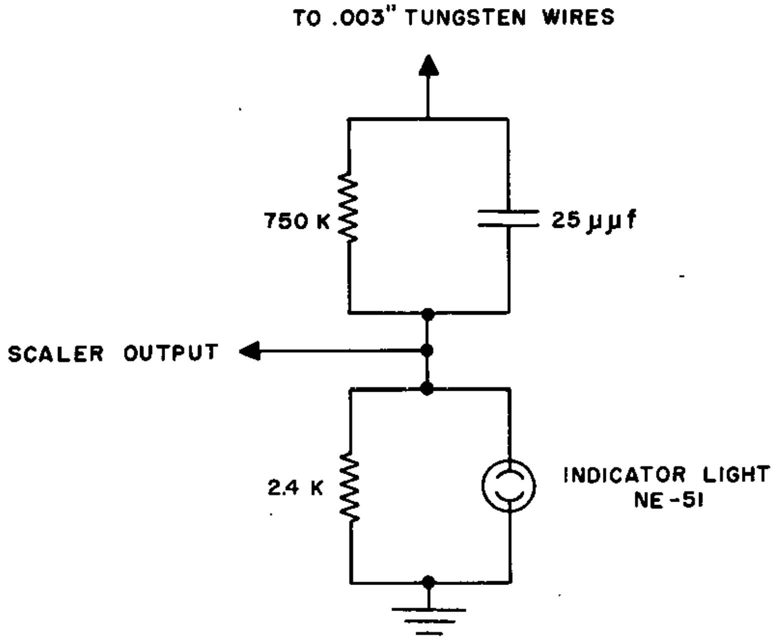
FIGURE 8

FIGURE 9

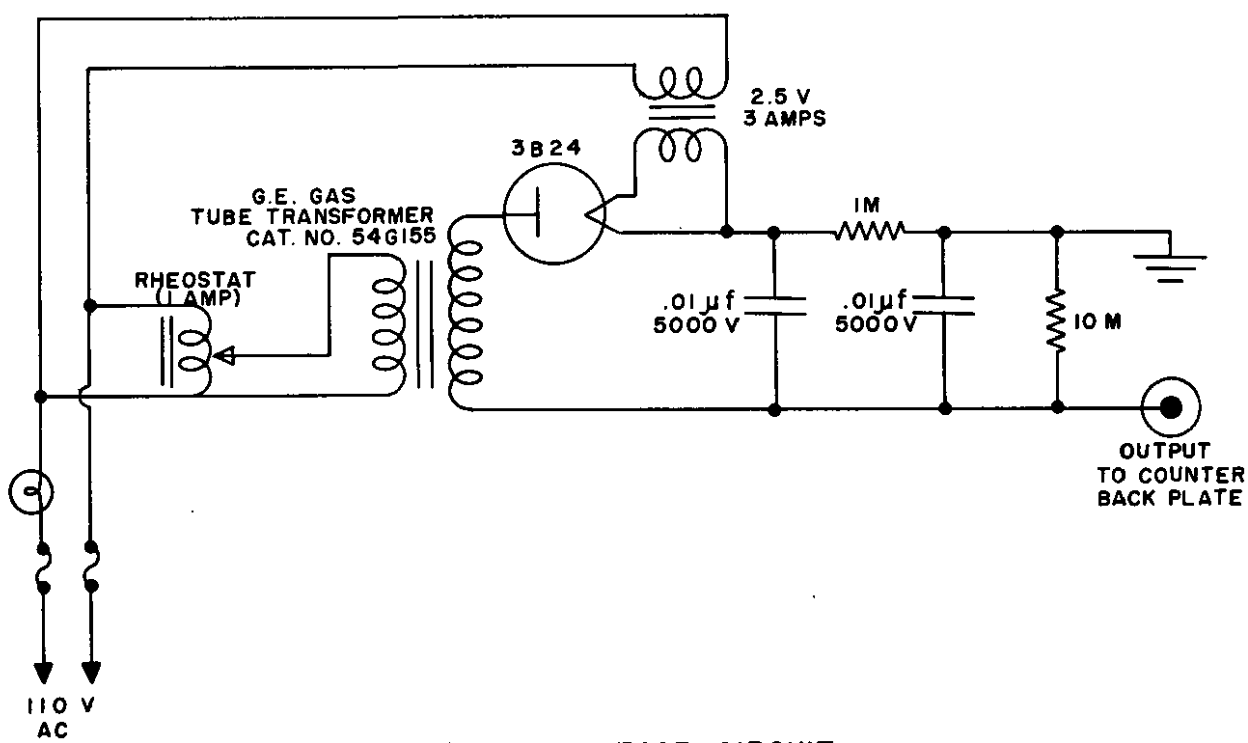



SURVEY METER, BOTTOM VIEW

FIGURE 10



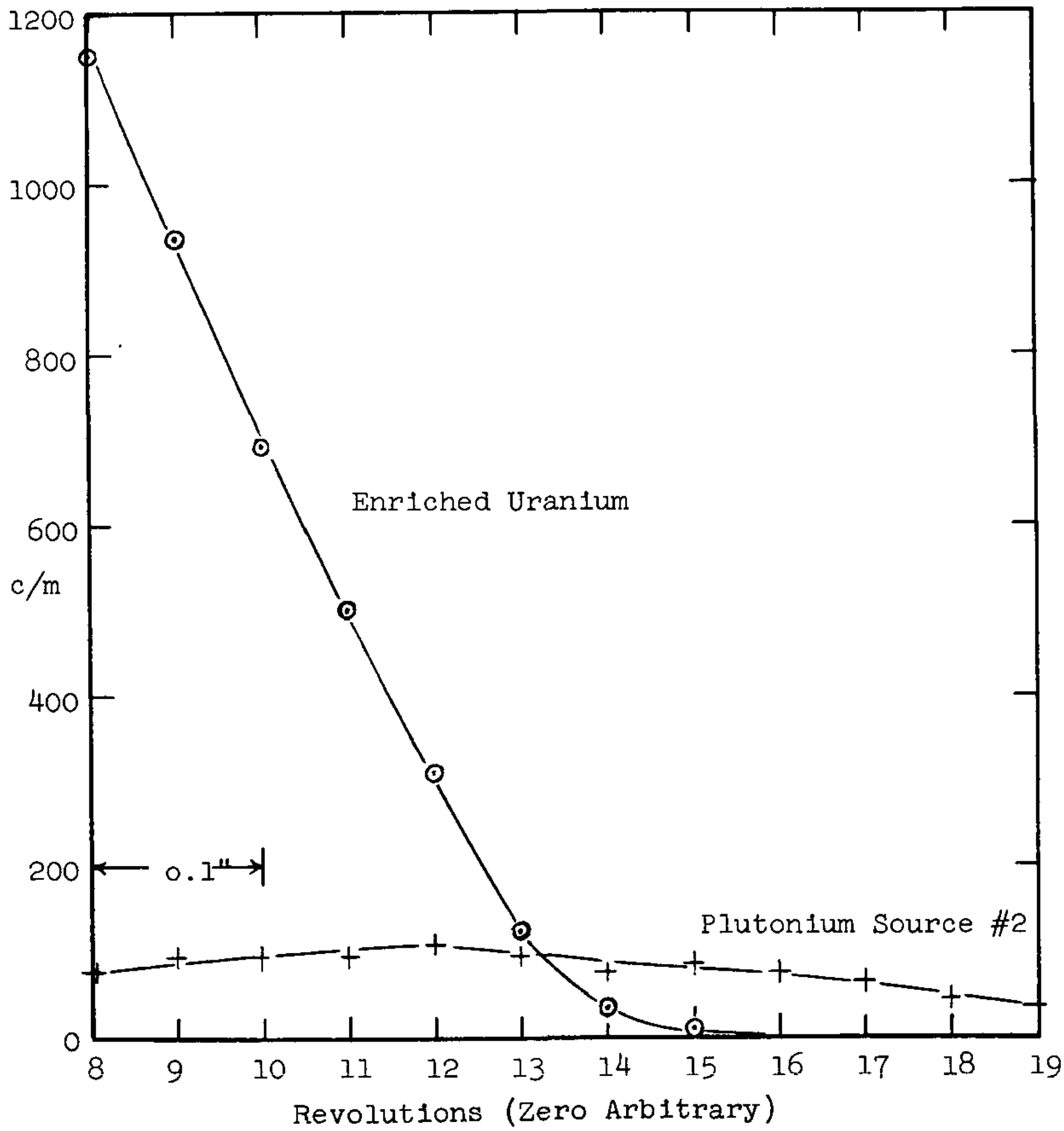

(a) SPARK COUNTER CIRCUIT




(b) HIGH-VOLTAGE CIRCUIT

CIRCUIT DIAGRAM OF SURVEY METER

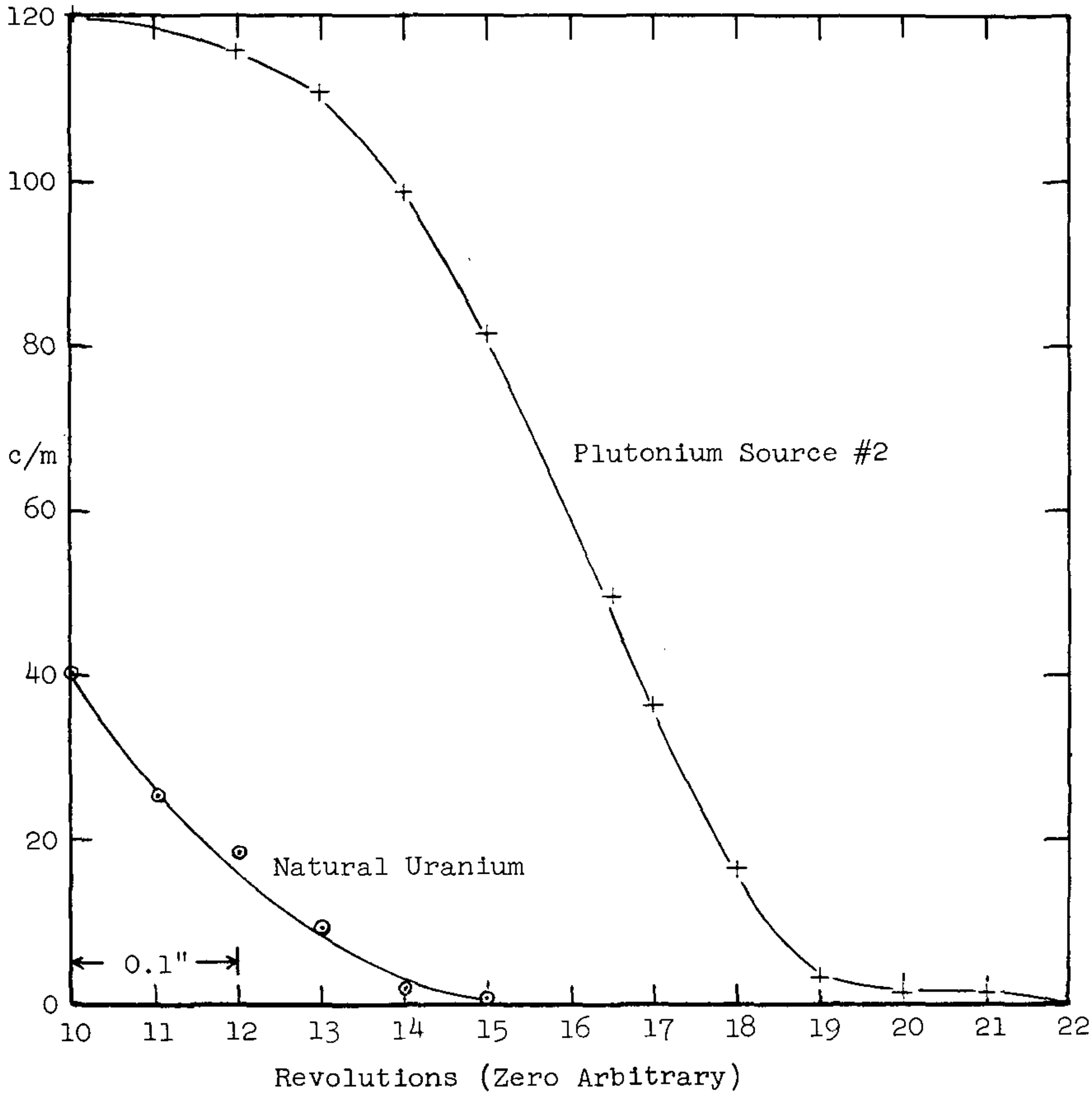
FIGURE 11




BRAGG RANGE CURVE OF ENRICHED U AND Pu

OBTAINED WITH THE SURVEY METER

FIGURE 12




BRAGG RANGE CURVES OF NATURAL U AND Pu
OBTAINED WITH THE SURVEY METER