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AN EXPOSURE METER FOR RADIOGRAPHY

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Report on
An Exposure Meter For Radiography

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Abstract

An exposure meter has been developed for use with all penetrating radiations harder than 100 kilovolt x-rays. The sensitivity may be varied to cover exposures from a fraction of a minute to 100 hours with type A film. A built-in standard of calibration is provided to check quickly circuit adjustments, eliminating the need for highly stabilized circuits. The exposure meter utilizes a simple type of intensity measuring circuit.

AN EXPOSURE METER FOR RADIOGRAPHY

1. Finding the correct exposure time in a radiographic problem is equivalent to determining the intensity of radiation striking the film. The common practice, however, is not to measure this intensity, but rather to measure the radiographic parameters on which it depends. Then, after the strength of the source of radiation, the source to film distance, and the thickness and composition of the specimen material are known, the radiographer refers to x-ray "technique charts" or the gamma ray "slide-rule". This indirect procedure is followed because simpler direct means of determining the intensity of radiation at the film position are not generally available. Exposure meters were described in N.R.L. Report M-1801, which utilized Geiger counters as the sensitive receivers. A number of meters were subsequently built, but each had a fixed sensitivity which limited its application to a relatively small range of wavelengths, and those designed for harder x-rays were too bulky for convenient handling. For practical purposes, an exposure meter should be introduced into the radiographic set-up with a minimum of difficulty, and it must have an adjustable sensitivity to be applicable to a wide range of hard radiations. This report describes a simplified meter with a sensitivity that can be varied by a factor of 1000, so that it may be used with all penetrating radiations harder than 100 kilovolt x-rays.

2. The general features of the new exposure meter are best described with the aid of the circuit diagram of Plate 1. The sensitive element is a small Geiger counter, whose anode id connected to the high voltage supply while the cathode is tied to the grid of a triode amplifier. When hard radiation strikes the counter, a pulsating current flow is initiated in the series circuit comprising the high voltage source, counter, and grid leak resistor. This resistor is paralleled by a condenser which averages out the irregularities in the current flow. The voltage drop in the grid resistor controls the current in the plate circuit and the milliameter indication is a measure of the intensity of radiation. By providing a selection of grid resistors, a variety of sensitivity ranges is obtained. For grid resistances under 10^8 ohms, the current flow in the counter circuit is negligibly affected by the external series resistance, and the potential developed at the grid of the amplifier is therefore nearly proportional to the magnitude of the grid leak resistance. Five or six grid resistors can be selected between one megohm and one hundred megohms, to give exposure ranges (as indicated on the one milliampere scale) covering nearly all the cases commonly encountered in gamma ray and x-ray radiography.

3. If different grid resistors for various sensitivity ranges only served to alter the scale of the amplifier circuit, it would be simpler to provide a set of shunts for the milliameter. The grid resistance, however, does more than just determine the current gain of the amplifier. A high grid resistance yields high sensitivity, but the response saturates quickly with increasing intensity. Lowering the grid resistance decreases amplification but brings about a

linear response at high intensities. The physical basis for the behavior of the counter in this type of circuit has been treated in detail in N.R.L. Report M-1800.

(4) The exposure meter is built in three units as shown in Plate (2). The entire power supply, consisting of high voltage for the counter and B and C voltages for the amplifier, is housed in the larger cabinet A. Unit B contains the triode and is equipped with the bias and high voltage potentiometer controls, and the grid resistance selector switch. The counter is encased in a bakelite form C, together with the capsule containing the small standard source of radium (Plate 3). A five foot length of two conductor cable connects the counter to the amplifier box. Between the amplifier and power supply, any length of cable is permissible. The milliameter may be plugged directly into the amplifier box, or connected through a suitable length of cable. When working with gamma rays, it is convenient to have the milliameter at the amplifier box. If x-radiation is used, the milliameter may be mounted on the control panel.

(5) Plate (4) illustrates the construction of the counter. The body of the tube is a machined brass cylinder, into which are fitted two glass caps, sealed with picein wax. The anode wire is centered through mica disks which limit the counting volume to a one inch length of tube. The small sensitive cross-section makes it possible to determine intensities of radiation reaching equivalent areas anywhere on the film. Argon and alcohol vapor comprise the gaseous filling of the tube. Four centimeters of argon and four millimeters of alcohol vapor pressure make a satisfactory mixture, with operating voltage in the neighborhood of 800 volts.

(6) Detailed circuit diagrams of the power supply and amplifier are drawn on Plates 5 and 6.

PERFORMANCE DATA

(7) The range of exposures ordinarily encountered in gamma ray radiography includes exposures of the order of a few minutes as well as some entending over 100 hours, with type A film. To cover this range, three separate sensitivity scales must be used. The calibration curves for these scales are shown in Plate 7. Plate 8 is a record of the exposure meter response with a grid combination of 100 megohms and .05 microfarads. At intervals, the meter was exposed to a given intensity of gamma rays, giving a deflection of $0.75 \pm .03$ milliamperes, corresponding to an 11.5 ± 0.5 hours exposure. The meter reaches full deflection in about one minute, and shows negligible variation in response over the two hour period of test. Plates 9 and 10 give similar information for the medium and low sensitivity scales. On the lowest scale the meter reaches full deflection in about 10 seconds.

(8) With 100 Kv x-rays, the majority of exposures fall on the medium and low scales. At 1,000,000 volts an additional scale is necessary using a five megohm resistor.

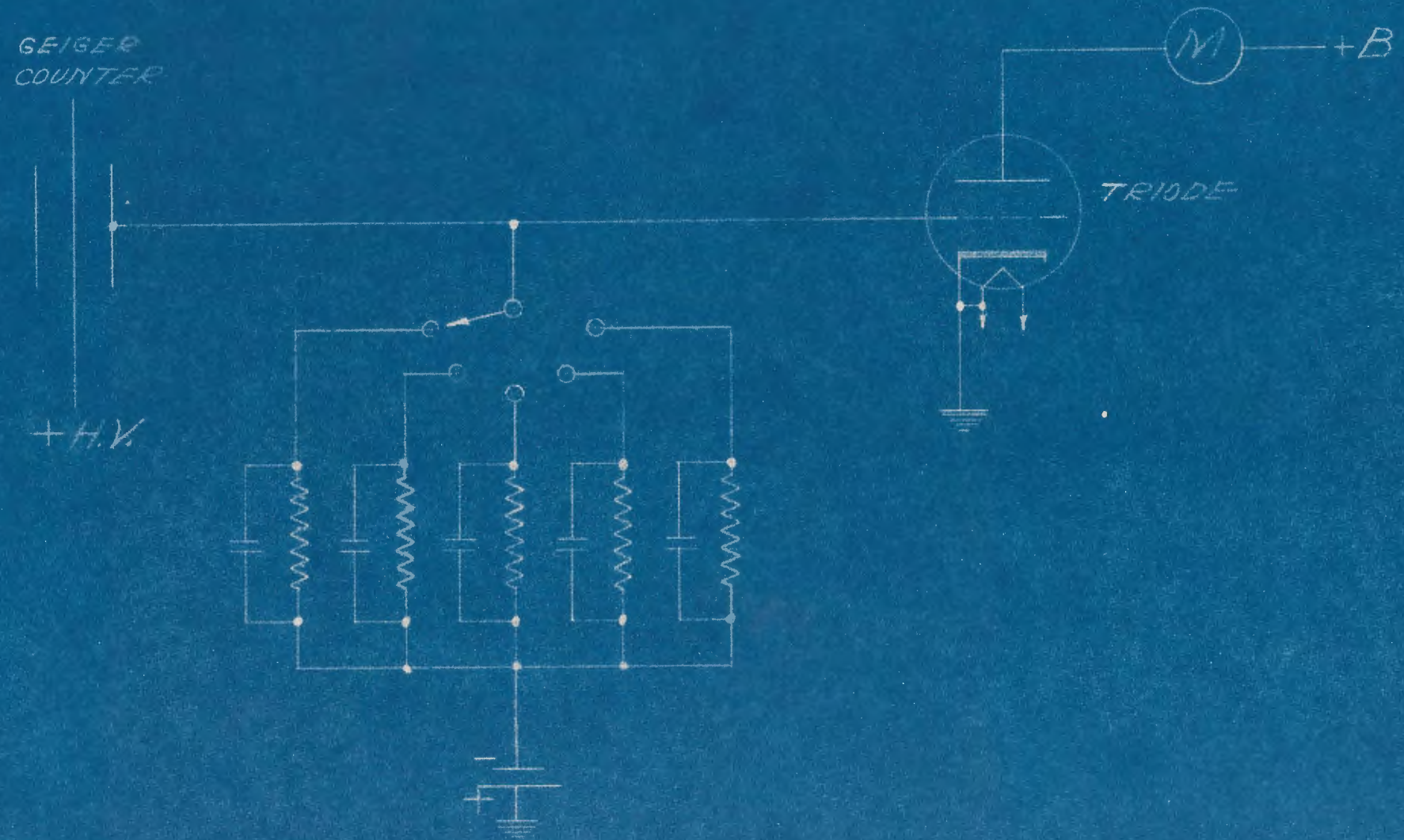


PLATE 1

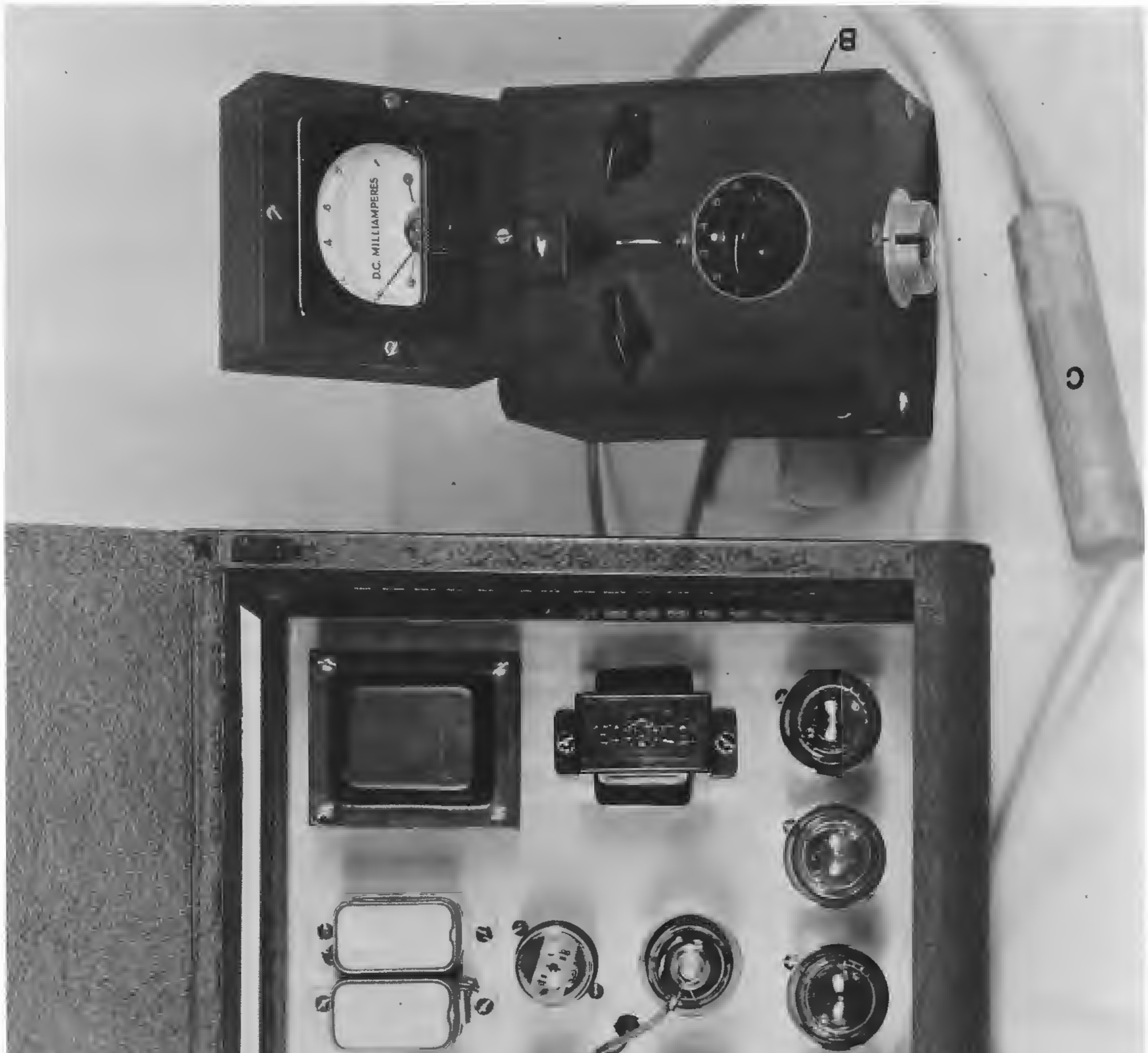


PLATE 2

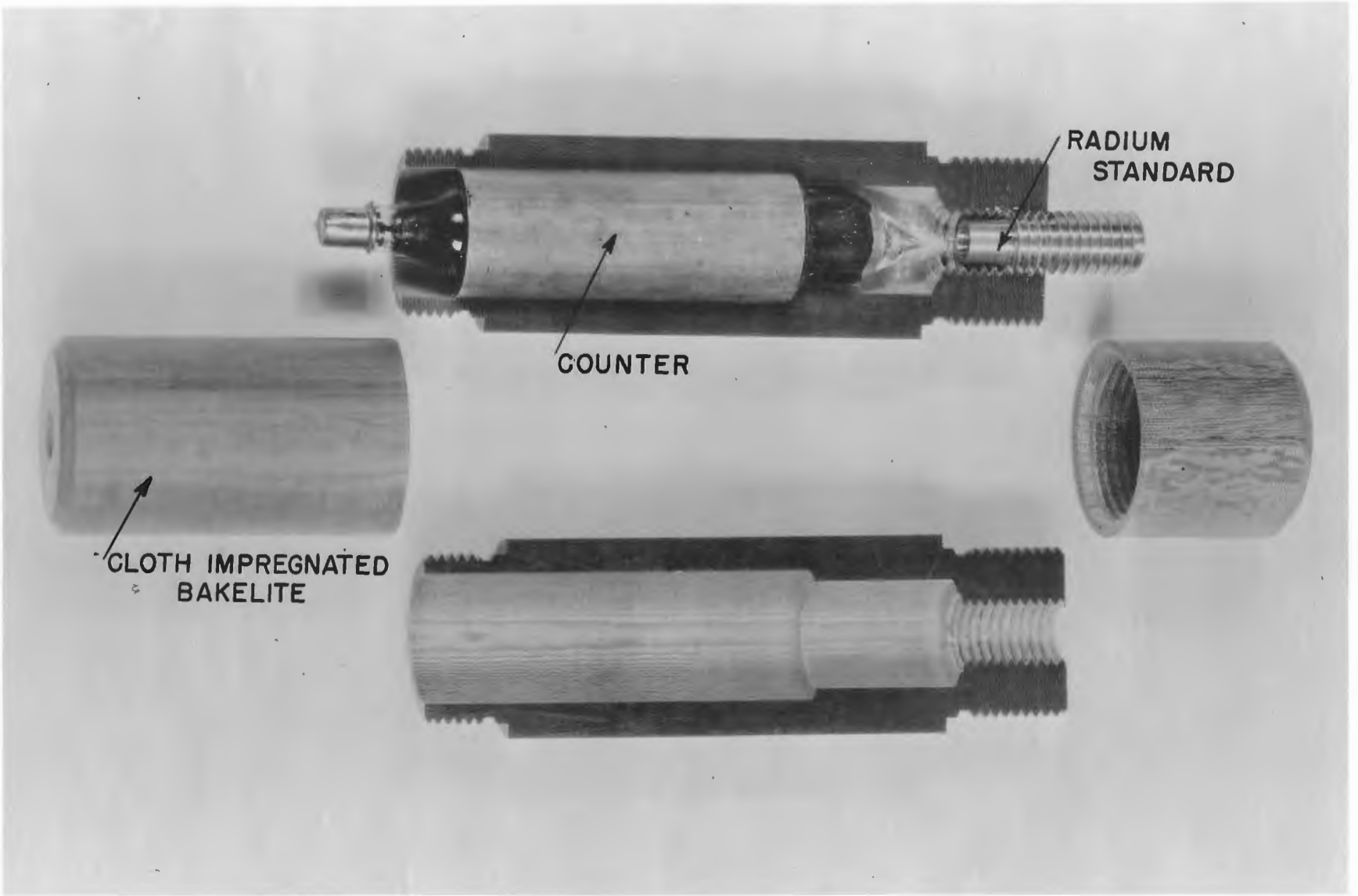
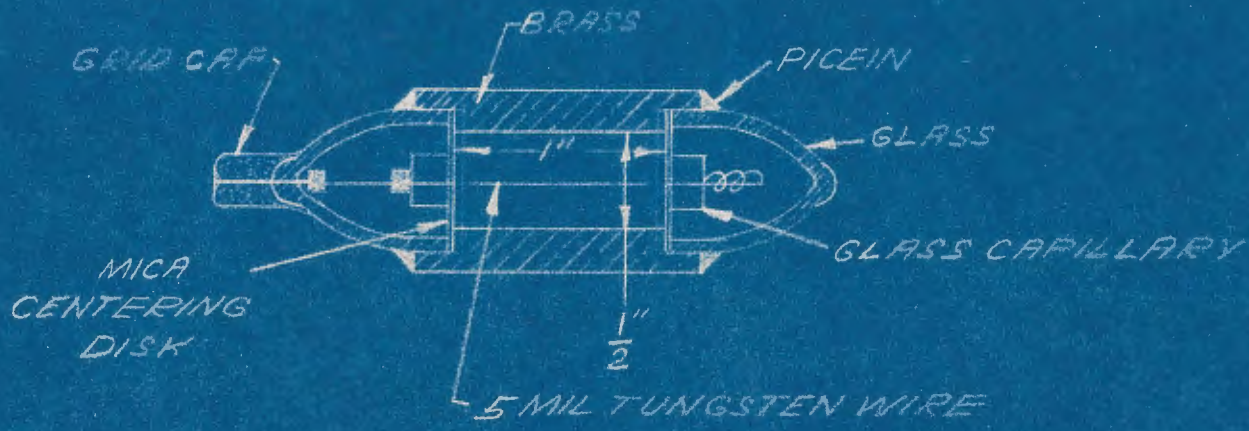


PLATE 3



GEIGER COUNTER FOR EXPOSURE METER

PLATE 4

POWER SUPPLY

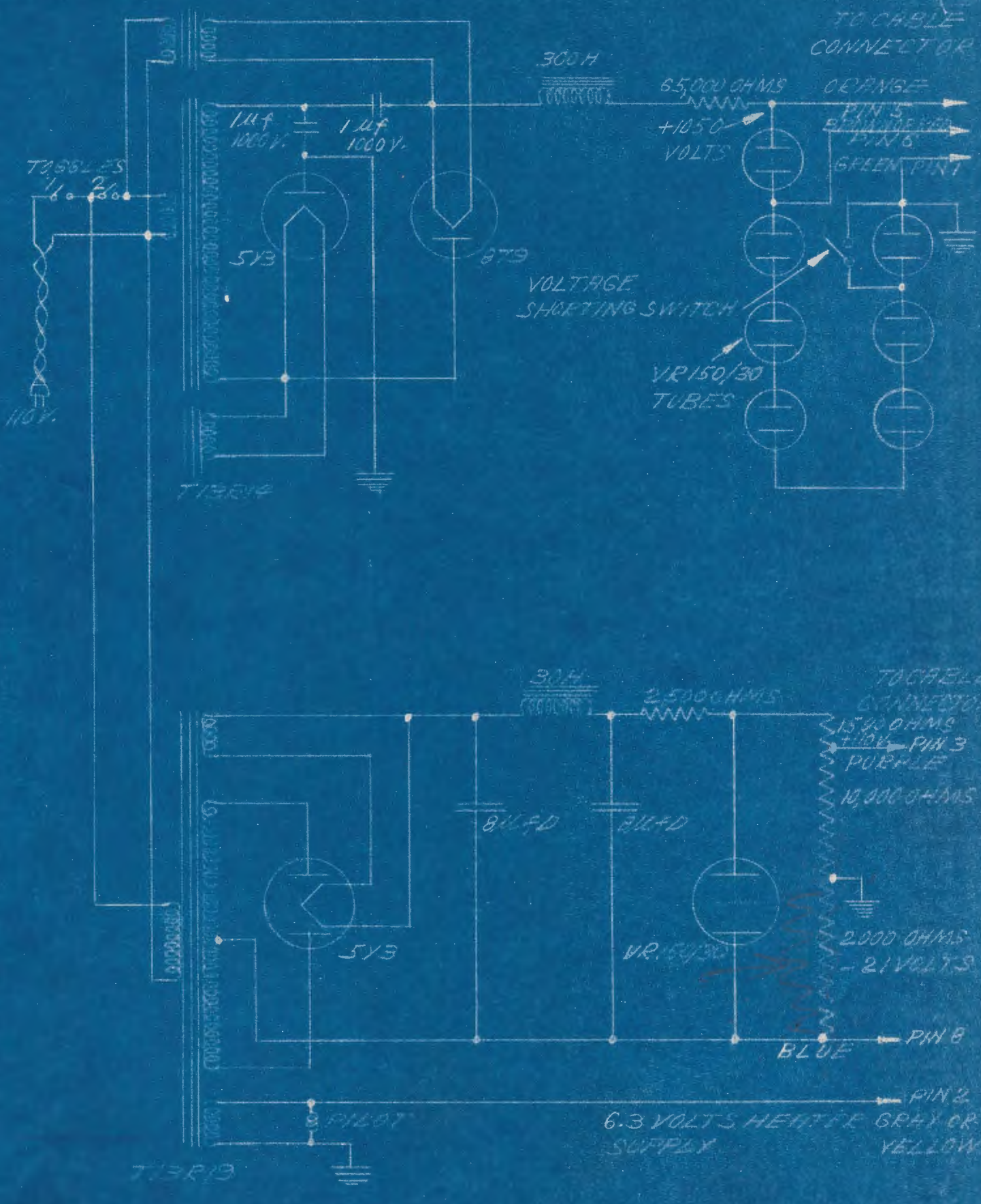


PLATE 5

AMPLIFIER CIRCUIT

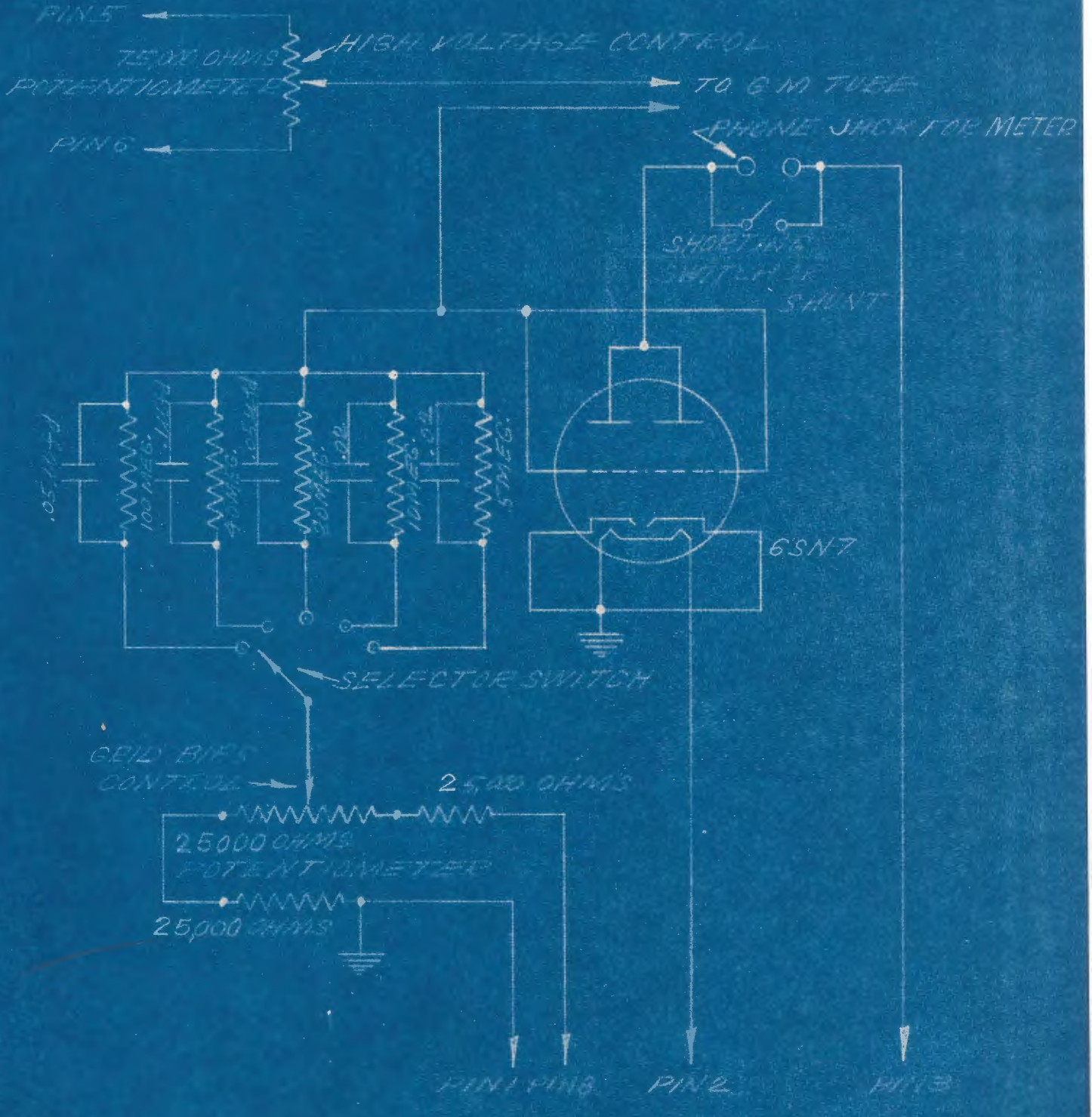


PLATE 6

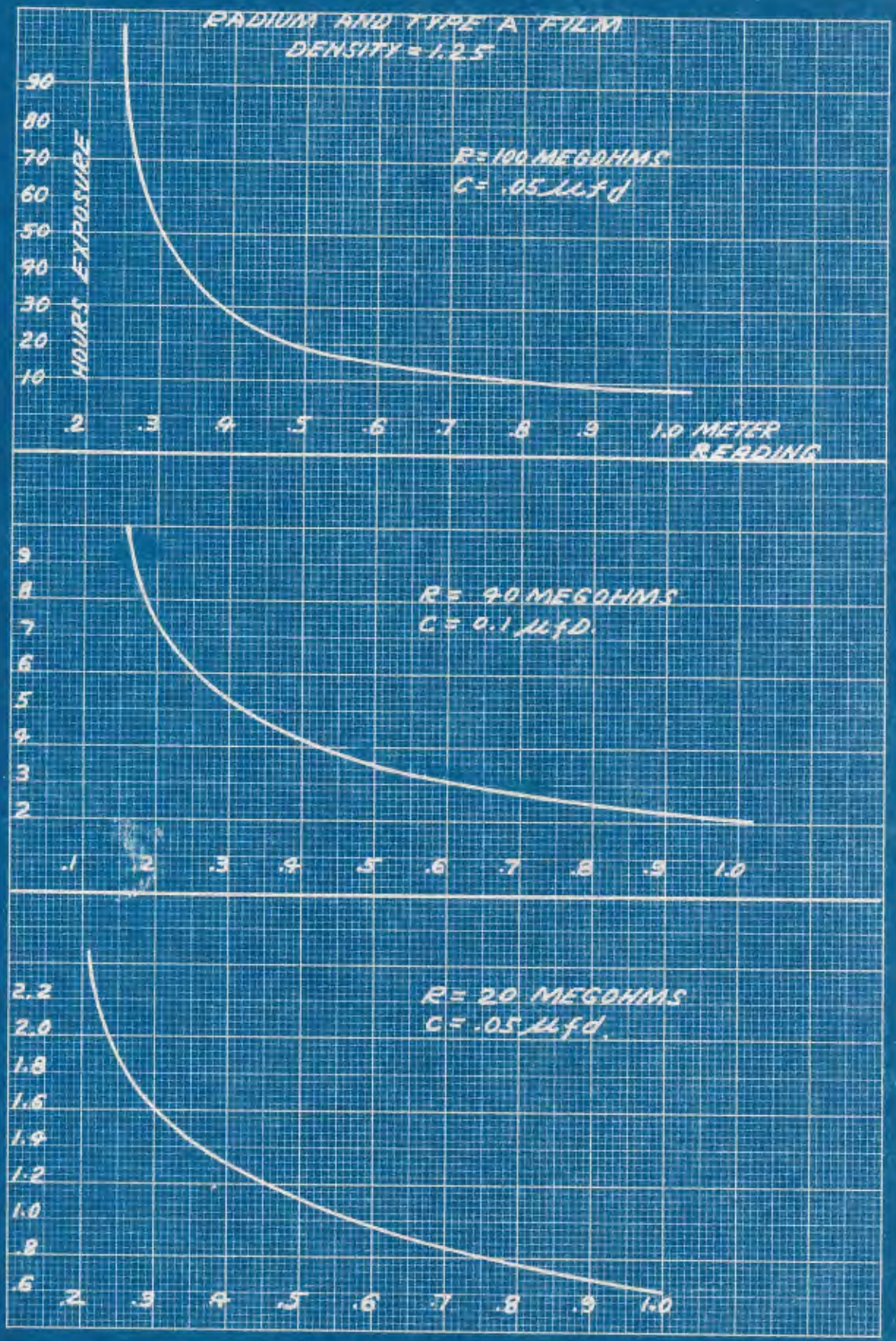
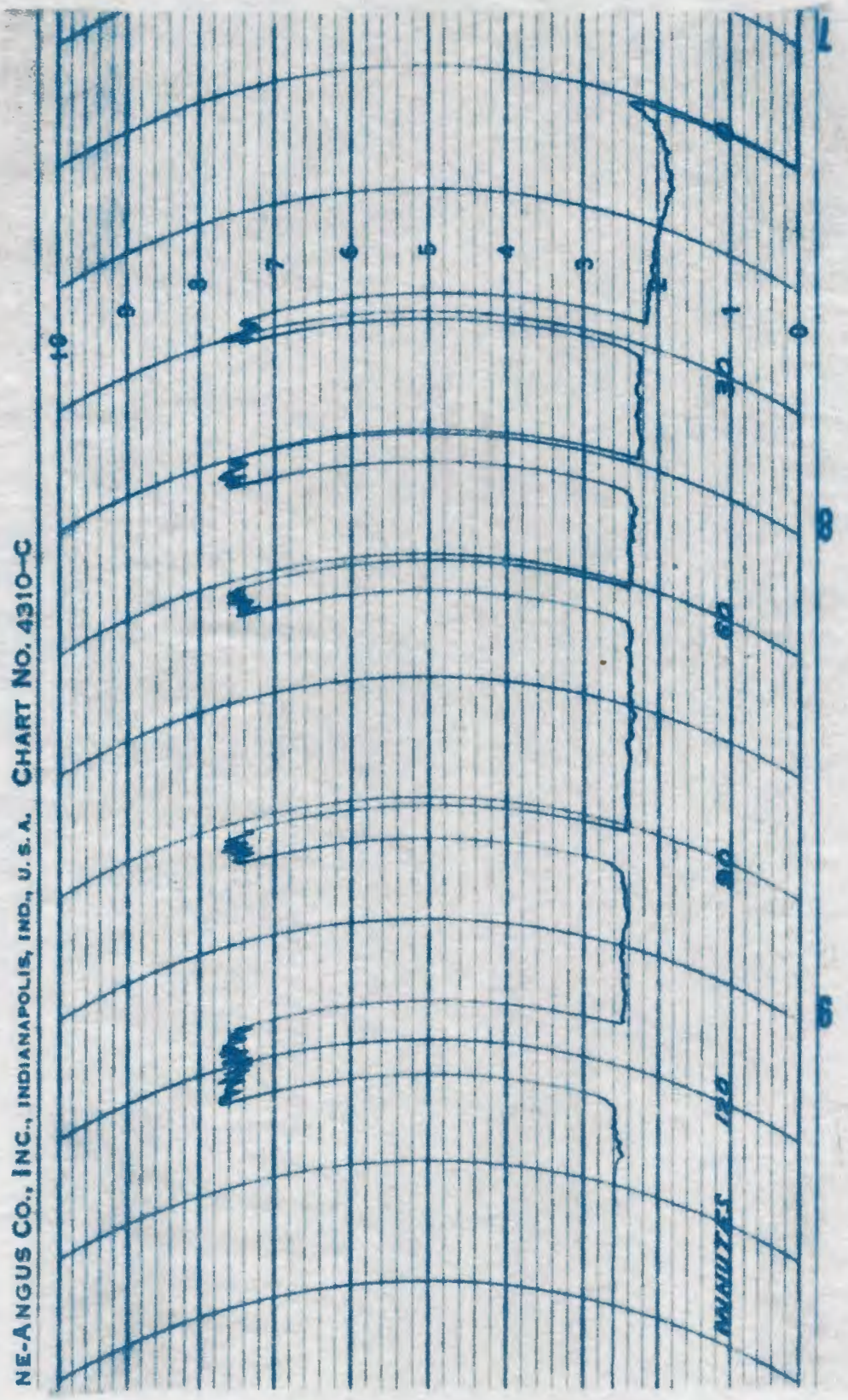
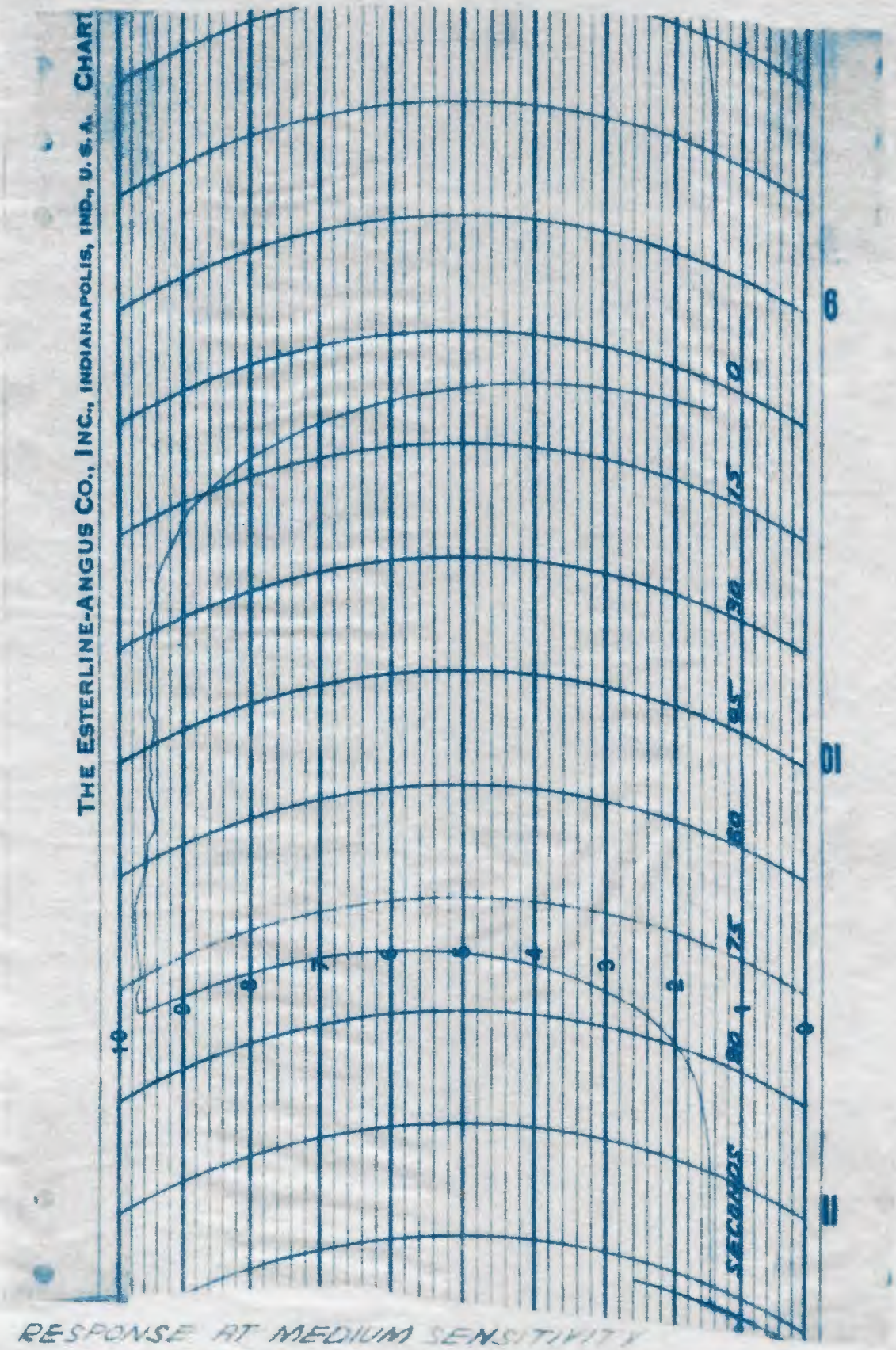


PLATE 7

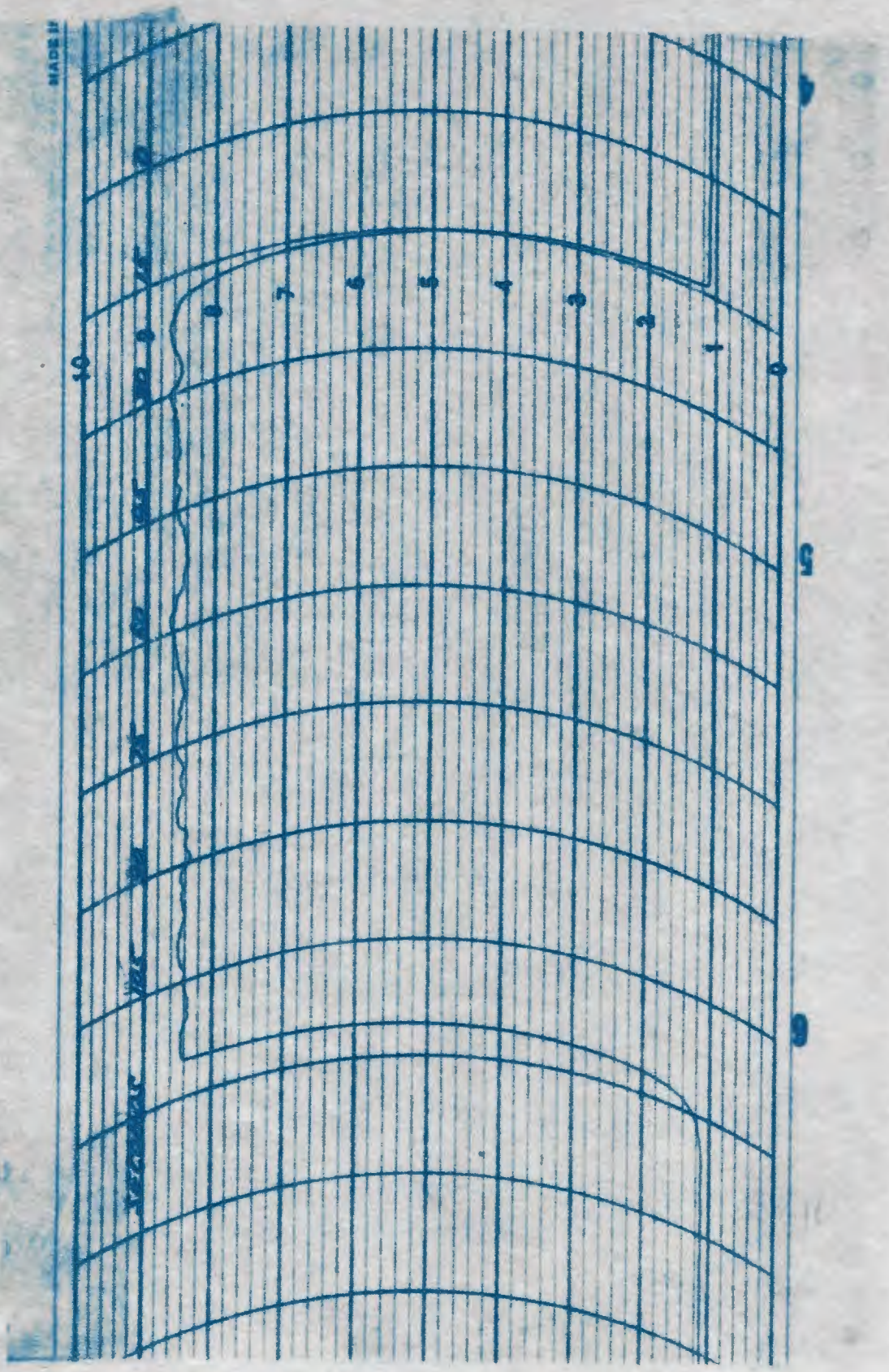


SENSITIVE SCALE - 10 HRS. TO 100 HRS. FOR 1.25 DENSITY WITH RADIUM AND TYPE "A" FILM

PLATE 8



RESPONSE AT MEDIUM SENSITIVITY
SCALE 2 HRS. TO 10 HRS. WITH EDIUM.
AND TYPE A FILM, DENSITY 1.25



RESPONSE AT LOW SENSITIVITY, 30 MINUTES TO 2.5 HRS. WITH RADIUM AND TYPE A FILM
DENSITY = 1.25

PLATE 10