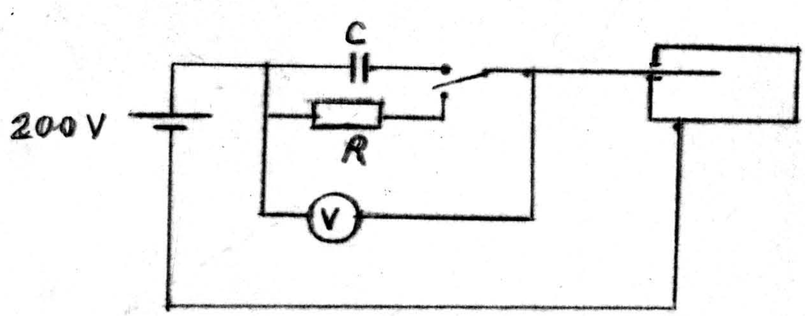
FORMATION OF X-RAYS IN CATHODE RAY TUBES
WITH HIGH ANODE VOLTAGES

X-rays originate whenever electrons hit an obstacle; consequently they form in cathode ray tubes when electrons hit an aperture, screen, walls, etc. At low voltages the radiation is of very long wavelengths and the glass walls of the tube absorb it completely. However, at second anode voltages above 15 kv, more than the maximum tolerated dosis may be omitted.

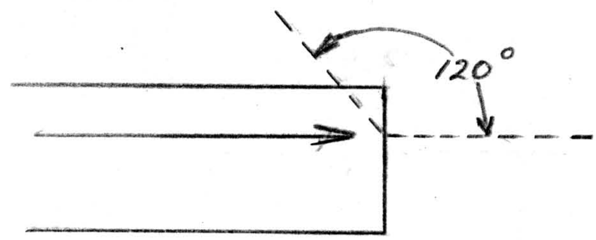
Unit - The international unit of x-ray quantity (Roentgen) is determined by the ionization produced in 0.001293 gram of air. The Roentgen (r) is the quantity of x-radiation which when the secondary electrons are fully utilized and the effects of radiation avoided produces in 1 cc of atmospheric air at 0°C and 76 C Hg pressure such a degree of conductivity that one E.S.U. of charge is measured under saturation conditions (1,2). The x-ray dosis is measured (1) in an air ionization chamber (celluloid for low voltage and glass for high voltage). The circuit sketch below allows both instantaneous and integrated measurements.



The maximum tolerated dosis for continued exposure (2) is 10^{-5} Roentgen per second or 0.25 Roentger per day. There is some doubt whether this is sufficient protection against second generation genetic effects and probably, 10 times smaller dosis (10^{-6} r/s) should be aimed at.

The intensity of x-rays as formed in cathode ray tubes (3) is proportional to the square of the anode voltage, directly proportional to the current and to the atomic number of the element forming the target, and inversely proportional to the square of the distance from the target. Absorption of x-rays is proportional to the third power of the wavelength of the radiation and proportional to the fourth power of the atomic number of the screen material.

The increase of x-ray dosis with anode voltage is shown in figures 1 and 2 for various screen and electrode materials. Curves 3 and 4 show the thickness of lead layer necessary to reduce x-rays to the desired dosis at different voltages. All these measurements were made through 0.5 mm hard glass and under the conditions indicated on the figures. All measurements were taken at an angle of 120° to the direction of the electron beam.



In practice the glass walls will usually be heavier. However, not much protection is afforded by hard glass. For instance, at 50 kv and 1 ma a 12 mm glass wall will reduce x-rays from a tungsten screen only to about 10^{-4} r/s, that is, 10 times the maximum permitted dosis.

However, the G12 glass used extensively in cathode ray tubes has a lead oxide content of about 30%. It is estimated (5) that the "lead equivalent" of a lead glass with 50% PbO is 17%, that is, a 10 mm layer of this glass will absorb as much radiation as a 1.7 mm layer of lead. Thus we may assume that G12 glass will have a lead equivalent of 10%; a layer of 4 mm thickness will be equivalent to 0.4 mm lead. From figure 3 this is found adequate to reduce x-rays emitted at 40 kv and 1 ma below the level of 10^{-6} r/s. According to figure 1, conventional screen and electrode materials give only ½ the "tungsten values" used in figure 3. In front viewing screens, we may also assume that a considerable amount of x-rays is absorbed by the screen material itself. Thus the protection afforded by 4 mm of G12 glass may be adequate up to 50 kv.

There is one patent (US 2,291,406 issued July 28, 1942, Alien Property Custodian; CP6) dealing with x-ray protection in cathode ray tubes. This uses an inside coating of lead sulfide or bismuth sulfide instead of the aquadag and recommends the use of a sufficient thickness of lead glass for the face plate.

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5-26-44

FIG. 1

X-RAY DOSIS vs ANODE VOLTAGE FOR VARIOUS SCREEN MATERIALS

Screen Current = 100 μA
Measuring Dist. = 500 mm

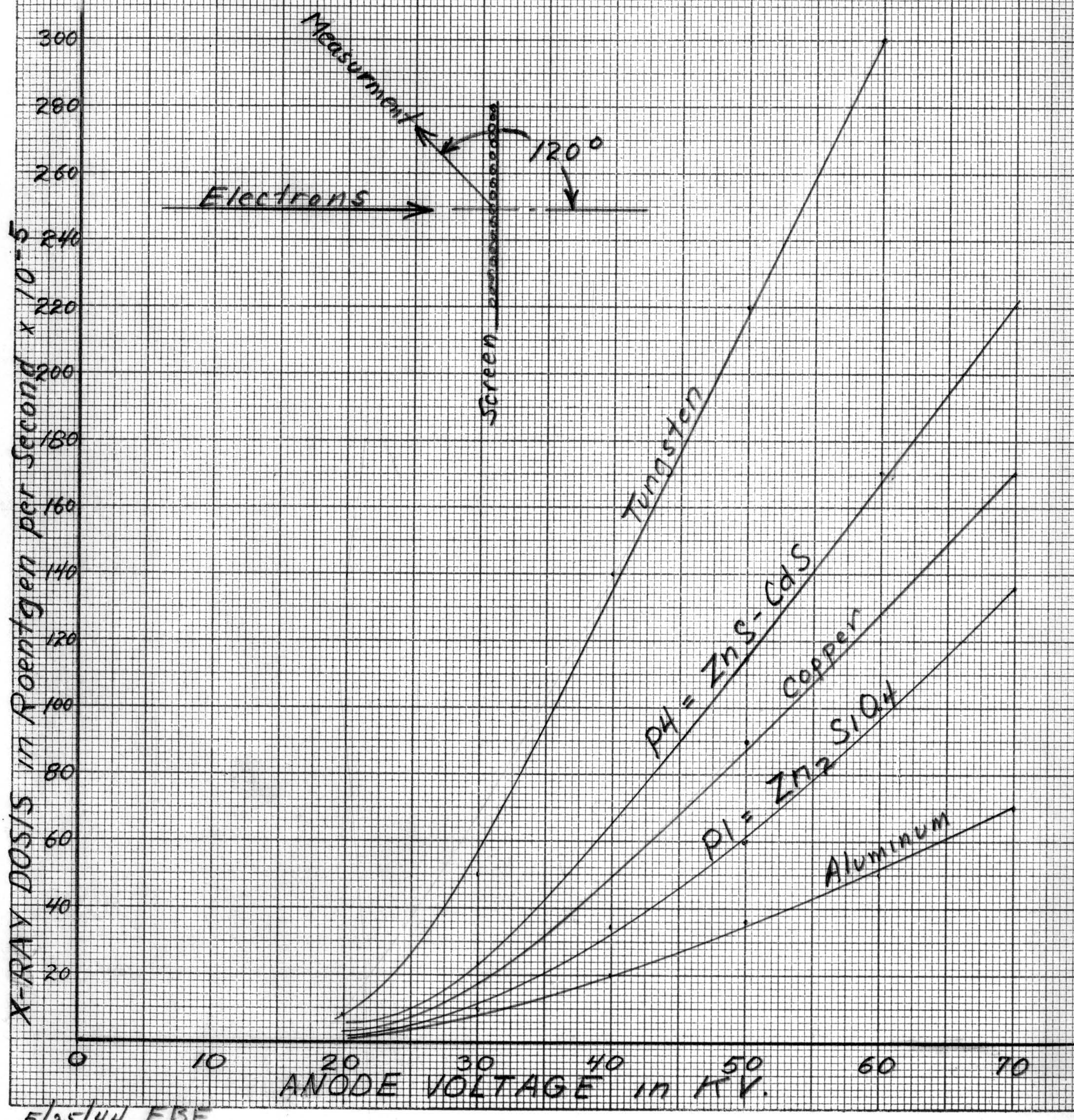

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FIG. 2

X-RAY DOSIS vs ANODE VOLTAGE FOR VARIOUS SCREEN MATERIALS

Screen Current = 100 μA
Angle of Observation = 120°
Distance from Screen = 300 mm

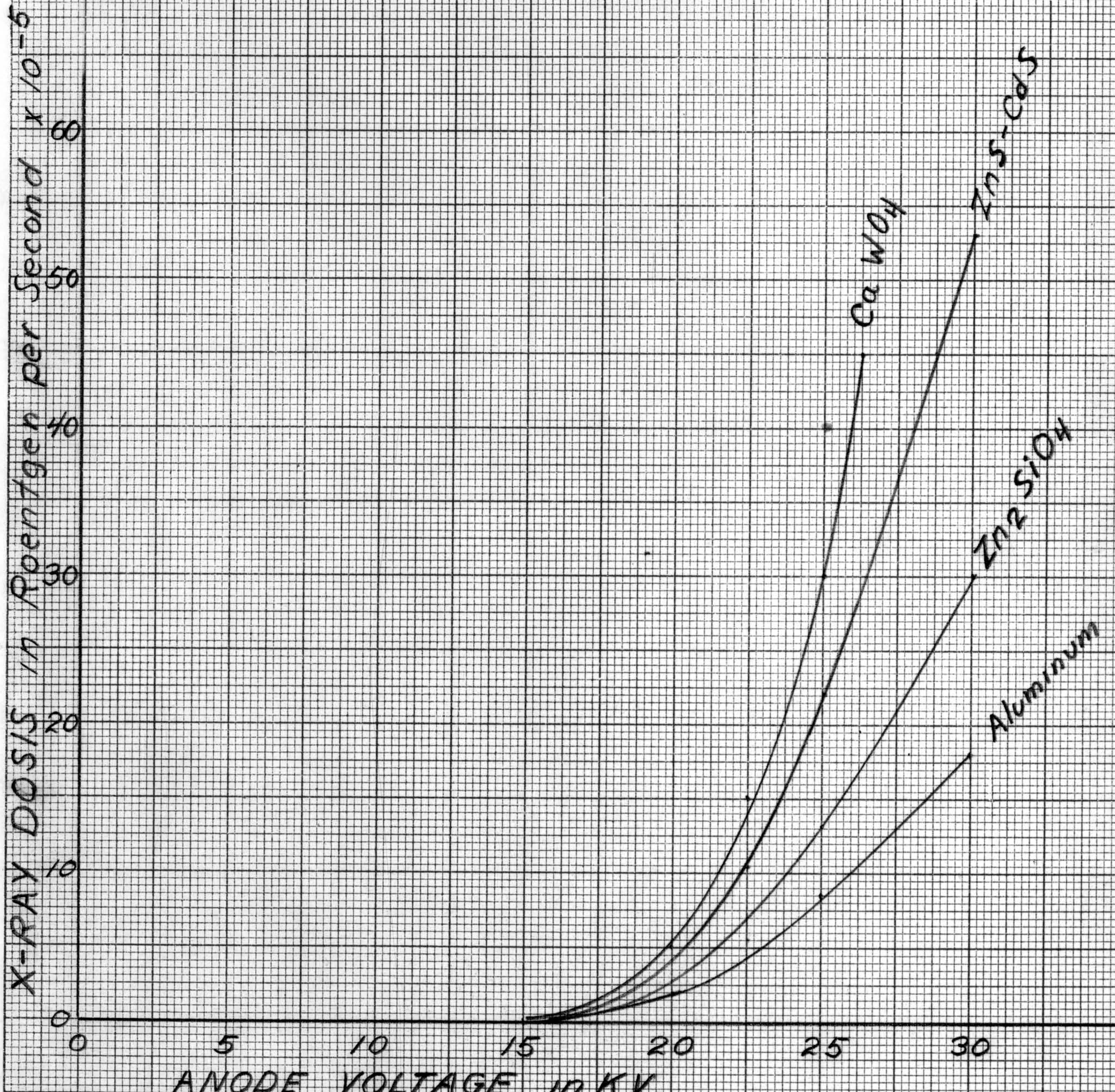

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FIG 3

THICKNESS OF LEAD TO REDUCE X-RAYS TO A DESIRED DOSIS AT VARIOUS ANODE VOLTAGES

Tungsten Target
Anode Current = 1ma
Measuring Distance = 300 mm

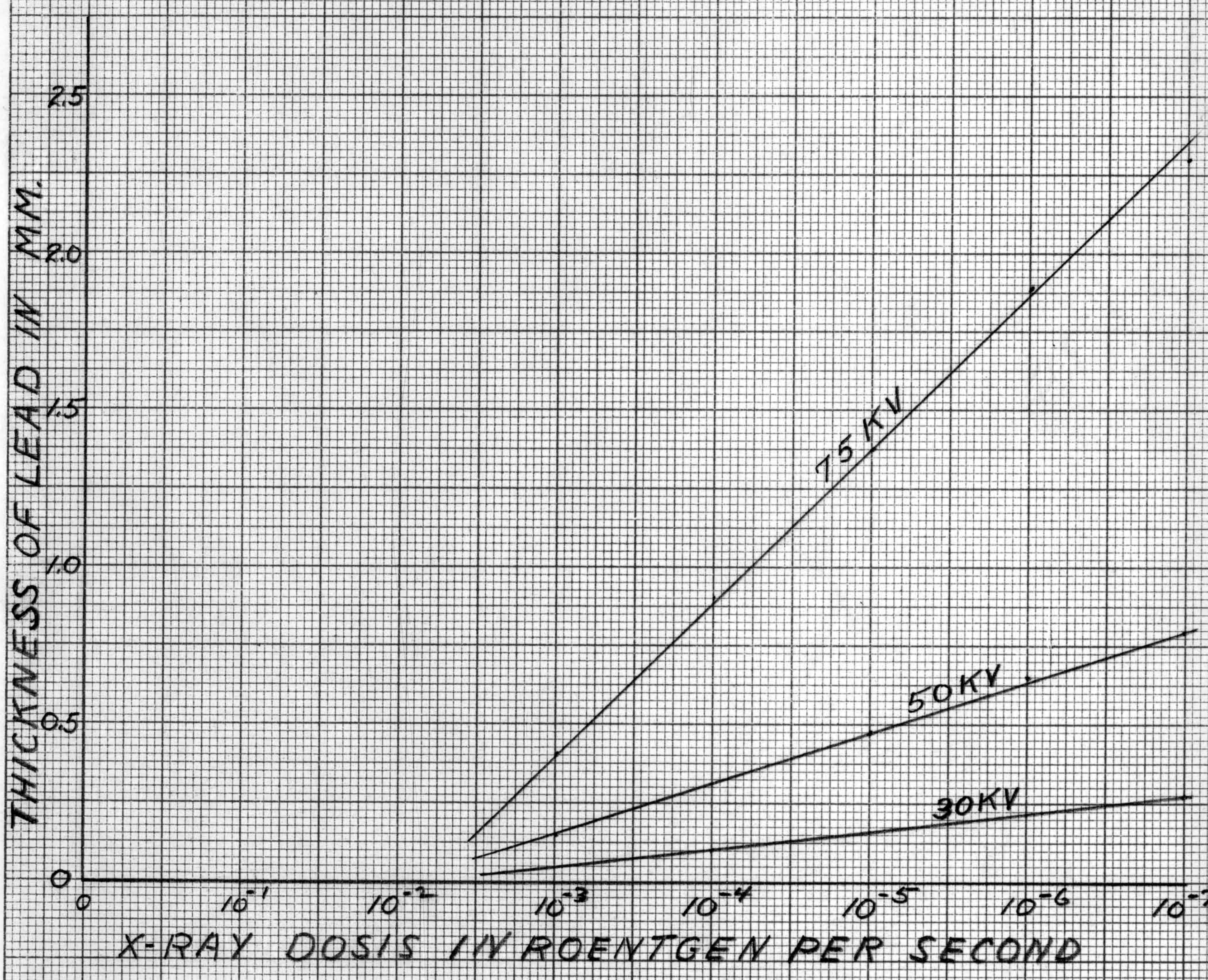
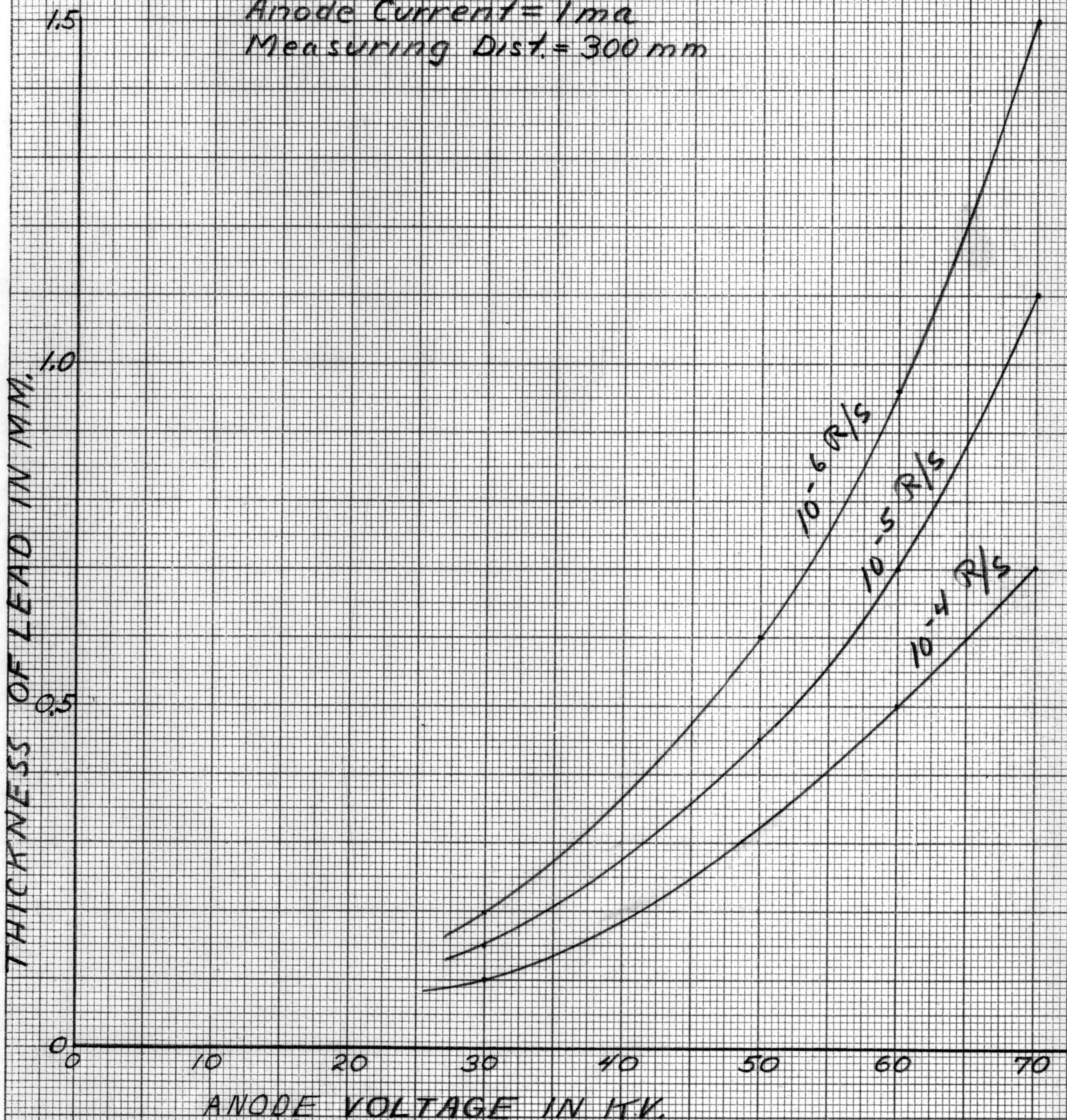


FIG 4.

THICKNESS OF LEAD TO REDUCE X-RAYS TO A DESIRED DOSIS AT VARIOUS ANODE VOLTAGES

Tungsten Target
Anode Current = 1 ma
Measuring Dist. = 300 mm



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   See also chapter on measurement of x-rays in E.M. Dugge, Biological Effects of Radiation, Volume 1, page 43 to 87.

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