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TECHNICAL DIVISION

RADIOGRAPHY OF URANIUM-ALUMINUM ALLOYS

WILLIAM H. WILSON

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RADIOGRAPHY OF URANIUM-ALUMINUM ALLOYS

William H. Wilson

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ABSTRACT

Techniques have been developed for radiographing uranium-aluminum alloys. An exposure chart for 15% uranium alloy has been constructed and is included as an aid in selection and operation of equipment. This information may be easily adjusted to apply to alloys containing other than 15% uranium. Since machines vary in radiation characteristics, the exposure data are intended only as a guide in the making of radiographs. These techniques have been employed to x-ray both cast ingots and rolled plate. Contrast and definition in the radiographs were good if the exposure time was kept low. Both porosity and segregation could be readily detected in the ingots.

THEORY

Absorption of x-radiation in a uranium-aluminum alloy is controlled principally by the uranium content as is indicated by Figure 1. These data appeared in the 30th edition, "Handbook of Chemistry and Physics" and have been converted here to linear coefficients. Figure 2 shows how density and atomic percent vary for 0-60 weight percent uranium alloys (rolled). Notice that a 40 weight percent uranium alloy is about 7 atomic percent and has a density only 50% greater than aluminum.

The classical law of absorption is as follows:

$$\text{Eq. 1.} \qquad I = I_o e^{-\mu x}$$

Where
I = emergent beam intensity
I_o = incident beam intensity
μ = linear absorption coefficient
x = specimen thickness

The above is an accurate statement only when it is expressed as a differential. The softer radiation is attenuated more and therefore the spectrum changes as the beam passes through the absorber. In other words, Equation 1 is expressed for a theoretical monochromatic beam.

[redacted]

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KEUFFEL & ESSER CO., N. Y. NO. 359-13
Two millimeters, one inch long
MADE IN U. S. A.

[redacted]

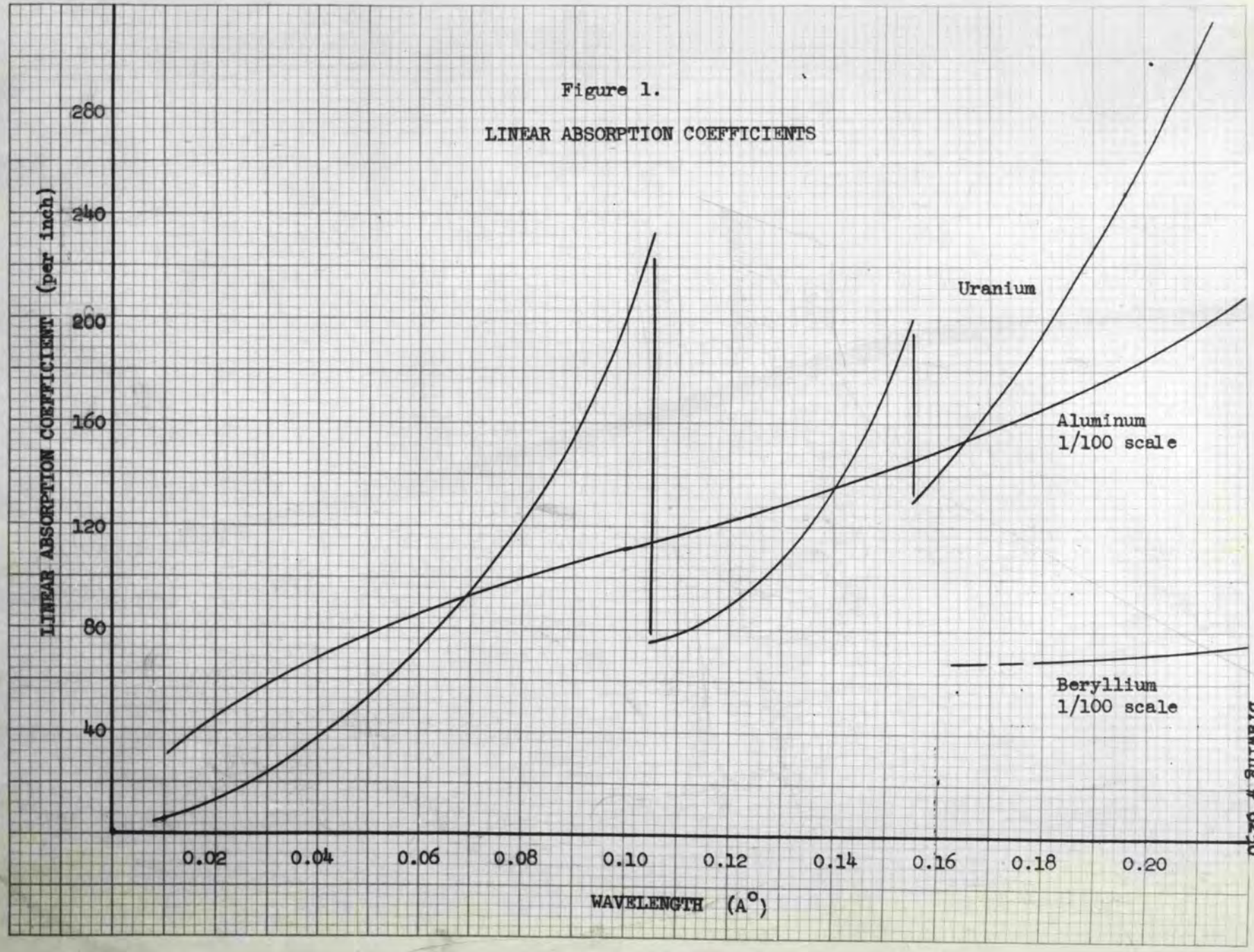

Figure 1.

LINEAR ABSORPTION COEFFICIENTS

Drawing # 6250

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Drawing # 6251

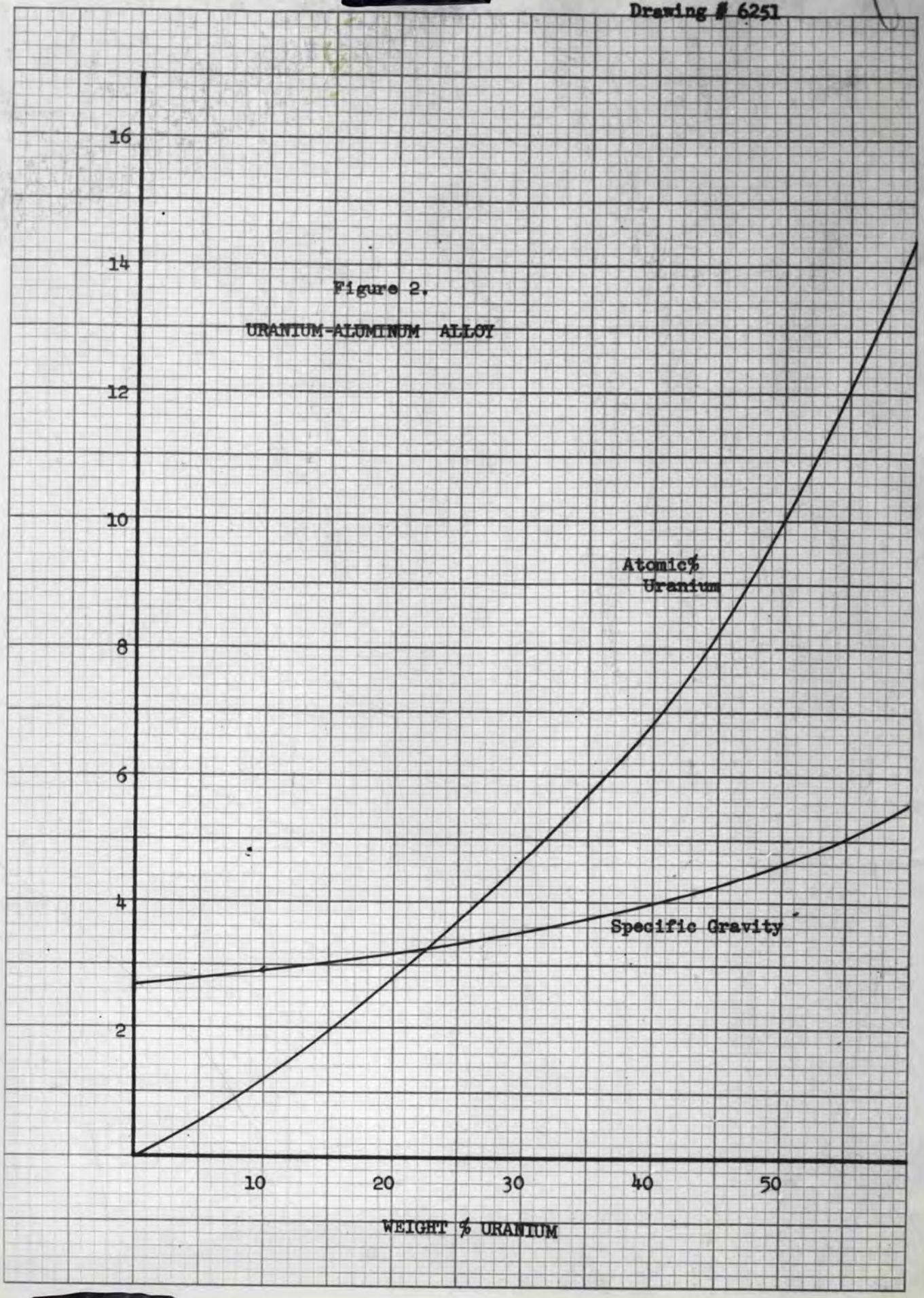

Figure 2.

URANIUM-ALUMINUM ALLOY

[redacted]

[redacted]

The radiation spectrum of a tube at a given voltage can be drawn qualitatively by finding the shortest wave length (λ_o) and wave length at which there is maximum intensity (λ_m). These points may be found approximately by the equations

$$\text{Eq. 2} \qquad \lambda_o = \frac{12345}{\text{peak voltage}}$$

$$\text{Eq. 3} \qquad \lambda_m = 3/2 \ \lambda_o$$

The spectrum can now be visualized as a distribution curve using these two points as shown in Figure 3.

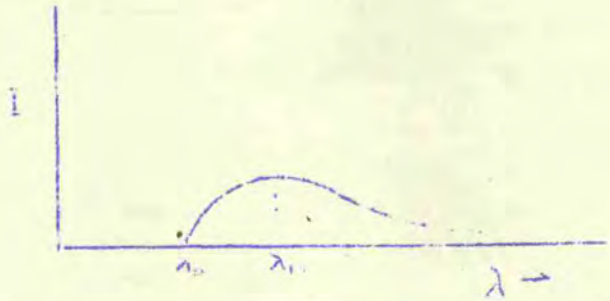

Figure 3. Typical Spectrum

By using a reasonable value (around 1%) for I/I_o, the absorption coefficient μ may be calculated for an alloy of a given thickness by using Equation 1. A value for the effective wave length corresponding to this coefficient may be obtained from Figure 1. Equations 2 and 3 will now convert this λ_m to a voltage commensurate with the specimen.

A striking picture of the influence of wavelength in penetrating a uranium alloy can be had by calculating the transmission (I/I_o) for several points. This is shown for a 20% U-Al alloy one inch thick in Figure 4. The voltage necessary for the corresponding λ_m is also given.

Beryllium does not impede x-rays very much as is shown by comparing it with aluminum in Figure 1. To get a transmission as low as a few percent in order to obtain good contrast would demand softer radiation than is available with the present machine.

EQUIPMENT

A Philips Searchray 150 KVP cabinet unit equipped with a watercooled shielded tube was used. The current can be varied from 4 to 8 milliamperes and the voltage from 24 to 150 KVP by stepless controls. After the machine was installed, Health Physics checked and found 400 mr radiation around the upper part of the cabinet at full power. The tube was therefore inclosed with 3/16" lead sheet and a subsequent check showed the radiation level below the 12.5 mr tolerance level.

[redacted]

Drawing # 6252

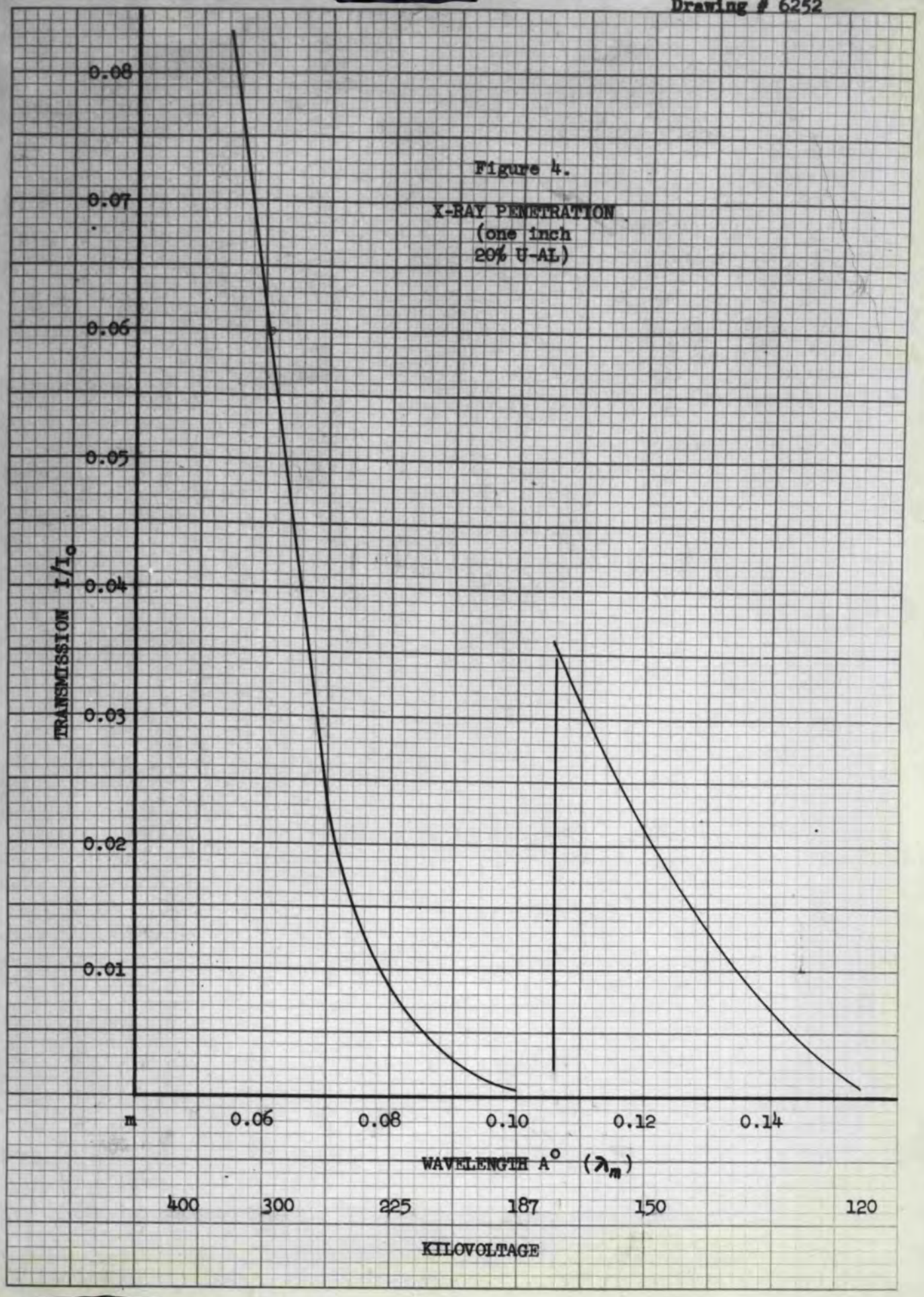

Figure 4.

X-RAY PENETRATION
(one inch
20% U-AL)

KEUFFEL & ESSER CO., N. Y. NO. 359-8
5 X 5 to the ½ inch.
MADE IN U. S. A.

[redacted]

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Eastman Kodak film, chemicals and accessories were used.

The metal to be x-rayed varied in thickness from 1/8" to 1" and was cast and rolled by the Engineering Materials Section of the Technical Division. Composition was determined in the analytical laboratory of the Chemistry Division. The alloys contained from 12 to 30% uranium, the balance aluminum.

PROCEDURE

The film was loaded in cardboard film holders backed with 0.010" lead to decrease back-scattering. The alloy was placed on the holder and blocked with lead bars to prevent undercutting around the edges. After exposure the film was developed for five minutes in rapid developer, rinsed in a dilute acetic acid bath, and fixed for eight minutes. It was washed and then dried at room temperature.

Initially the density was not measured by instrument but the film was accepted as correctly exposed if it fell into a range suitable for easy examination. Later on measurements were made on the radiographs and the density was found to vary from 1.8 to 2.2

DISCUSSION OF RESULTS

Figure 5 represents the information obtained from this work in standard exposure chart form. Specimen thicknesses were adjusted so that the data would be correct for a 15% U ingot, although most of the exposures were made on alloys near this composition. However, the chart may be used for compositions from 10 to 30% U by simply changing the thickness proportionate to the weight percent. For instance a 1/2", 30% U ingot should be exposed approximately the same amount as a 1", 15% U ingot. The theoretical inaccuracy of this method is apparently compensated by the smaller amount of diffusion and absorption by the aluminum in the thinner specimen.

In general the contrast is good. Segregation of UAl_5 and porosity appear quite plainly. However, exposures of more than 30 milliampere-minutes lose detail due to diffusion. Use of a front lead screen will add some clarity to the radiograph and should be used when making long exposures. Exposures from 2 to 12 milliampere minutes give best compromise between contrast and detail.

Some work was done on beryllium but the results were not altogether satisfactory. A softer radiation than can be had with 24 KVP would be advantageous. Only large voids and cracks perpendicular to the beam were noted on examination of the negatives. Slow film should be used and high film densities will increase contrast.

September 30, 1948

W. H. Wilson

Section IV
Engineering Materials

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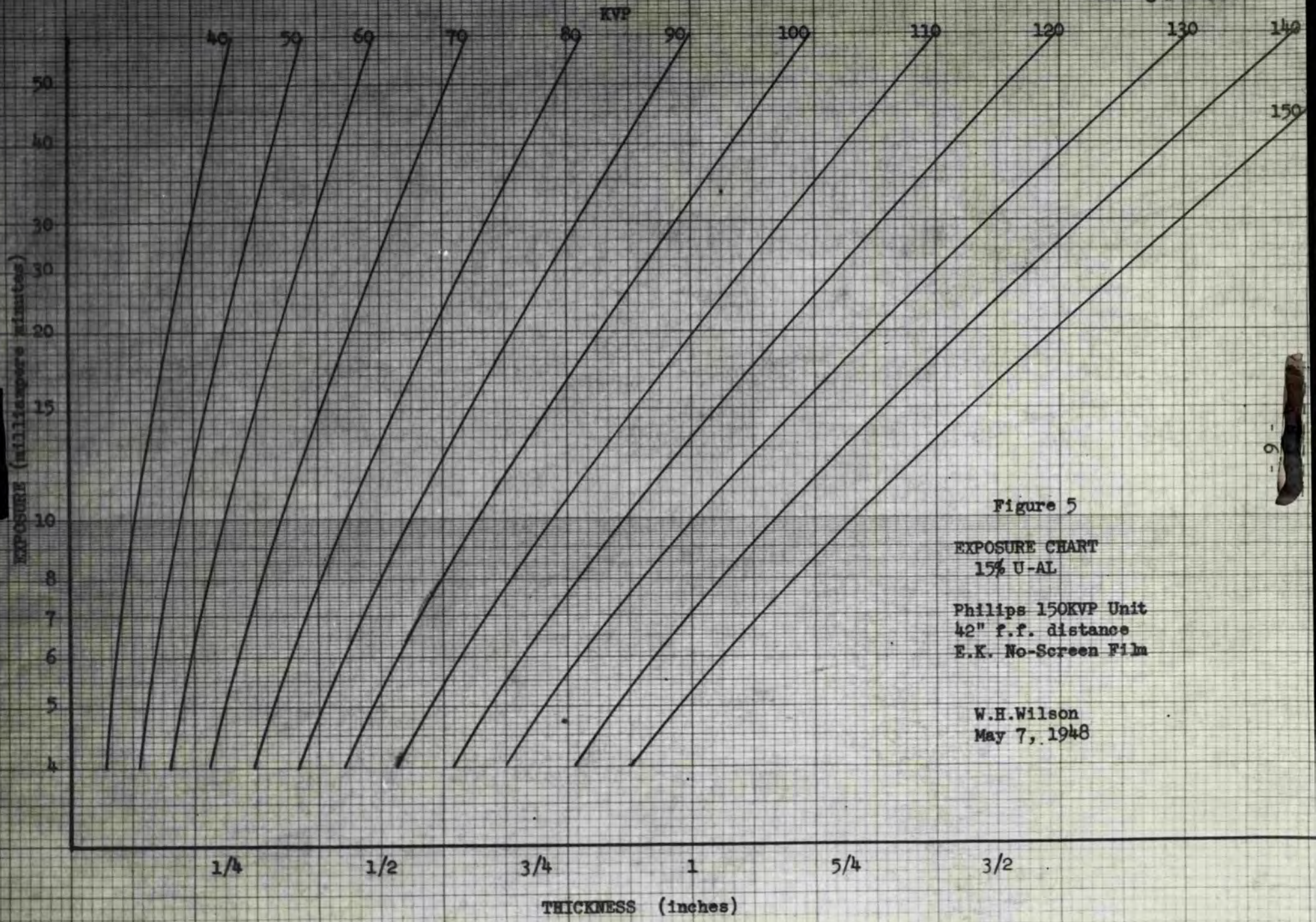

Figure 5

EXPOSURE CHART
15% U-AL

Philips 150KVP Unit
42" f.f. distance
E.K. No-Screen Film

W.H.Wilson
May 7, 1948