NATIONAL BUREAU OF STANDARDS REPORT

10 270

MEASUREMENT OF THICKNESS OF CHROMIUM ON CURRENCY PRINTING PLATES

Technical Report

To

Bureau of Engraving and Printing

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards [1] was established by an act of Congress March 3, 1901. Today, in addition to serving as the Nation's central measurement laboratory, the Bureau is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To this end the Bureau conducts research and provides central national services in four broad program areas. These are: (1) basic measurements and standards, (2) materials measurements and standards, (3) technological measurements and standards, and (4) transfer of technology.

The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

> Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic and Molecular Physics—Radio Physics [2]—Radio Engineering [2]—Time and Frequency [2]—Astrophysics [2]—Cryogenics.[2]

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; develops, produces, and distributes standard reference materials; relates the physical and chemical properties of materials to their behavior and their interaction with their environments; and provides advisory and research services to other Government agencies. The Institute consists of an Office of Standard Reference Materials and the following divisions:

> Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations in the development of technological standards, and test methodologies; and provides advisory and research services for Federal, state, and local government agencies. The Institute consists of the following technical divisions and offices:

> Engineering Standards—Weights and Measures — Invention and Innovation — Vehicle Systems Research—Product Evaluation—Building Research—Instrument Shops—Measurement Engineering—Electronic Technology—Technical Analysis.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center consists of the following divisions:

> Reactor Radiation—Linac Radiation—Nuclear Radiation—Applied Radiation.

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in the selection, acquisition, and effective use of automatic data processing equipment; and serves as the principal focus for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

> Information Processing Standards—Computer Information — Computer Services — Systems Development—Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System, and provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

> Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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MEASUREMENT OF THICKNESS OF CHROMIUM ON CURRENCY PRINTING PLATES

Technical Report

January 1 to June 30, 1970

By

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To

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MEASUREMENT OF THICKNESS OF CHROMIUM ON CURRENCY PRINTING PLATES

Fielding Ogburn

National Bureau of Standards, Washington, D. C. 20234

INTRODUCTION

There is a need for a nondestructive means of measuring the thickness of chromium on the electroformed nickel plates used to print currency. The measurement should have a reliability of at least ±10% up to a thickness somewhat greater than 8 µm (0.3 mil).

Several commercially available thickness gages can be used to measure the thickness of chromium layers on nickel, but their accuracy for this application is eitehr too poor or unknown. In the latter category are the magnetic type gages such as the Permascope and Accuderm and the beta backscatter type, such as the Beta Scope and Micro-derm. In addition there is the fluorescent x-ray method.

This report covers an evaluation of these methods of measuring the thickness of the chromium and the initial stages of developing a fluorescent x-ray technique using a radioisotope instead of an x-ray generator.

PREPARATION OF STANDARD THICKNESS SAMPLES

To evaluate the thickness gages, we prepared specimens of chromium plated nickel with known thicknesses of chromium.

We started with 5 x 8 inch sheets of low carbon steel which had been plated with at least 50 μm (2 mils) of Watts nickel (buffed). These we plated uniformly with conventional chromium in a cell designed to obtain uniform thickness distribution and then cut them up into 3 cm (1 inch) squares.

To determine the chromium thickness we turned to x-ray techniques which we found to be quite sensitive to the chromium thickness. We measured each of 18 squares cut from the center of a panel to establish the relative thickness of each square. To establish the absolute thicknesses, we determiend the weight of chromium on each of three or four squares by conventional stripping-weight loss methods. Then by treating these stripped specimens as calibrating standards we calculated the weight per unit area of chromium on each of the other squares. We thus built up a set of standard thickness samples with thicknesses of approximately 0.02, 0.1, 0.2, 0.3, 0.4, and 0.5 mil.

EVALUATION OF METHODS

To determine the sensitivity of each instrument we measured one specimen of each thickness with each instrument. The accompanying figures show a plot of thickness vs instrument reading for each instrument.

Magne-gage

With this instrument, one dial division corresponds to 0.02 mil or 6% at 0.3 mil. This corresponds to the uncertainty of the gage if it is carefully calibrated and operated by the same individual. Errors double this can be expected if the operator does not exercise care.

Permascope

The uncertainty of this instrument appears to be between ±5 and 10%. We have not had much experience with this instrument, but it appears that the reproducibility can be improved with experience. We also understand that a new probe is available which incorporates a spring device enabling more reproducible positioning.

Beta Scope

At 0.3 mil, our measurements with this instrument had an uncertainty of about 0.05 mil. This instrument counts backscattered beta particles. If the time of counting is increased, the precision is improved. Double the time improves the precision by a factor of 1.4. The uncertainty of 0.05 mil is based on a 4 minute count.

Fluorescent x-rays

With fluorescent x-ray techniques, one has the option of measuring either the x-rays characteristic of the coating, Cr-Kα, or of the substrate, Ni-Kα. We found that for thicknesses less than about 0.1 mil, Cr-Kα measurements give the best results and for thicker coatings, Ni-Kα is best. The precision of the method is better than 1% in the 0.1 to 0.5 mil range using Ni-Kα radiations.

Kocour Thickness Tester

This instrument measures the current required to anodically dissolve the chromium over a well defined area about 1/8 inch in diameter. The readout is in thickness units. It would be suitable for the currency plates as far as accuracy is concerned, but it is destructive to the coating.

Summary of Evaluations

Both the Magne-gage and the Permascope appear to have the precision required by the Bueau of Engraving and Printing, but only if used by a reliable operator. The Accuderm is, we believe, equivalent to the Permascope.

The Beta Scope, and its equivalent, the Microderm, do not meet the precision requirements.

The fluorescent x-ray method offers much better precision than required and is rapid, but requires rather elaborate equipment cost-about $25,000.

All these methods must be calibrated with standard thickness samples. Suitable standards can be prepared easily by the National Bureau of Standards and it is possible that they are available commercially.

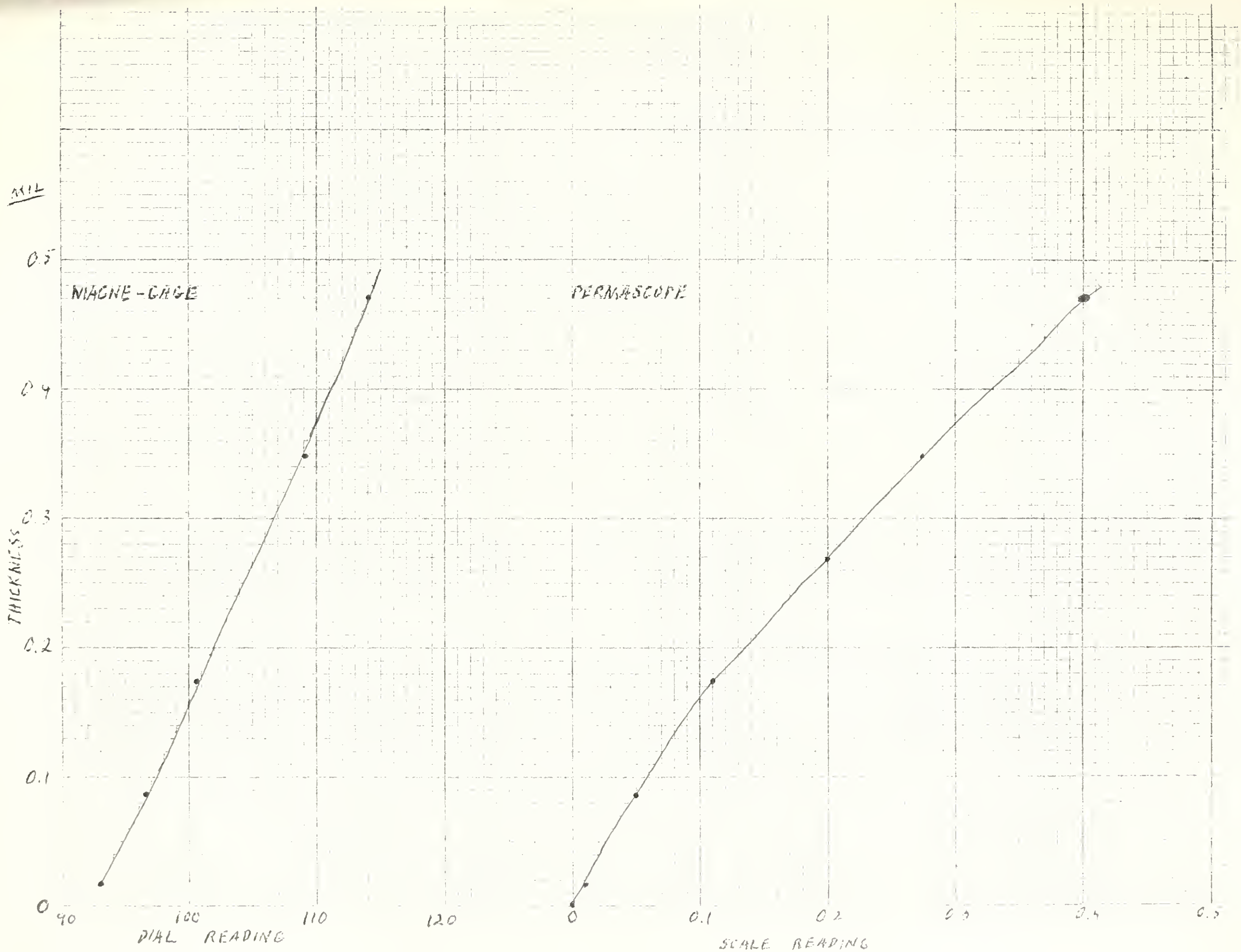
RADIOISOTOPE TECHNIQUE

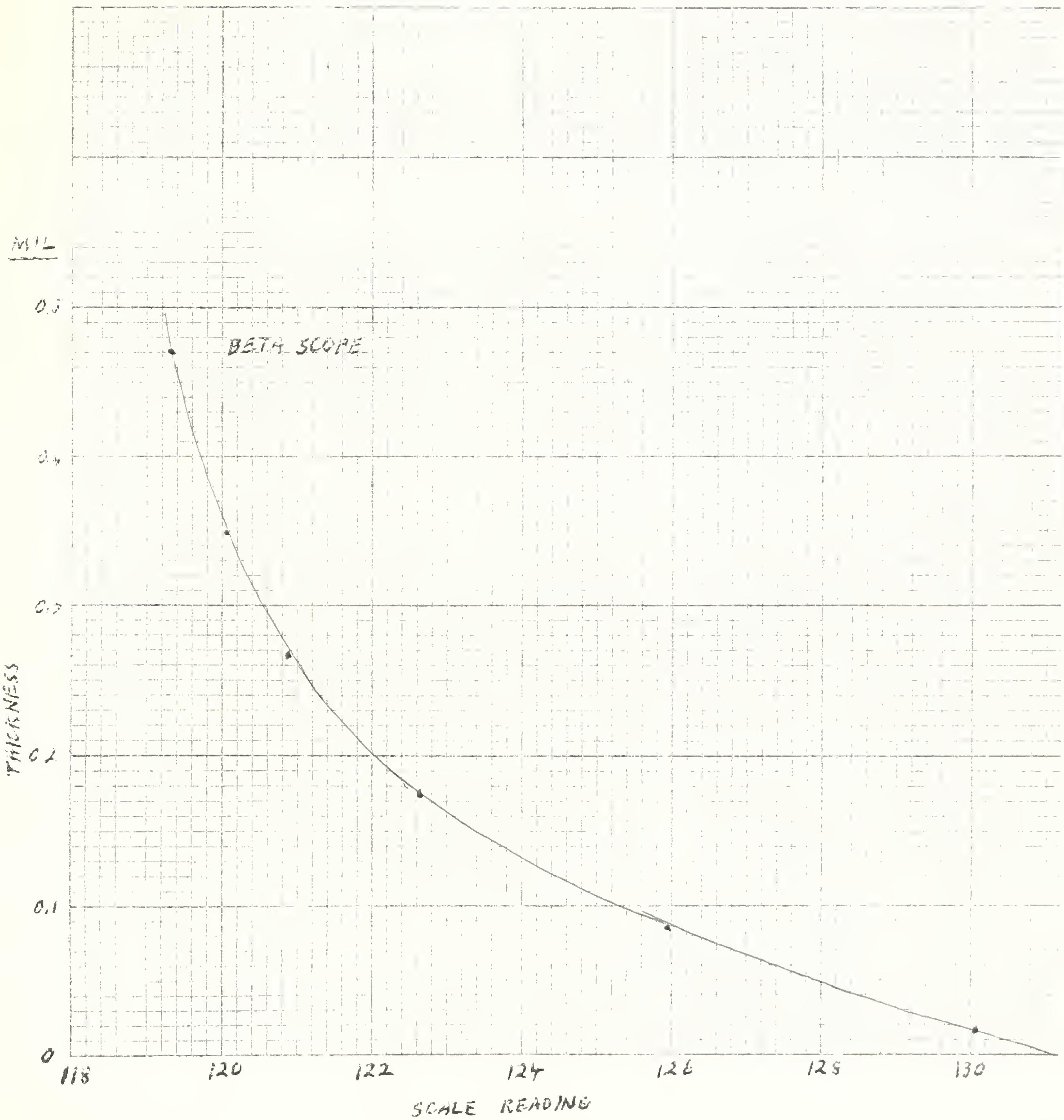
The fluorescent x-ray method can be modified by replacing the x-ray generator with a radioisotope and doing away with the spectrometer. This would allow a more compact unit and less expensive by a factor of 10. In principal it would be equally reliable.

To evaluate this method, it was first necessary to assemble from scratch the detector and the electronic equipment. We obtained the components at no cost to this project. Actually the equipment we were able to borrow was suitable for gold coatings and not for chromium. With the intention of later converting the assembly to something suitable for chromium we went ahead with the setup for gold to obtain needed background and experience.

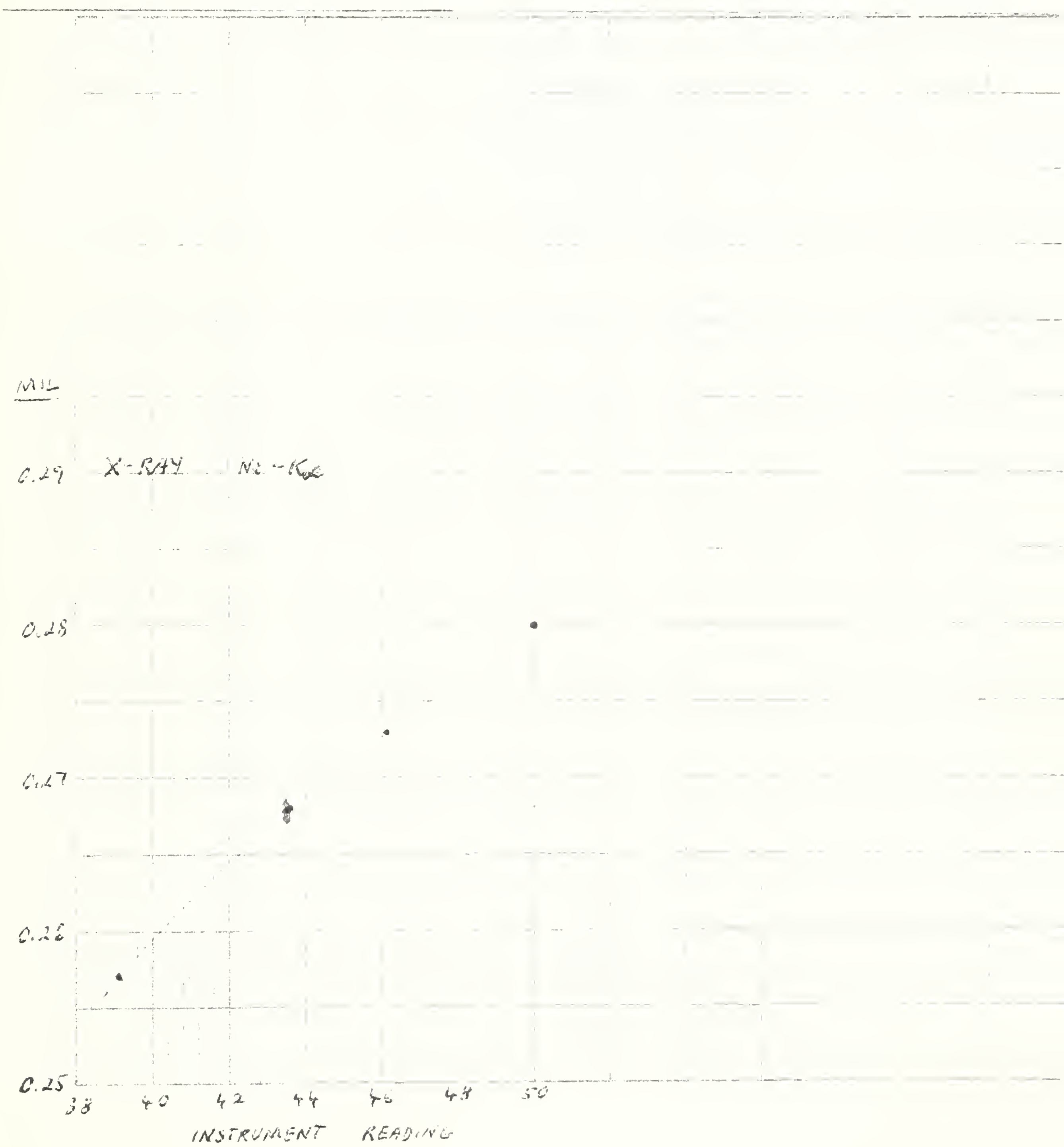
At this time we have demonstrated that the method works well for gold coatings on nickel. The critical aspects are kind and activity of isotope; the design of a jig to accurately and reproducibly align the radioactive source, detector, and specimen; and the design of the jig to minimize interference of scattered and stray radiation. These three factors determine the reliability of the thickness determinations and will have to be changed when switching from gold to chromium measurements.

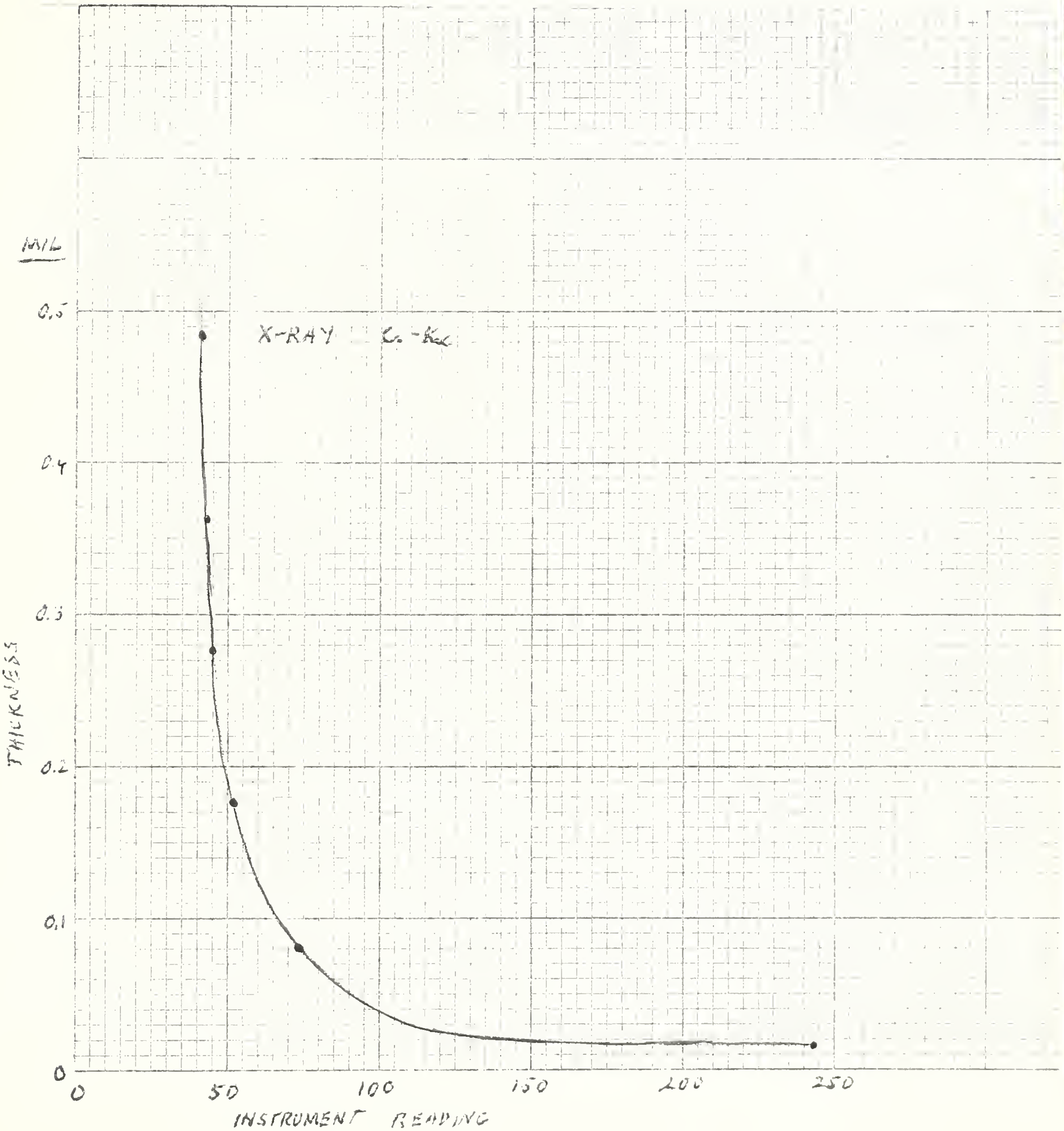
In brief, the radioisotope technique is promising, but needs to be specifically designed for chromium and tested.


MIL
THICKNESS
0.5
0.4
0.3
0.2
0.1
0
MAGNE-GAGE
PERMASCOPE
90
100
110
120
DIAL READING
0
0.1
0.2
0.3
0.4
0.5
SCALE READING



MIL
0.5
0.4
0.3
0.2
0.1
0
THICKNESS
BETA SCOPE
118
120
122
124
126
128
130
SCALE READING


MIL
0.29
X-RAY
0.28
0.27
0.26
0.25
38
40
42
44
46
48
50
INSTRUMENT READING


MIL
0.5
0.4
0.3
0.2
0.1
0
THICKNESS
X-RAY Cu-Kα
0
50
100
150
200
250
INSTRUMENT READING

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