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Instrumentation

A CLADDING THICKNESS TESTER FOR FLAT FUEL ELEMENTS

by

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Instrument Development Division

August 1955

[redacted]

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

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ABSTRACT

A tester utilizing eddy currents was developed to measure the thickness of aluminum cladding on uranium plates. The instrument measures aluminum thickness between 0.015 inch and 0.030 inch to an accuracy of better than ±0.001 inch. The measurement is not affected by a nickel layer between the aluminum and the uranium.

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TABLE OF CONTENTS

LIST OF FIGURES

A CLADDING THICKNESS TESTER FOR FLAT FUEL ELEMENTS

INTRODUCTION

A rapid test was needed to determine the thickness of the cladding on uranium plates. The instrument had to be insensitive to variations in the thickness and magnetic properties of a nickel diffusion barrier between the aluminum cladding and the uranium core. No known commercial instrument met these requirements. This report covers the development of a suitable instrument.

SUMMARY

A tester, utilizing eddy currents, was developed to measure the thickness of the aluminum cladding on flat fuel elements. The sensing element is a small, hand-held probe. The instrument measures the average aluminum thickness of a 0.25 square inch area to an accuracy of better than ±0.001 inch in one second. The presence of the nickel layer does not affect the accuracy of the instrument.

DISCUSSION

The problem of measuring the thickness of cladding on one type of flat fuel element is complicated by a nickel diffusion barrier between the aluminum and the uranium. The effective permeability of the nickel layer may be altered by mechanical working during the cladding process and by the fact that nickel will form alloys with the aluminum and with the uranium. These effects rule out the possibility of using a reluctance method(1) for determining the thickness of the aluminum. The difference in the electrical resistivity of the components suggested that eddy-current techniques could be used, if the effect of the nickel could be minimized.

PRINCIPLE OF THE INSTRUMENT

The electrical impedance of a coil in an a.c. circuit depends upon its self-impedance, its position with respect to any conducting material, and the resistivity and thickness of the conducting material(2)(3). Eddy currents induced in the material produce a field that opposes that of the coil. This field decreases the inductive component of the coil impedance and increases the resistive component. When a probe coil is placed on an aluminum plate, the impedance of the coil is decreased by an amount which is a function of the thickness of the plate. For two plates in contact, it can be demonstrated that small variations in the thickness of the plate that is more remote from the coil have little effect on the probe if the resistivity of this plate is much larger than that of the plate adjacent to the coil (Figure 1). This is true when the probe is placed on aluminum backed by uranium.

It was observed (Figure 2) that the change in inductance produced by placing nickel under the probe is less as the frequency is increased. At 3 kc and above, changes in the thickness and permeability of the nickel have very little effect on the impedance of the probe (Figure 3). By operating above 3 kc, the cladding thickness tester avoids the complications that would otherwise be introduced by the variable nickel layer.

DESCRIPTION OF THE TESTER

The cladding tester (Figure 4) determines aluminum thickness by essentially measuring impedance. A probe coil and the primary of a current transformer are connected in series and driven at 5 kc by an oscillator. The output of the current transformer is rectified and compared to a d.c. reference voltage derived from the oscillator output. The resultant difference voltage is presented on a meter.

The probe (Figure 5) consists of 500 turns of #40 copper wire housed in a ferrite cup core. The cup core is Type F261, "H" material made by the General Ceramics and Steatite Corporation. The coil is wound on a nylon bobbin and cemented in the cup core which in turn is cemented in a micarta holder. In use, the probe is placed with the open face in contact with the cladding to be measured.

The current and voltage transformers are identical and consist of a primary of 500 turns of #36 copper wire and a secondary of 3000 turns of #40 copper wire wound on a micarta bobbin. The bobbins are cemented in ferrite cup cores (General Ceramics and Steatite Corporation Type F269, "H" material) and mounted under the chassis on stand-off insulators.

The oscillator, a Hewlett Packard Model 200CD, is mounted in the tester (Figure 6). The complete tester is shown in Figure 7.

The meter is zeroed by adjusting the reference voltage to equal that developed by the current transformer, with the probe on a standard plate which has a 0.015-inch thick cladding. The range of the meter is determined by the oscillator output potentiometer inside the cabinet.

PERFORMANCE

The instrument was evaluated by R. H. Vanderlaan of the Savannah River Laboratory. Standards were prepared by grinding down sections of a clad plate. The cladding on these standards varied from 0.015 inch to 0.031 inch as measured with an optical comparator which had an accuracy of ±0.001 inch. The instrument readings for the various standards are given in Figure 8. Only two points are outside a spread of ±0.001 inch and one of these is beyond the linear range of the instrument. The limit of accuracy of the calibration (±0.001 inch) is determined by the accuracy of the optical comparator.

After the instrument was calibrated, two aluminum-clad uranium fuel plates were tested. The plates were then sectioned and cladding thicknesses were measured by optical means for each section. The results are compared in the table shown below.

	PLATE 151			PLATE 108	
Section	Instrument Reading (Inch)	Optical Measurement (Inch)	Section	Instrument Reading (Inch)	Optical Measurement (Inch)
1	0.035	0.040	1	0.020	0.020
2	0.029	0.030	2	0.019	0.019
3	0.026	0.026	3	0.024	0.023
4	0.0325	0.033	4	0.022	0.023
5	0.033	0.034	5	0.023	0.024
6	0.034	0.035	6	0.023	0.024
7	0.030	0.031	7	0.024	0.024
8	0.024	0.025			
9	0.025	0.025			
10	0.025	0.026			

After initial warm-up, the instrument drift corresponds to less than 0.001 inch in cladding thickness over a 24-hour period. The slope of the calibration curve does not change with this drift. Therefore, it is only necessary to reset the zero position. The standards used to calibrate the instrument must be of the same material as the cladding to be measured and should be prepared by the same process. The probe must be in contact with the cladding and the cladding below the probe must not contain any discontinuities.

The instrument serves as a convenient and rapid means for the nondestructive spot testing of the cladding thickness of flat fuel elements.

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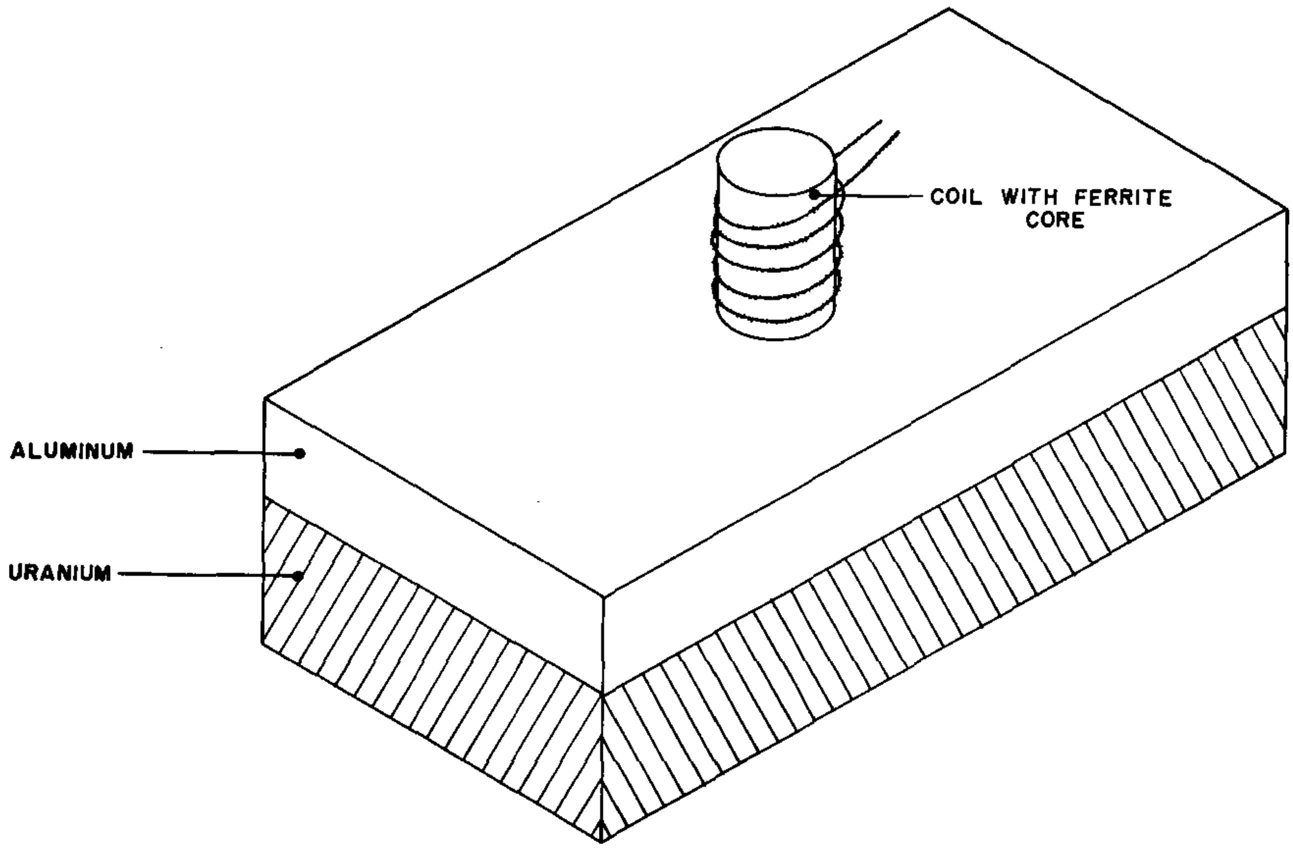
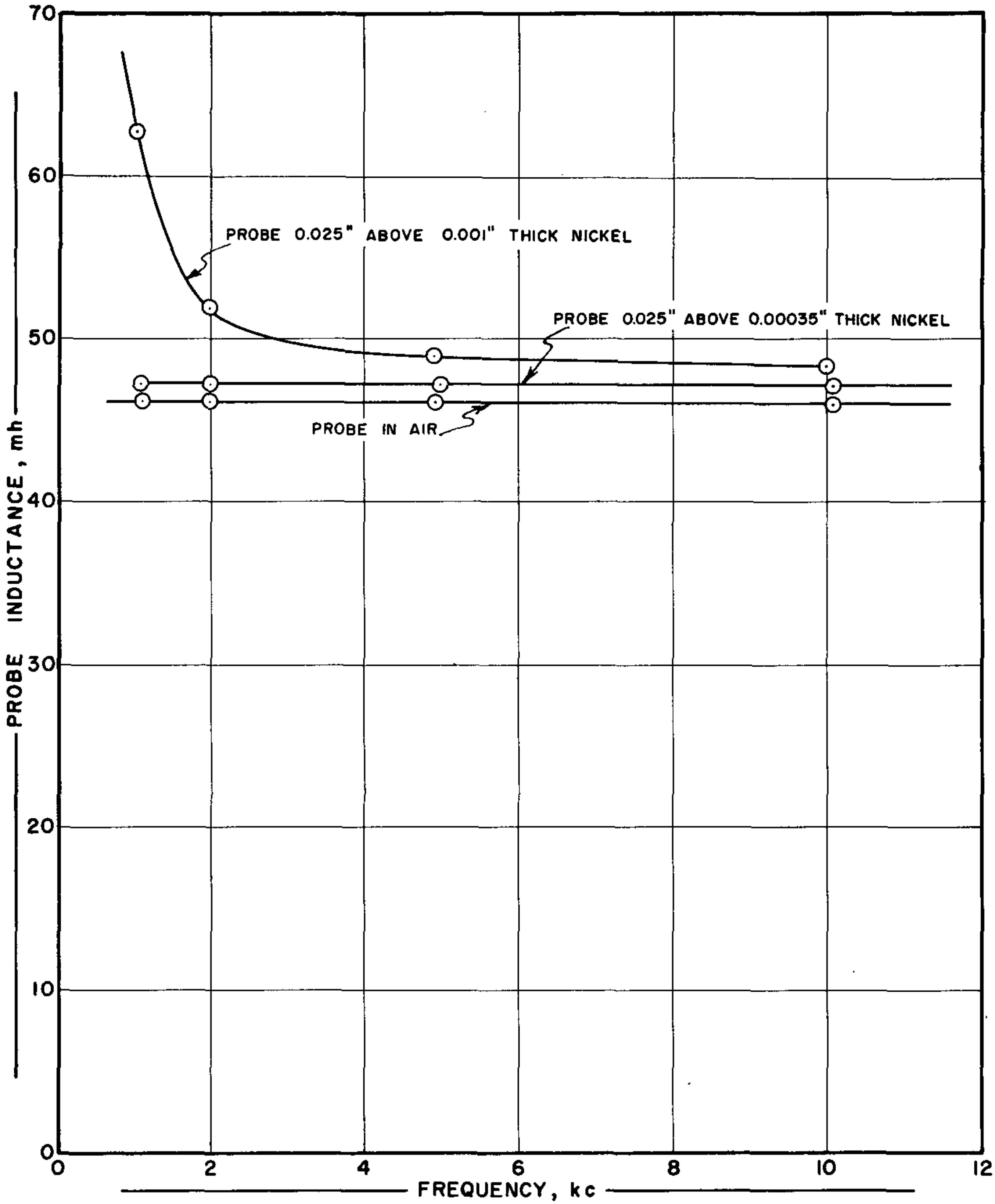
FIGURE 1



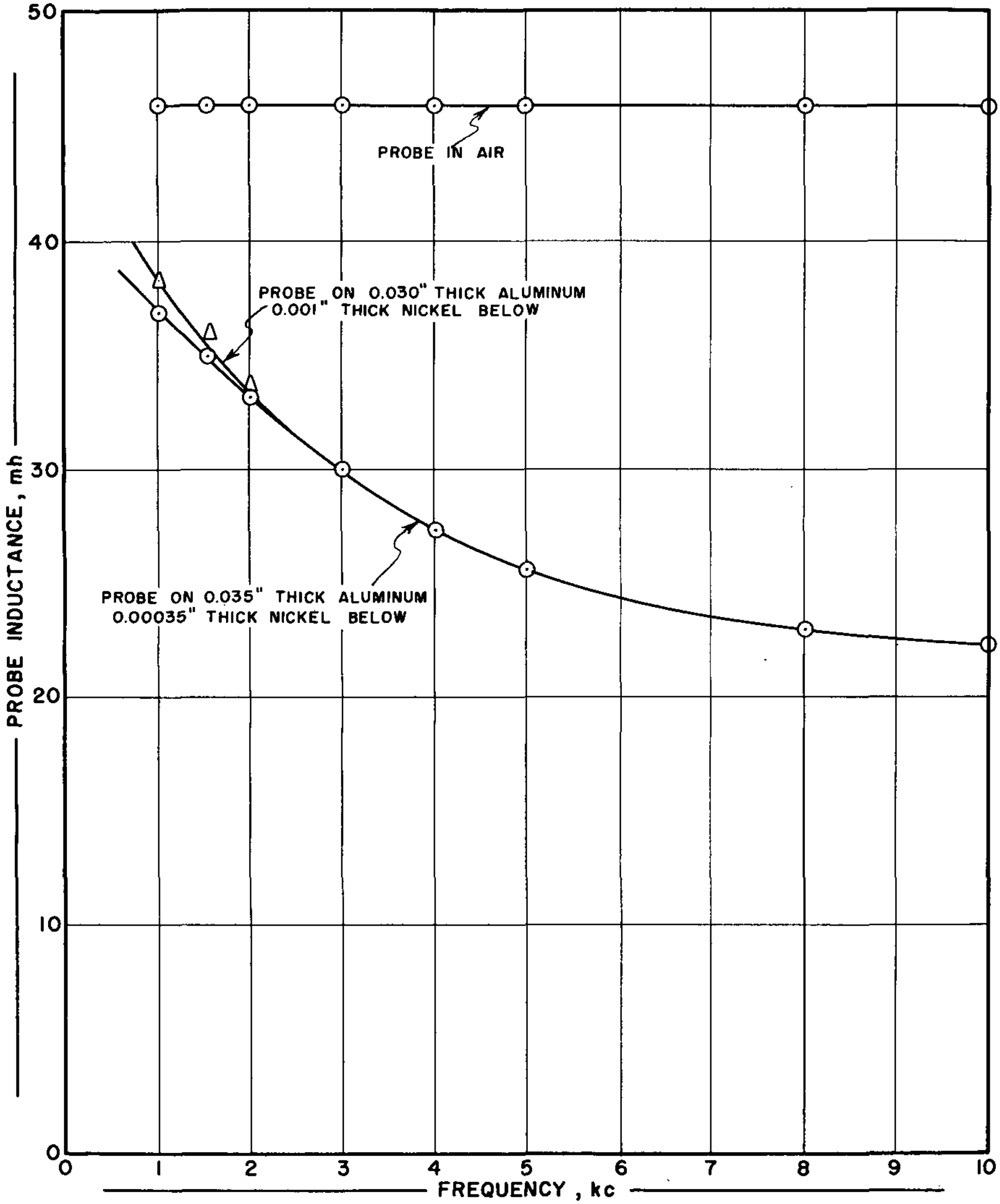
PROBE COIL ON ALUMINUM-URANIUM LAMINATION

FIGURE 2



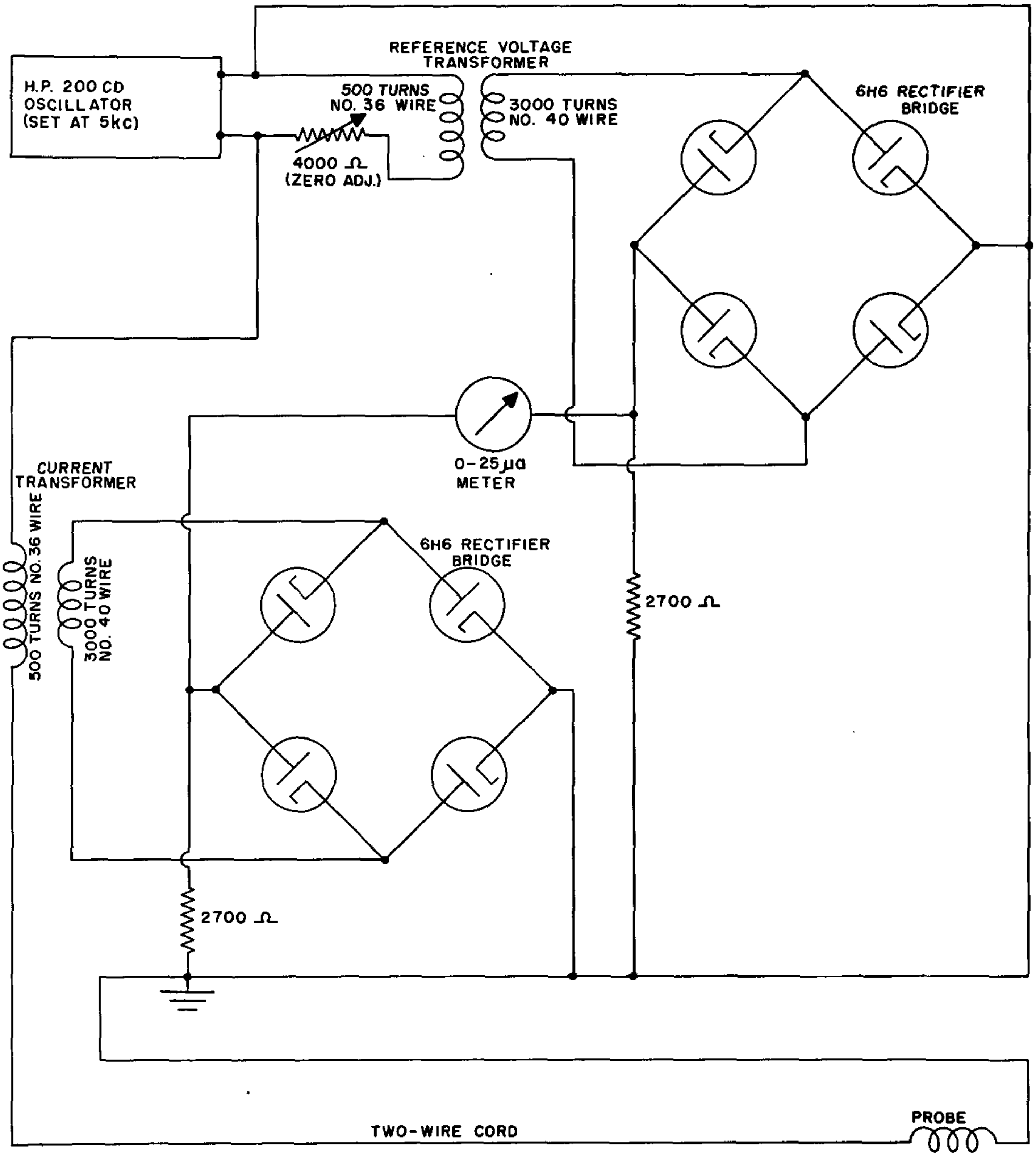
INDUCTANCE OF PROBE IN AIR AND OVER NICKEL

FIGURE 3



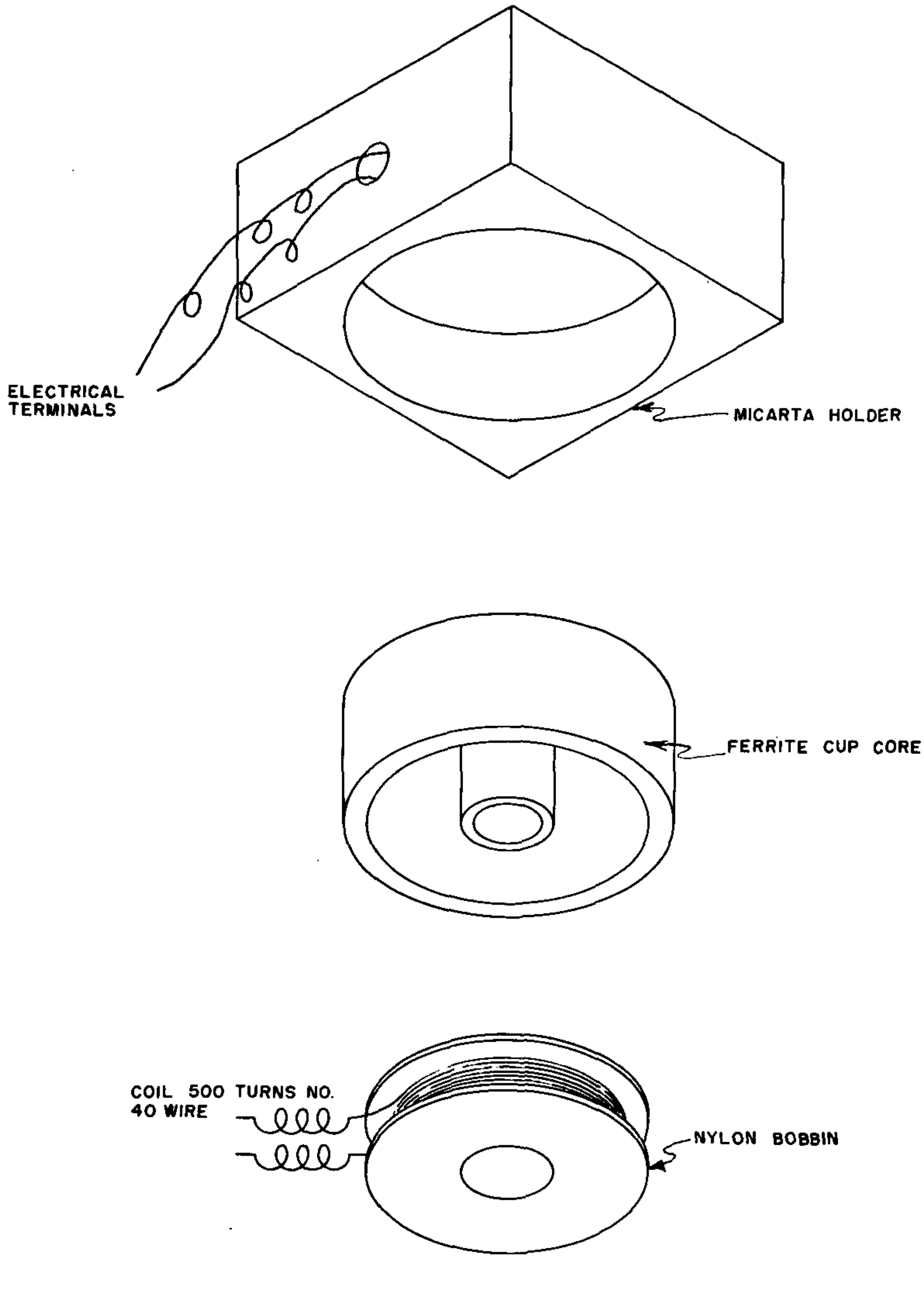
INDUCTANCE OF PROBE ON AN ALUMINUM-NICKEL LAMINATION

FIGURE 4



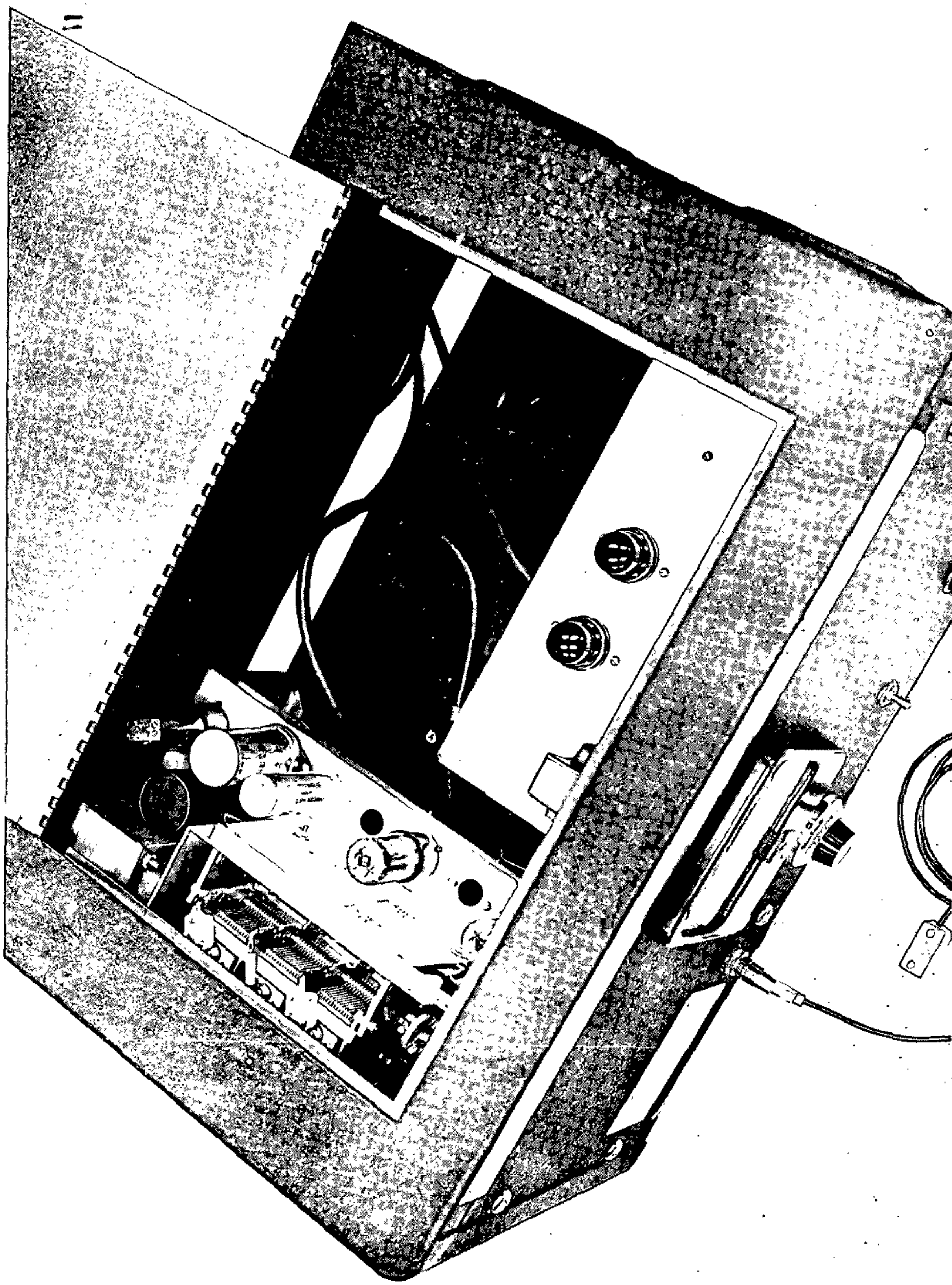
CIRCUIT DIAGRAM OF THE CLADDING TESTER

FIGURE 5



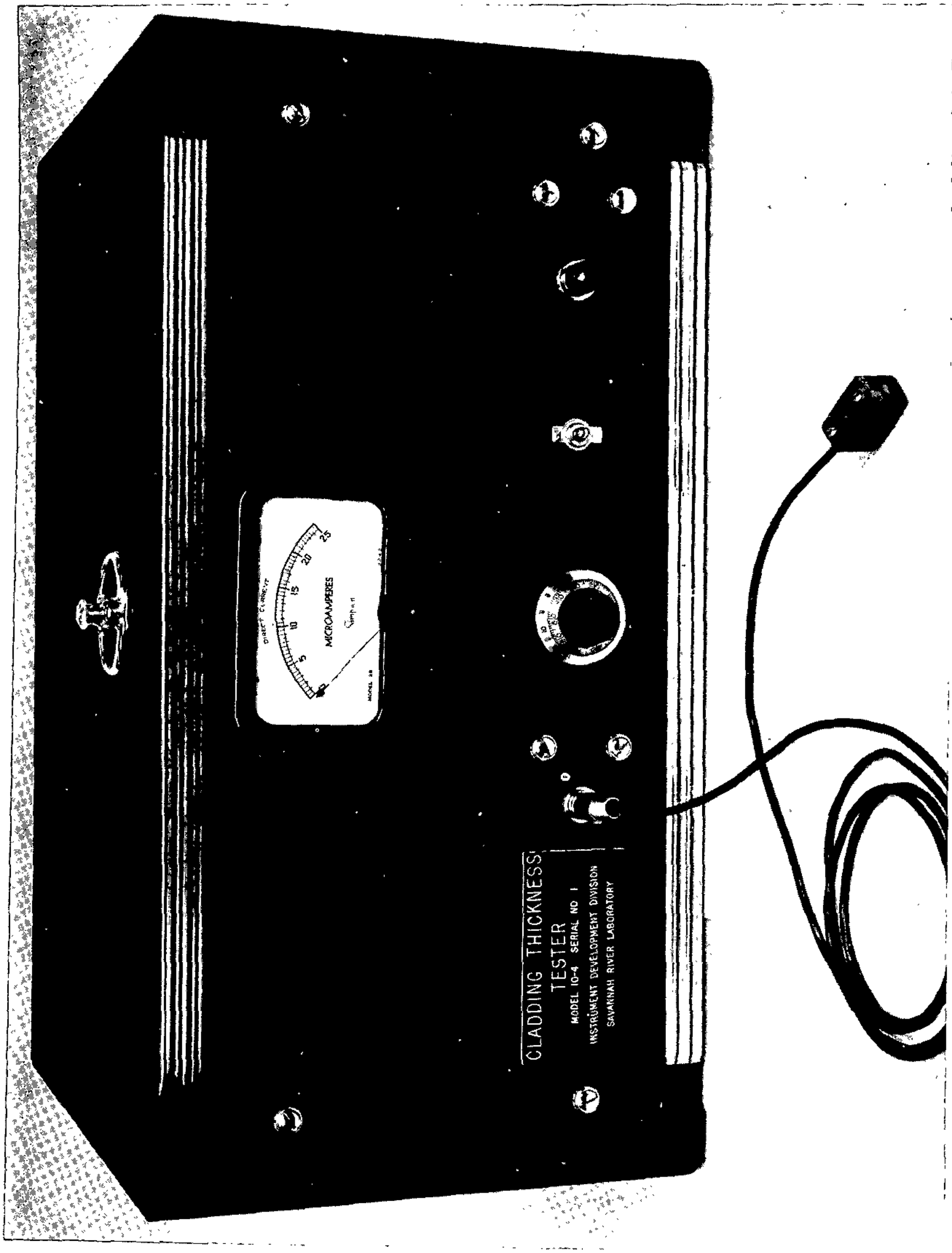
PROBE AND HOLDER

FIGURE 6



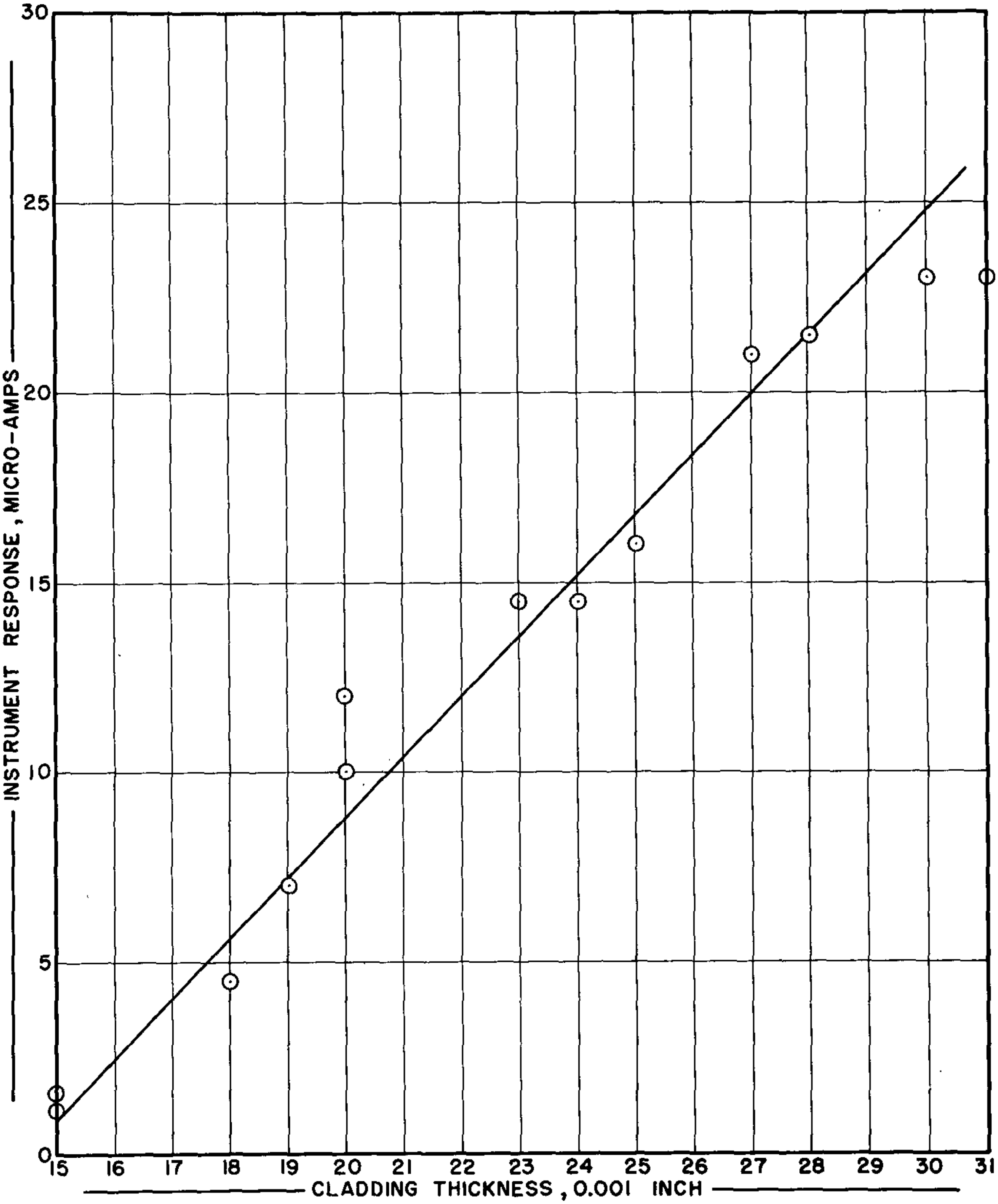
PHOTOGRAPH OF INSTRUMENT LAYOUT

FIGURE 7



PHOTOGRAPH OF THE CLADDING THICKNESS TESTER

FIGURE 8



INSTRUMENT RESPONSE