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LB-835

AN ELECTRONIC THICKNESS GAUGE FOR VERY THIN METAL FOILS

RADIO CORPORATION OF AMERICA

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Approved

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Introduction

In order to obtain a uniform, wide-range response in high-quality velocity microphones, the ribbons are made of aluminum foil about 0.0001 inch thick. If the foil thickness is too great by even a few per cent, the increase in the mass of the ribbon causes the microphone response to be deficient for frequencies above 7 or 8 kc. Consequently, it is desirable to have some means of checking the thickness of a foil before the considerable amount of time and labor is expended in cutting, preparing and mounting a ribbon. Apparently the suppliers of the foil have no satisfactory method for measuring thicknesses of very thin foils, since variations in thickness between sheets were found to be as large as 12 per cent within one group of eleven sheets having nominal thicknesses of 0.0001 inch.

In some cases the supplier will cut the sheets to a prescribed width and length and rely on a measurement of weight for an indication of thickness. This is not a satisfactory solution, however. With sheets whose weights are only a few milligrams, uncertainties in weighing, along with uncertainties in length and width, yield thickness indications which cannot be considered accurate to better than about ±4 per cent unless elaborate and exceedingly tedious weighing and measuring procedures are followed.

This bulletin describes a method whereby the electrical properties of the thin sheets can be used to compare the thicknesses of similar sheets quickly and conveniently with improved accuracy over ordinary weighing methods.

Method

The electronic method of comparing thickness makes use of the fact that the inductive coupling between two coils is reduced when a conducting sheet is interposed between them. If one of two inductively coupled coils carries an alternating current, an alternating e.m.f. of the same frequency is induced in the second coil. When a metal sheet is interposed, a circulating current is induced in the sheet, and there is a corresponding reduction in the e.m.f. induced in the second coil. The reduction in e.m.f. is a function of the frequency, the resistivity of the sheet, and the thickness of the sheet. It is assumed that the area of the sheet is great enough so that essentially all of the coupling field between coils passes through the sheet.

For a sheet of a given thickness and resistivity, the frequency can be made sufficiently low to induce a circulating current throughout the body of the sheet. In such a case a change in thickness of the sheet alters the coupling between coils in the desired manner. However, the effect of interposing the sheet decreases with decreasing frequency, so that if the frequency is too low the shielding effect of the sheet is too small to measure easily. On the other hand, for sufficiently high frequencies the induced currents are confined to thin layers near the surfaces of the sheet and do not penetrate into the interior. This is a manifestation of the well-known skin effect. When this condition exists, changes in thickness will not alter the shielding effect of the sheet. Therefore, an optimum frequency, or range of frequencies, exists for which this type of measurement is useful. The optimum frequency must be selected with regard to the thickness of the sheet and to the material composing it, that is to say, the resistivity. For aluminum foils between 0.05 and 2 mils in thickness, frequencies in the neighborhood of 2 Mc per second were found to be satisfactory. It is evident that the choice of frequency is not critical. For sheets thicker than 2 mils, lower frequencies will be required.

Construction and Operation

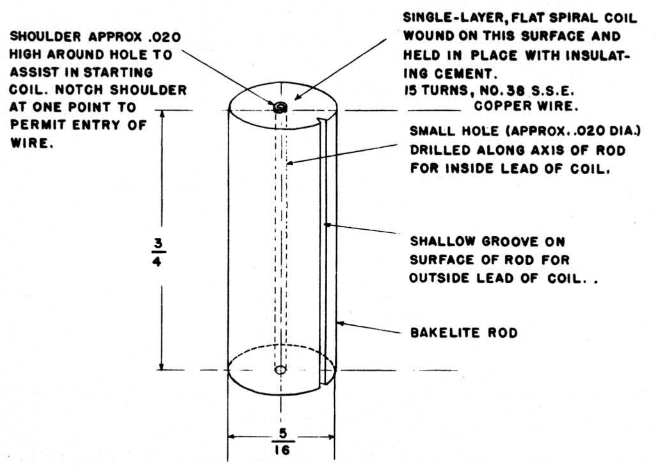

Fig. 1 - Coil form for electronic thickness gauge.

The principles outlined in the preceding section have been embodied in an instrument which will now be described. Each of the two coils consists of 15 turns of No. 38 S.S.E. copper wire wound in a flat spiral on the end of a 5/16-inch diameter bakelite rod. This coil form is shown in Fig. 1. The center lead is brought out through a small hole drilled along the axis of the rod. The outer lead lies in a groove cut in the side of the rod. Each rod is $\frac{3}{4}$ inch long and is mounted in a hole drilled through a bakelite block 1 inch thick, so that the coil is nearly flush with the surface of the block. The blocks are 4 inches wide and 6 inches long and are mounted one above the other, their large surfaces being horizontal. Bakelite block spacers are provided to keep the adjacent faces of the two blocks, and hence the two coils, separated by 5/32 inch. The two coils are directly opposite one another on the same vertical axis. A sketch of the arrangement is given in Fig. 2.

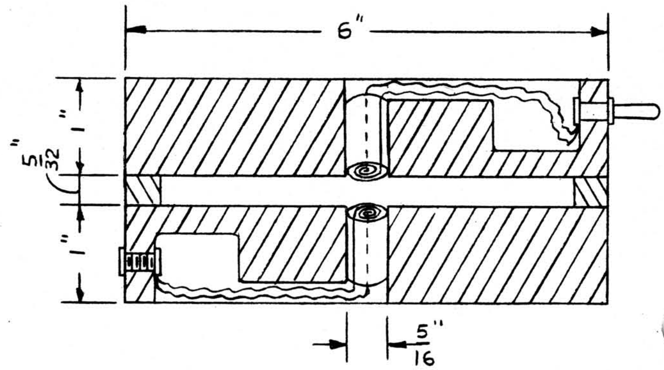

Fig. 2 - Sketch of gauging table of the electronic thickness gauge.

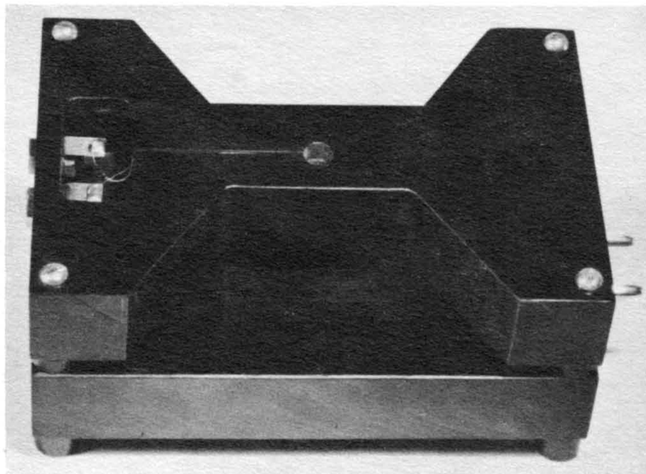

Fig. 3 - Photograph of the gauging table.

The lower block serves as a table on which the metal foil to be tested can be placed and moved into position between the coils. The upper block has been partly cut away to permit the foil to be inserted easily. Leads from the

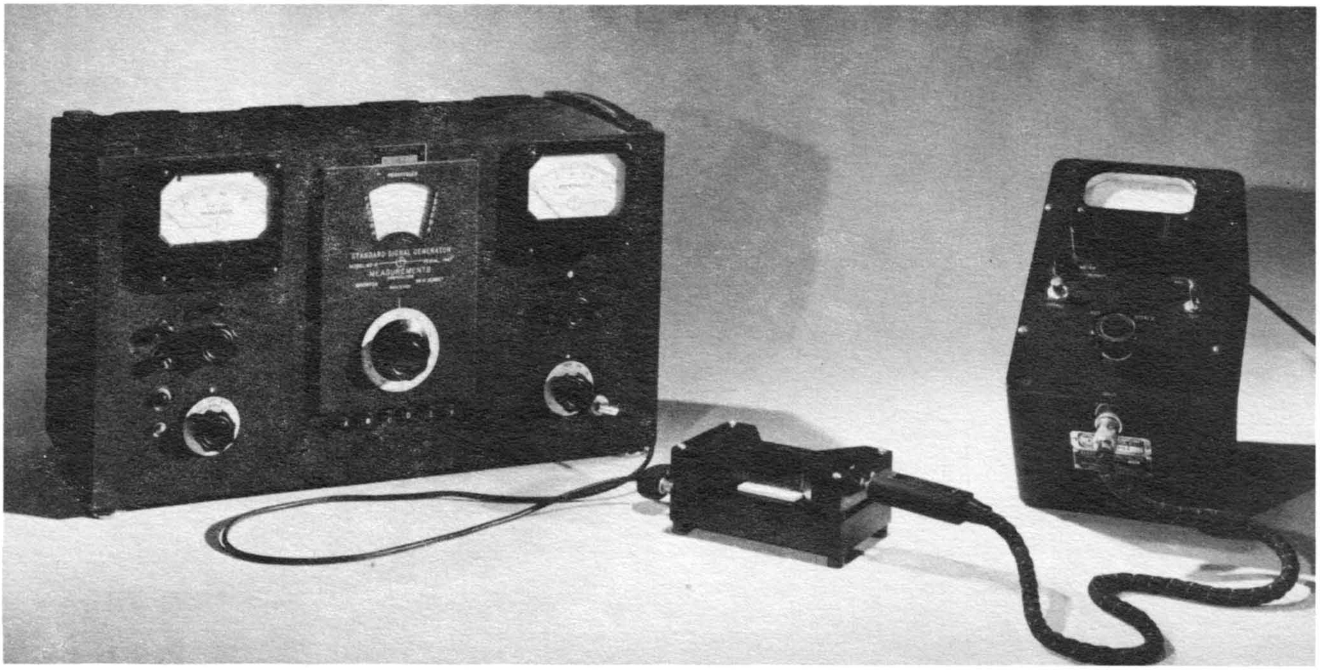

Fig. 4 – The complete test setup of the electronic thickness gauge.

coils go to two sets of plug-in connectors to which a signal generator and a vacuum-tube voltmeter can be connected. A photograph of the gauging table is shown in Fig. 3. The complete testing setup, including signal generator and voltmeter, is shown in Fig. 4.

In use, the signal generator is connected to the lower coil and set to the desired frequency. The level is adjusted to give a convenient indication on the voltmeter which is connected to the upper coil. Then the metal foils to be compared are inserted one after the other between the coils and the respective reductions in meter reading are noted. A greater reduction indicates a thicker foil, other things being equal. Since the presence of a dielectric between the coils does not appreciably alter the coupling, foils being tested can be left in their protective cardboard covers during a measurement. This is a most desirable feature since foils of 0.0001-inch thickness are extremely delicate and should not be handled unnecessarily in the open.

Results

A group of eleven aluminum sheets approximately 0.0001 x 1 x 2 inches was tested in detail, both by the electronic method and by weighing. Weighing was performed on a Chainomatic analytical balance. The lengths and widths were measured with a toolmaker's microscope. The density of aluminum was taken as 2.70 grams per cubic centimeter to arrive at a figure for the thickness of each foil. In the electronic comparison a frequency of 2 Mc was used. The experimental data are presented in Table I. Graphical plots of the data are shown in Fig. 5, one plot showing the relative voltage reduction as ordinate, and the other using the voltage reduction expressed in decibels. The straight lines were fitted to the data by a method of least squares. The random scattering of the data is due to experimental error, both in the weighing method and in the electronic method.

Conclusions

The slope of the straight line in the first graph of Fig. 5 shows that a change in voltage of 1 db represents a change in thickness of 0.0134 mil. Since significant readings accurate within ± 0.15 db are possible, the electronic thickness gauge is capable of comparing thicknesses of aluminum foils in the neighborhood of 0.1 mil with a precision of

±0.002 mil, or ±2 per cent. This precision represents an improvement over the ±4 per cent obtainable with the conventional weighing and measuring method. Equally important advantages of the electronic method are the rapidity and and convenience with which measurements may be made, and the fact that the foils may be retained in their protective covers during measurement.

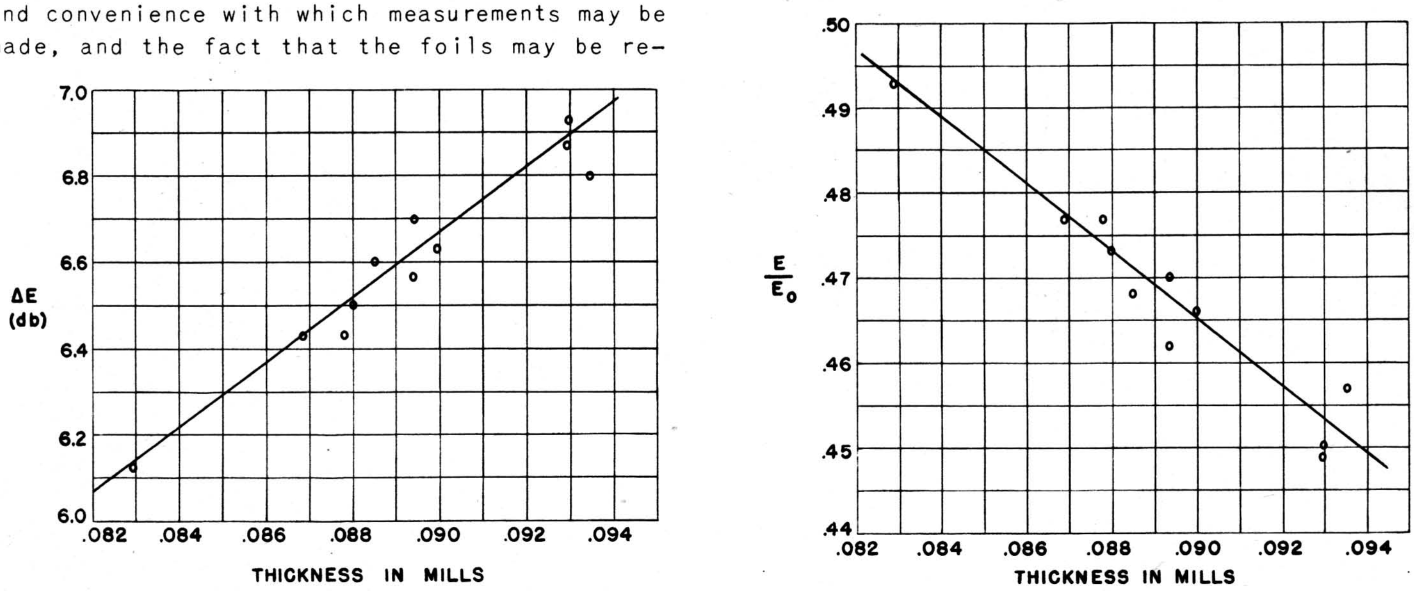

Fig. 5 - Graphical plots of data from Table I.

TABLE I

Data Obtained by Electronic Method and By Weighing Method for Nominal 0.1 mil Aluminum Foil

Sample No.	Weight In Milligrams	Length In Inches	Width In Inches	Area In Sq. Inches	Thickness In Mils*	Relative Voltage Reduction	Voltage Reductions In DB
1	8.43	2.019	1.064	2.14	.0894	.470	6.57
2	8.65	2.000	1.054	2.11	.0930	.450	6.87
3	8.45	1.999	1.029	2.06	.0930	.449	6.93
4	8.44	2.031	1.068	2.17	.0885	.468	6.60
5	7.90	2.002	1.020	2.04	.0878	.477	6.43
6	7.65	2.001	1.052	2.10	.0829	.493	6.13
7	8.15	2.001	1.063	2.13	.0869	.477	6.43
8	8.60	2.051	1.062	2.18	.0894	.462	6.70
9	8.15	2.043	1.029	2.10	.0880	.473	6.50
10	8.45	2.033	1.053	2.13	.0900	.466	6.63
11	8.65	1.996	1.052	2.10	.0935	.457	6.80

*Using density of aluminum = 2.70 grams/cm.^{3}

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