A Strain gauge bridge

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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO BRANCH

A STRAIN GAUGE BRIDGE

OTTAWA

SEPTEMBER, 1943

A STRAIN GAUGE BRIDGE

Summary

This strain gauge bridge was developed early in 1942 by the Radio Branch at the request of the Aeronautical Engineering Department of the National Research Council. It was neither intended as a prototype, nor as a competitor in the commercial field.

With a storage battery for filament and dry batteries for plate voltage, it is compact enough and sufficiently rugged to permit of operation in an aircraft in flight. Its usable sensitivity is roughly six times that of the Baldwin Southwark Strain Gauge Bridge, #SR-4, and about fifteen times that of a standard d-c galvanometer type bridge. The reading is direct and linear with strain.

General

The specifications for the performance of this bridge were tentatively outlined as follows:-

1. It should be capable of detecting strains of the order of one part in a million, and have a linear scale direct-reading indicator.

2. It should be sufficiently compact to use in aircraft from storage batteries or the aircraft's generator.

3. It should be shock-proof to typical aircraft vibrations when operating at required sensitivities.

Direct current bridge methods were out of the question for the sensitivity and ruggedness required, so an a-c bridge was designed which incorporates an oscillator-amplifier to supply voltage to the bridge proper, together with a tuned amplifier-detector circuit to indicate unbalance. The output of the tuned a-c amplifier is rectified and fed to two 0 - 100 microammeters, the readings of which are directly proportional to the strains.

Rubber shock mountings are provided for the bridge equipment and for the indicating meters. (See Photographs, Figs. 3 and 4.) In these photographs a rubber pad is visible under the meter, but the Lord mounting framework has been detached from the bridge itself.

Generator

A Colpitts oscillator circuit (Fig. 1) is used with a high-Q tank circuit consisting of a special 50 millihenry choke tuned to 4200 c.p.s.

This ensures that the frequency will be stable under conditions of varying voltages. Half of a 6F8G tube is used for the oscillator and the other half comprises a buffer amplifier. The buffer amplifier drives a 6V6 power tube capable of providing 1/4 to 1/2 watt output. A step-down transformer is used in the output of the 6V6 with an output impedance of 125 ohms to match the bridge approximately. The generator draws approximately 9 mils at 180 volts for the 6V6 stage, and about 2 mils at 90 volts for the oscillator buffer stage.

Amplifier-Detector

A transformer is placed across the bridge with an input impedance of 200 ohms with a voltage step-up ratio of 20:1. The primary is centre-tapped to ground. A potentiometer, R_6, with 3 db. steps, follows this transformer to adjust the sensitivity of the instrument to the operating conditions. The first stage of the amplifier is a high gain pentode, type 6SJ7, with a tuned circuit in its grid. This is followed by a high mu triode, 6SF5, having tuned circuits in both its grid and plate circuits. The output of the 6SF5 is fed through an isolating voltage divider to the pentode section of a 6B8. The output of the pentode is rectified by the diode section of the 6B8 and passed through two 0 - 100 d-c microammeters in series. These meters are located in separate boxes and connected to the bridge through long lengths of shielded cable. One of the meters is used for line-up purposes and for visual observation, while the other meter is placed in a dark box and photographed from time to time when a record of the readings is required.

The amplifier has a band pass which is peaked at the oscillator frequency and is half down in voltage at 3900 c.p.s. and 4850 c.p.s. The response at low frequencies such as encountered under normal vibration conditions up to about 1000 cycles is negligible. The gain of the amplifier is rather more than 100 db, and 150 microvolts a-c. input will give full scale output on the meter. There is no evidence of noise or microphonics.

Bridge Circuit

The 125-ohm output of the generator passes through two 2000-ohm isolating resistors to a special centering potentiometer, R_1, having discrete steps. A vernier control, R_2, is provided for fine control of centering.

Two arms of the bridge, of course, are formed by the two 100-ohm strain gauges. These gauges are usually mounted on the apparatus under examination so that they operate in opposite phase. Alternately, one gauge may be inoperative, in which case its function is to provide a resistance with the same temperature characteristics as the active gauge.

The third arm of the bridge is made up of the rough adjustment potentiometer, R_3, the smooth adjustment potentiometer, R_4, and a fixed series resistance. The fourth arm has a fixed 100-ohm resistance in series with a 1-ohm resistance. A 200-ohm rheostat, R_5, is connected across the 1-ohm resistance in series with the "Sense Key". The output transformer of the amplifier-detector is connected across the bridge in the usual manner.

Operation

The batteries are connected and the set turned on to warm up a few minutes before using. The sensitivity control, R_6, is turned down for the preliminary balancing. It will be noted that there is no danger of burning out the indicating meters under any circumstances since the output stage of the amplifier quickly saturates before the danger point is reached, though it is linear up to full scale of the meter. If the two strain gauges have resistances that do not differ by more than a few ohms, a rough balance may be obtained by adjustment of R_3. It may also be necessary to adjust the step potentiometer R_1. The sensitivity of the bridge is now increased and the fine balance achieved by simultaneous adjustment of the fine potentiometer R_2, and of R_4. This is in accordance with the usual bridge balancing technique, and with a little experience the operator should be able to perform the series of successive approximations necessary to balance the bridge easily and quickly.

The bridge should be balanced with the sensitivity control in the position in which it will be used, because with the control in its present position in the circuit, there is a slight reaction on the bridge. This might possibly be obviated by putting the control between the 6SJ7 and the 6SF5. In fact, there are several small points in the design and construction of this instrument which might well be improved in a future model.

The "sense" switch is used to indicate whether the strain is positive or negative. Because a-c is used throughout, the meter will give a positive deflection for either strain. However, after a deflection has been obtained, it is only necessary to depress the sense switch to ascertain the polarity of the strain since the reading will increase for one polarity and decrease for the opposite. The magnitude of this "sense unbalance" is adjusted by the rheostat R_4 to suit the operator's taste and convenience, since it will depend on the sensitivity level in use.

Using standard 100-120 ohm strain gauges connected to a strained element so that they operate in push-pull, it is found that full scale deflection is obtained on this bridge for a strain of 24 arbitrary units under the same conditions that the Baldwin Southwark SR-4 strain indicator requires a strain of 145 units for full scale deflection. A calibrated gauge equipment was not available for this test, so that it is not possible to express the strains in absolute units, i.e. in micro-inches per inch.

The linear indicator scale may be calibrated for a given sensitivity setting in the laboratory by using standard strain gauges and by producing known strains in the metal under test. The general calibration curve for this instrument is given in Figure 2. The bridge will then hold its calibration as long as the batteries remain in good condition. A shift of the zero between experiments or between measurements is of no consequence since the bridge may be re-balanced to the new zero with confidence that the meter calibration remains unchanged.

S. Korenberg
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HP
September 1943

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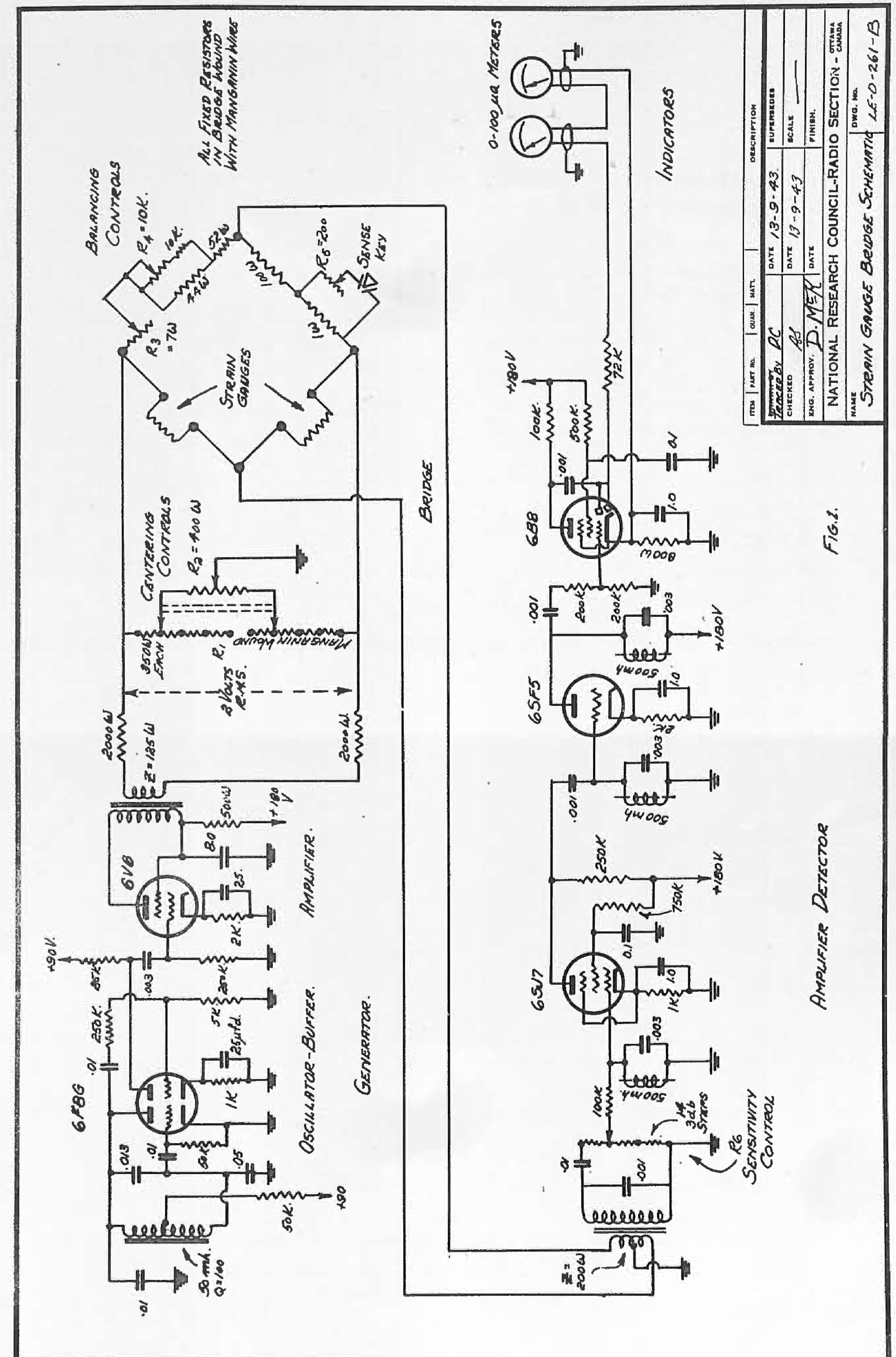

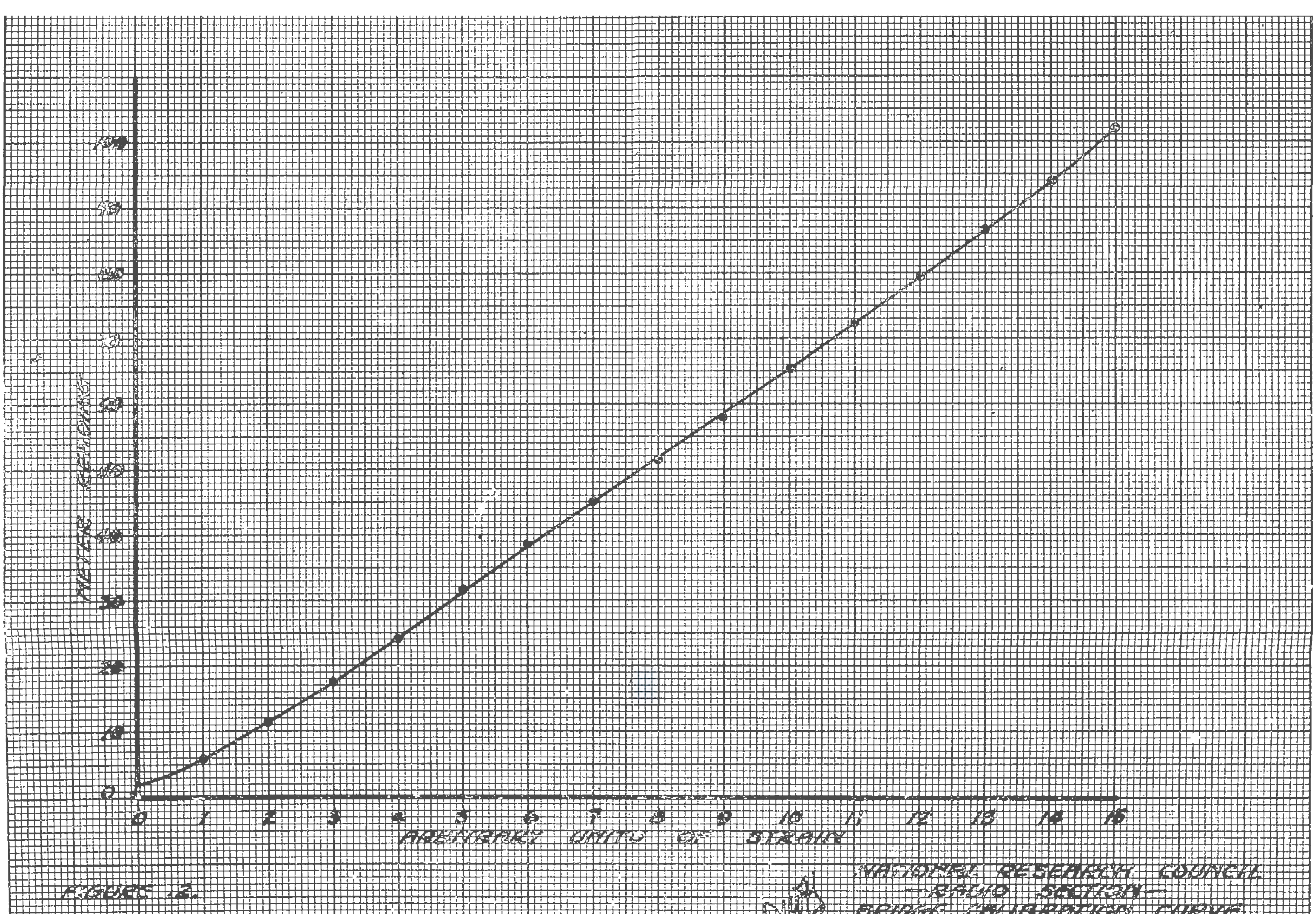

FIGURE 2.

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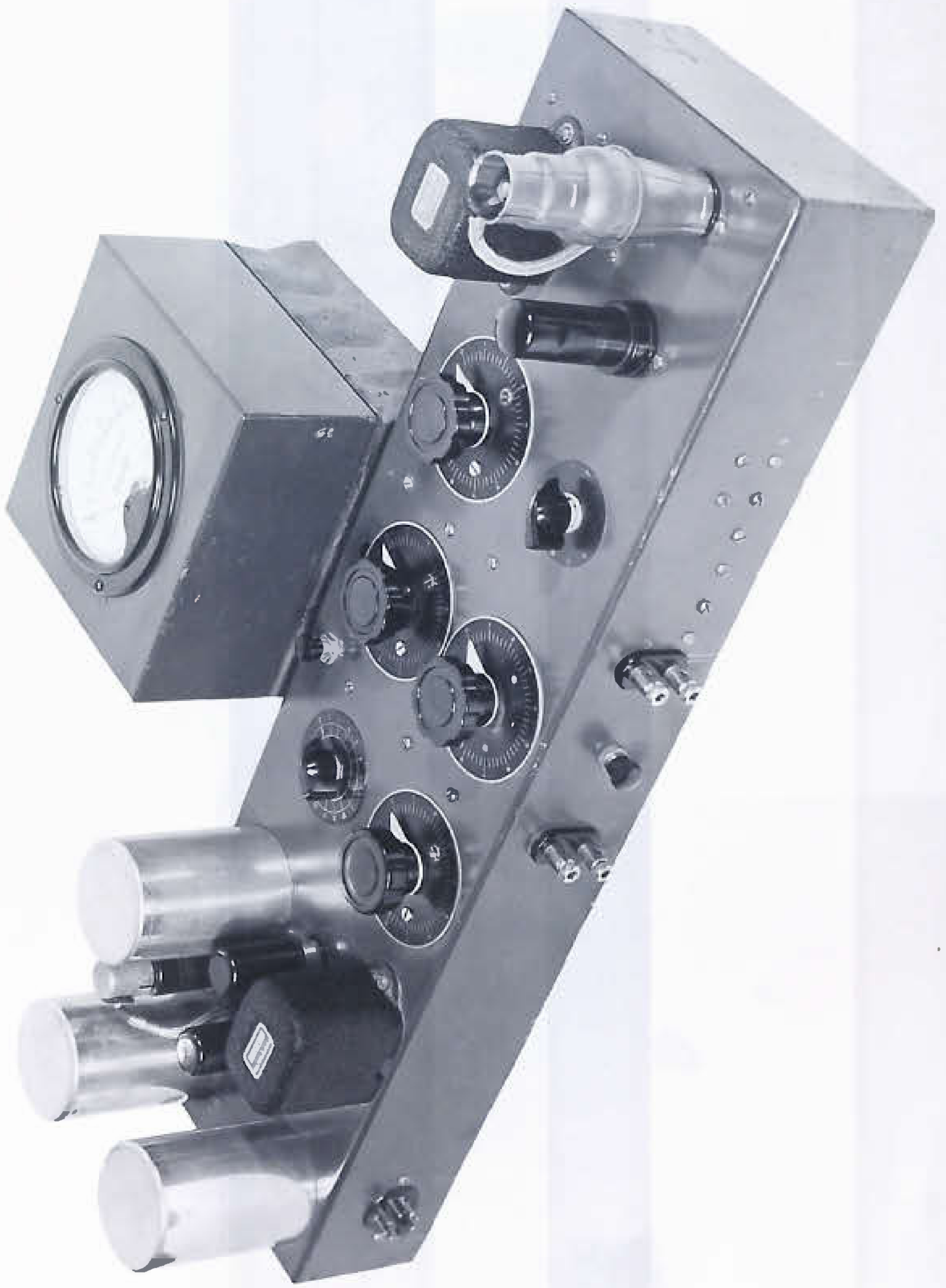
BRIDGE CALIBRATION CURVE.

LE-0-262-R.



NRC
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FIG. 3

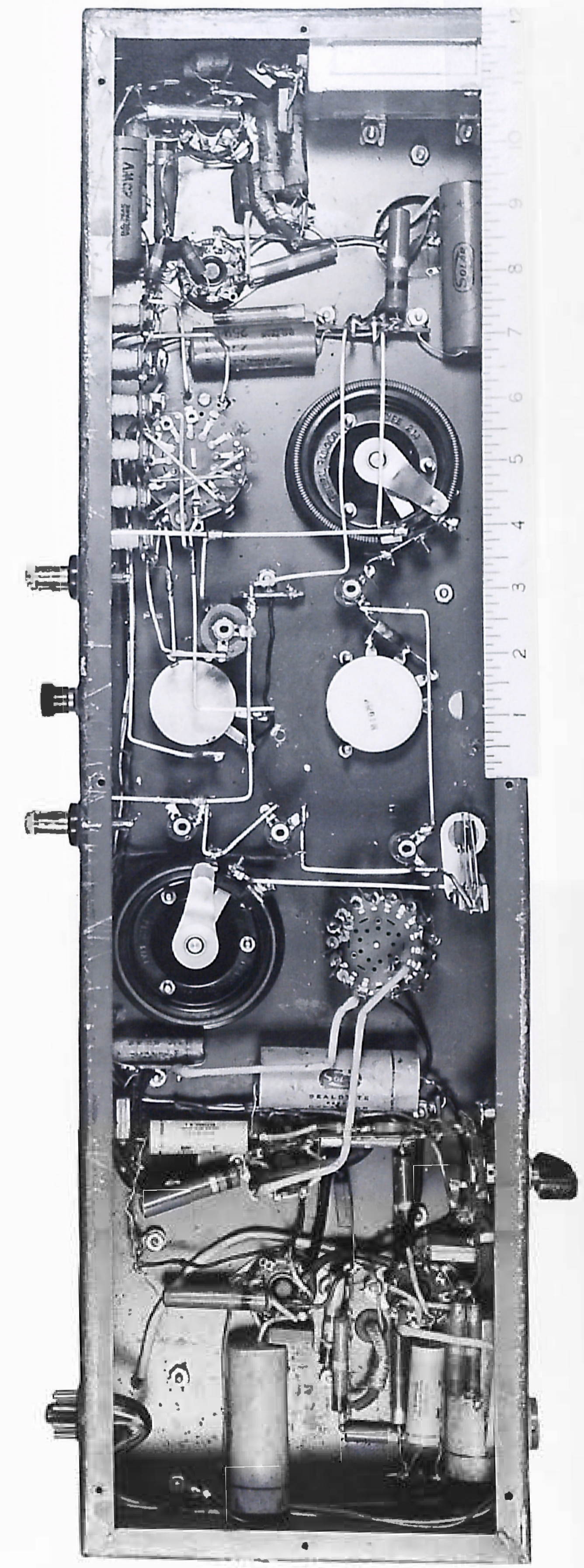

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FIG.4