NATIONAL BUREAU OF STANDARDS REPORT

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A MODIFICATION OF THE METERING-BRIDGE CIRCUITS OF TRANSMISSOMETER INDICATORS

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
0201-20-2327	May 1959	6407

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Department of the Navy
Washington 25, D. C.

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A Modification of the Metering-Bridge Circuits of Transmissometer Indicators

This report describes modifications made in the bridge circuit of the transmissometer indicator in an effort to improve stability and gives results obtained from the modified circuits. The stability of the modified bridges is considerably better than that of the conventional bridges and the useful life of the voltage-regulating tubes is increased.

I. INTRODUCTION

The output circuit, or voltmeter section, of the transmissometer indicator is a bridge using a type OC3/VR105 tube in one arm. Instability of this voltage-regulating tube may cause undesirable shifts in the electrical zero of the bridge. Shifts of zero may also result from unstable type OD3/VR150 tubes in the regulated B+ supply. The stability and useful life of these tubes seem to vary greatly with the manufacturing process. Therefore, a study was made on the stability and linearity of response of modified bridge circuits which use a triode amplifier type tube instead of a voltage-regulating tube.

Since two indicator bridges are currently used, one with a 0-5-milliampere output and the other with a 0-1-milliampere output, modified circuits having these outputs were tested.

II. CIRCUIT MODIFICATIONS

The bridges and the related parts of the conventional transmissometer indicator circuits are shown in figure 1. The circuits of the modified bridges are shown in figures 2 and 3.

The voltage-regulating tube (V203) of the bridge was changed to one section of a twin-triode amplifier-type 6SN7, or 5692, tube, which provides a reference operating point for the bridge and will be called the reference tube (V202B). The amplifier tube (V202) in the bridge was changed from the twin-triode used in the 5-milliampere bridge and a single-triode used in the 1-milliampere bridge to the other section of the twin-triode reference tube. This section of the tube, designated V202A, which amplifies the incoming signal from V201, will be called the signal-amplifier tube.

In both modified bridges, the values of R213 and R214 were chosen to obtain an optimum operating condition. In the cathode circuit of the modified 5-milliampere bridge, R212 is common to both the reference and signal sides of the bridge. In the 1-milliampere modified bridge, R212 is used only in the cathode circuit of the signal-amplifier tube. The signal-amplifier side of the 1-milliampere bridge was designed to be similar to the conventional 1-milliampere indicator.

Grid bias for the reference tube in both modified bridges is obtained from an added voltage divider consisting of R233 and R234 connected between regulated B+ and ground with the grid of the reference tube connected to the junction of these resistors. The required grid bias for the signal-amplifier tube of the modified bridges was obtained by the cathode resistor (R212). In order to accommodate the variations in characteristics of the type 6SN7 tubes, the zero-adjustment potentiometers of both the 1-milliampere and the 5-milliampere bridges were replaced with potentiometers of higher resistance.

Basically, the modifications affect only the metering bridge. However, the current flowing from the low end of the modified bridges to ground is considerably lower than the current from the conventional bridges. Therefore, in order to obtain operating conditions similar to those of the conventional indicator circuits, other minor modifications are required. In addition to the change of the zero-adjustment potentiometer, the resistances of the bias-adjustment potentiometer (R207) and the minimum-bias resistor (R208) were increased. No changes of the R-C circuit (R211 and C214) or of the calibration circuits (R205 and R206) were required. In the B+ supply the value of the dropping resistor (R231) was increased.

III. TEST PROCEDURE

A transmissometer indicator using each of the modified bridges was tested. Eighteen twin-triodes (type 5692 or 6SN7) and numerous single triodes (type 6J5) were tested in the bridges to determine the values of components and the range of adjustments necessary to accommodate the acceptable tolerance of tubes.

To check the linearity of response of the bridges, a signal of known frequency was fed into the input of the test transmissometer indicator from the horizontal deflection plates of a cathode-ray oscilloscope. The electrical zero of the bridge was correctly adjusted. When a signal of 3600 pulses per minute was fed into the indicator, the calibration was adjusted for an output meter reading of 0.90 (nine-tenths of full scale). The frequency was then varied in steps from 3600 to 15 pulses per minute and the indication as a function of the pulse rate was determined.

Each modified bridge was installed in a transmissometer indicator and was operated for several months to determine its stability. During this operational stability test, the signal was obtained from the receiver of a typical field installation. Daily zero and calibration checks were made following the instructions of NBS Report #2588. During this period, similar checks were made on a conventional 5-milliampere indicator.

Tests were made to determine the extent of zero shifts of both modified bridges and of conventional 5-milliampere bridges when the signal was changed from a fast to a slow pulse rate. These tests were performed by varying the light incident on the receiver generating the signal. The electrical zero was checked periodically before, after, and during these tests, which extended over periods up to 24 hours.

The power to the conventional 5-milliampere indicators and to both modified indicators was turned off and left off for several hours. The indicators were then energized and the time required for the electrical zero, with no applied signal, to stabilize was noted and recorded.

The tubes in the indicators of both modified bridges and of three conventional 5-milliampere bridges were carefully checked over a period of about one year. The checks on these tubes were made as prescribed by NBS Report #2588, and all tube replacements were recorded.

IV. RESULTS

Typical results of linearity-of-response checks of the modified bridges are shown in figures 4 and 5. The maximum deviation from a linear response, as shown in these figures, is less than one percent of full scale and occurs at a reading near the midpoint of the scale.

The results of the tests for operational stability of the electrical zero, zero shifts for change in pulse rate, stabilization time after energizing the indicator, and the replacement of tubes are given in table I.

Table I.

Results of Tests of Transmissometer Indicator-Bridge Circuits

Argument	1-milliampere modified bridge	5-milliampere modified bridge	5-milliampere* conventional bridge
Stability of Electrical Zero During 3 Months Routine Operation**			
Average change per day (percent of full scale)	±0.03%	±0.08%	±0.36%
Maximum drift of zero (percent of full scale)	+ and -1%	-2%	+3%
Maximum time without noticeable shift (days)	43	20	3
Total number of observed shifts	7	14	42
Shifts of Electrical Zero for Changes in Pulse Rates			
Total drift (percent of full scale)	less than 0.5%	less than 0.5%	0.5%, 0.5%, 0.5%
Time required to stabilize (minutes)	less than 5	less than 5	60 to 120, 60 to 120, 15 to 20
Time Required to Stabilize Electrical Zero After Energizing the Indicator			
Total time required (minutes)	5	less than 5	10, 20, 120
Tube Replacement			
Number of tubes replaced in bridge (OC3)	-	-	1, 0, 1
Number of tubes replaced in bridge (5692)	0	0	0, 0, 1
Number of OD3 tubes replaced in B+ supply	7	10	17, 4, 9

* Three 5-milliampere conventional bridges were included in the tests except as indicated.

** Only one 5-milliampere conventional bridge was used in this test.

The preferred values of components for the modified bridges are shown in figures 2 and 3. Significant voltages at the signal-amplifier and reference tubes are given in table II.

Table II.

Significant Voltages and Currents of the Modified Bridges

Arm of the Bridge	Transmission Reading	Plate Voltage	Plate Current	Cathode Voltage	Grid Voltage
	Percent	Volts	Milliamperes	Volts	Volts
		Values for the 5-Milliampere Bridge			
Signal-Amplifier	90	180	6.9	30	27
" "	0	190	2.2	28	21
Reference	90	184	1.30	30	23
"	0	190	5.4	28	23
		Values for the 1-Milliampere Bridge			
Signal-Amplifier	90	93	2.1	28	27
" "	0	98	1.01	25	22
Reference	90	95	3.2	24	23
"	0	98	4.1	23.5	23

V. DISCUSSION OF RESULTS

During routine operations the number of noticeable shifts and the average daily change of the electrical zero in the modified indicators were reduced to 1/3, or less, of those of the conventional 5-milliampere unit. The 1-milliampere modified bridge was noticeably more stable than the 5-milliampere modified bridge, but the effect of this improvement was negligible. The modifications reduced the time required for stabilization of zero after the indicator was energized and after changes in pulse rates.

The error in linearity of response of the modified bridges was less than one percent of full scale. The response of the modified bridges was somewhat less linear than that of the conventional bridges, but this response is adequate for operational requirements.

Instability of the voltage-regulating tubes, types OC3 and OD3, is a primary source of error in the transmissometer indicator and thus strict limitations on these tubes are necessary. In order to keep this error at a minimum, frequent testing and replacing of these tubes may be required. During the tube replacement test period the OC3 tubes in the conventional 5-milliampere indicators had a longer than normal life; whereas the OD3 tubes in the B+ supplies were from an unusually poor lot except for those in one conventional unit which were from an earlier group. Although the OD3 tubes in this unit had been in service for some time at the beginning of the test and were not replaced for 9 months thereafter, four of these tubes were replaced in this unit during the remaining three months of the test. The modifications had virtually no effect on the rate of replacement of type OD3 tubes in the B+ supply, since the replacement criteria were based on the requirements for the conventional circuits. The inferior performance of these tubes was detected on the monthly check and not from an unstable electrical zero.

Following the tube replacement test, for a period of eight months OD3 tubes were replaced in the modified and conventional indicators only when necessary to eliminate troublesome electrical zero shifts. During this period several tubes had to be replaced in the conventional units but there were no replacements in the modified units. At the end of the eight-month period the tubes in all units were tested and about one-half of the OD3 tubes in these units were replaced. Because of the improved stability of the electrical zero, wider tolerances in the OD3 tubes for use in the indicator B+ supply may be permissible and consequently the maintenance may be reduced. A monthly visual check and a quarterly test of the voltage-regulating tubes would probably be adequate for the modified bridges.

Twin-triode tubes, type 6SN7 or 5692, with a section in each arm of the bridge, were found to be more satisfactory for use in the modified circuits than individual single-triode tubes, type 6J5. Modifications using 6J5 tubes provided a more stable electrical zero than conventional 5-milliampere bridges provided, but the zero of these modified units would drift for several hours before stabilizing after the indicator was energized. On the other hand, when 6SN7 tubes were used in the modification, the zero stabilized in a few minutes and the error in linearity of response was less than that observed when 6J5 tubes were used.

In the modification of the cathode and grid circuits of the signal-amplifier tube (V202A) and the reference tube (V202B), the values of the components were selected to provide the most satisfactory performance for the particular unit. The values of two of these components, R212 and R234, should have tolerances of 10 percent or less in order to provide adequate zero and calibration adjustment for the variations in performance of different 6SN7 tubes.

The modifications discussed in this report are relatively easy to accomplish in the existing transmissometer indicators. No additional space on the outside of the chassis is required and only two or three additional resistors are needed on the inside. The resistors and potentiometers that require changing are similar to the present components but have different values. A few changes in wiring are necessary and, to avoid confusion, the surplus tube socket should be removed. An experienced technician could probably make the modification of an indicator at a field installation and have the unit back in operation in two to four hours.

If the replacement rate of type OC3 or OD3 tubes is, or becomes, undesirably high, or if zero shifts require too much attention, these modifications should be considered as a solution. In order to keep the circuits uniform, the modification, other than on a test basis, should be implemented only if it is worthwhile to modify all existing units.

VI. CONCLUSIONS

After several tests had been made on the modified and nonmodified bridge circuits, and after a long period of routine operation of the various transmissometer indicators, it was concluded that:

1) The modified bridge circuits have considerably fewer zero shifts than the conventional circuits.

2) After the units are energized, the modified indicators stabilize in less time than the conventional indicators.

3. The modified circuits provide acceptable linearity of response.

4. The modified indicators stabilize faster at low signal rates than the conventional indicators.

5. The stability and tolerance requirements of type OD3 tubes in the power supply are less critical for the modified indicators than for the conventional indicators.

6. An evaluation of the service experience of existing installations will be required to determine if the cost of making the modification on existing units is justified by the improvement in performance.

May 1959
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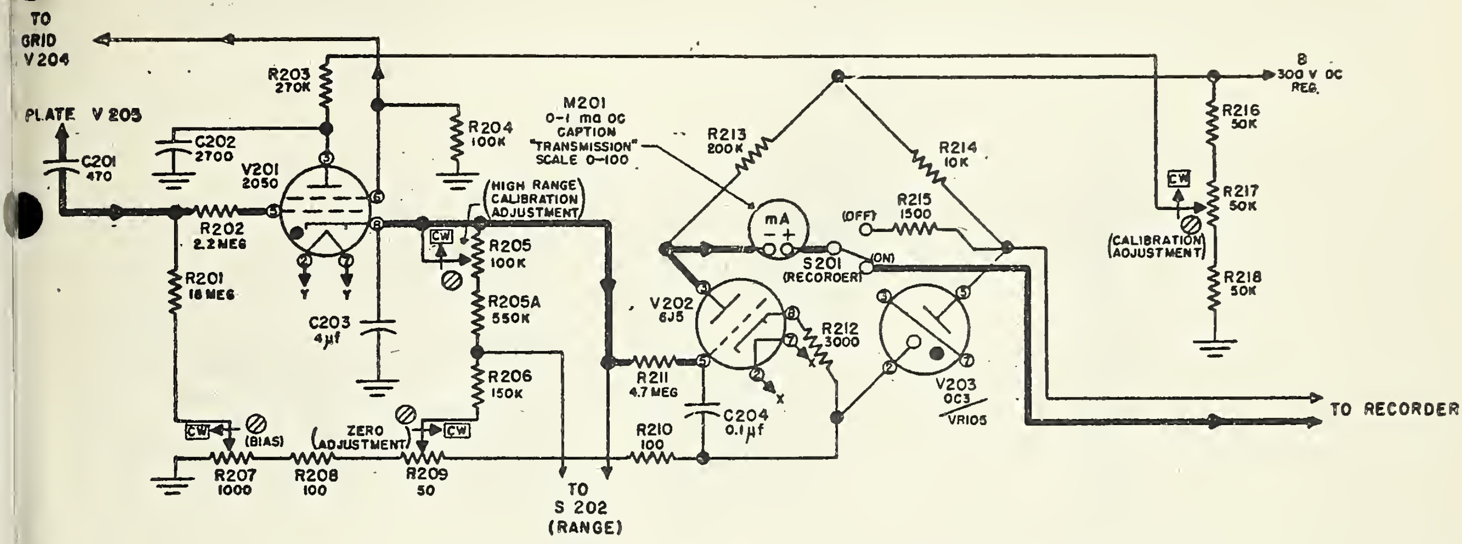

Figure 1a. Schematic diagram of voltmeter section of the 1-milliampere convential indicator.

Note: The 5-milliampere indicator is similar except for the following component changes.

Component	1ma. bridge	5ma. bridge
C-202	2700 μμf	3000 μμf
R-208	100	not used
R-209	50	100
R-210	100	47
R-212	3000	390
R-213	200 K	40 K
R-214	10 K	8 K
R-215	1500	360

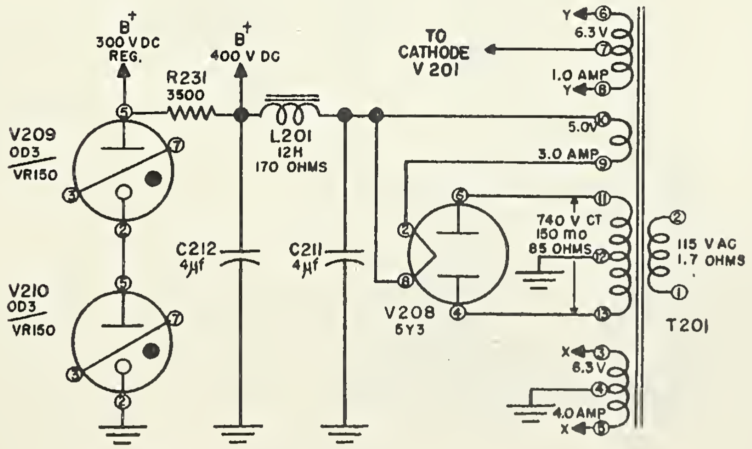

Figure 1b. Transmissometer indicator power supply.

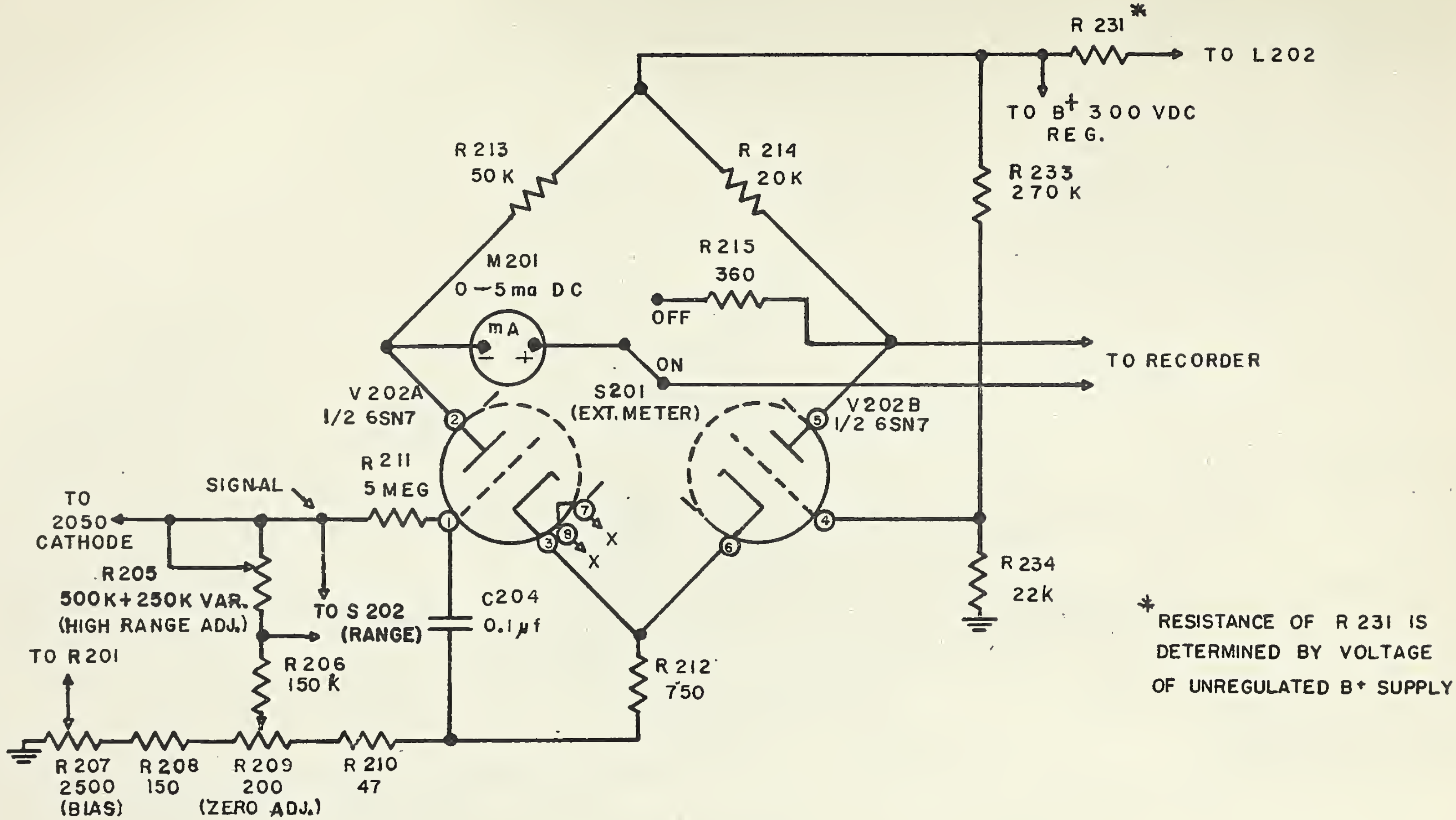

Figure 2. Circuit modifications of the metering bridge for the 5-milliampere indicator.

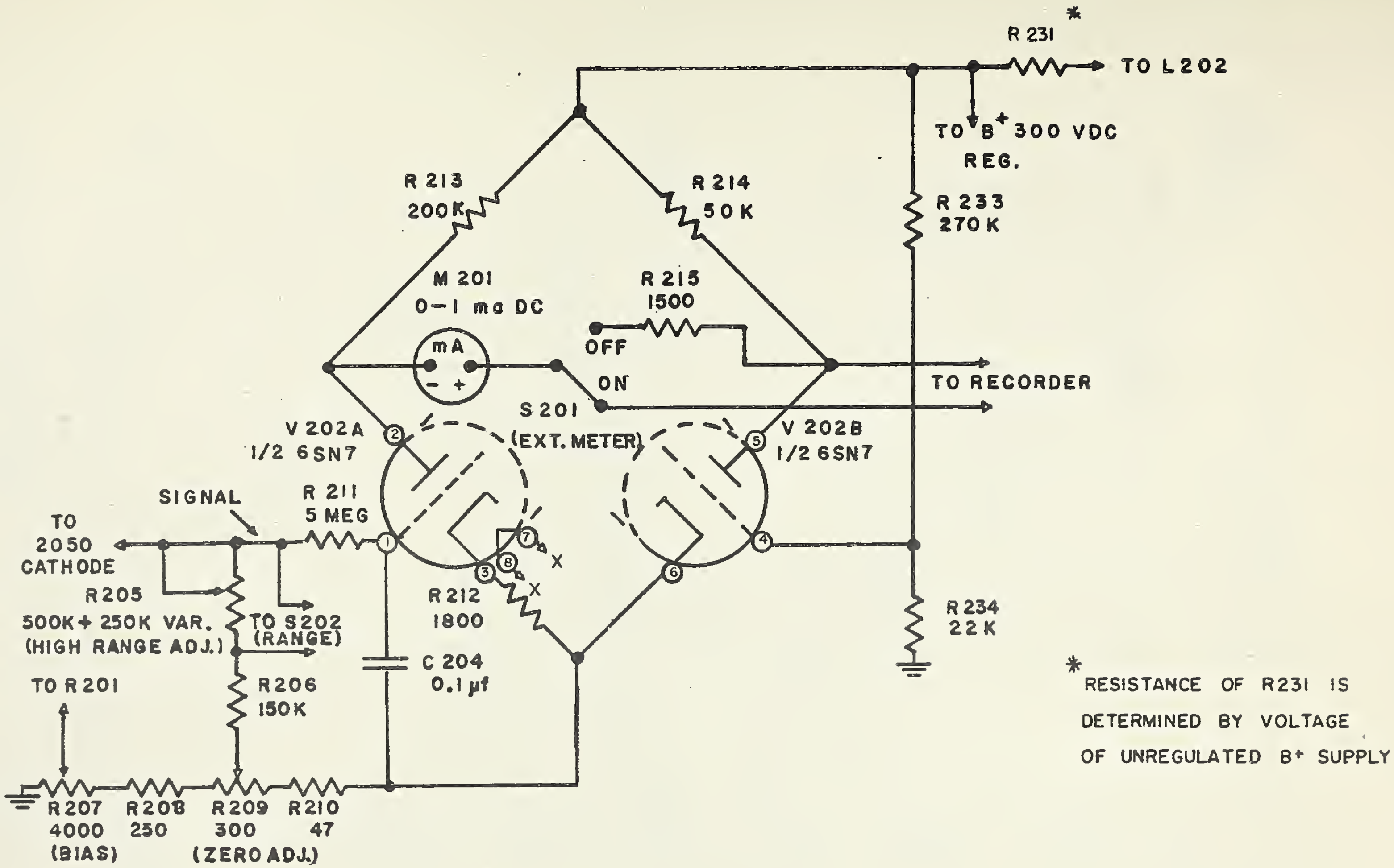

Figure 3. Circuit modifications of the metering bridge for the 1—milliampere indicator.

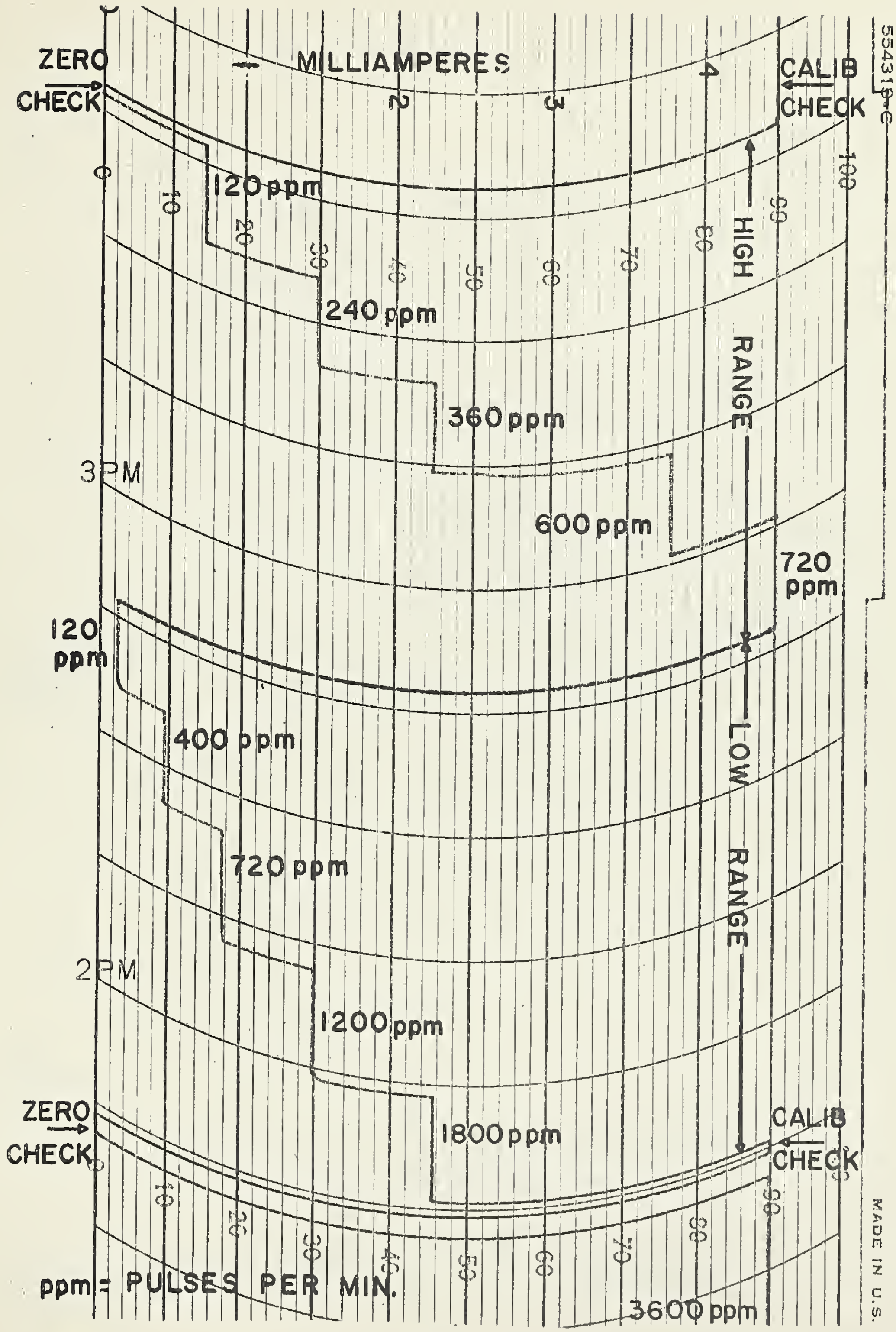

Figure 4. Test of linearity of response of the 5-milliampere modified indicator.

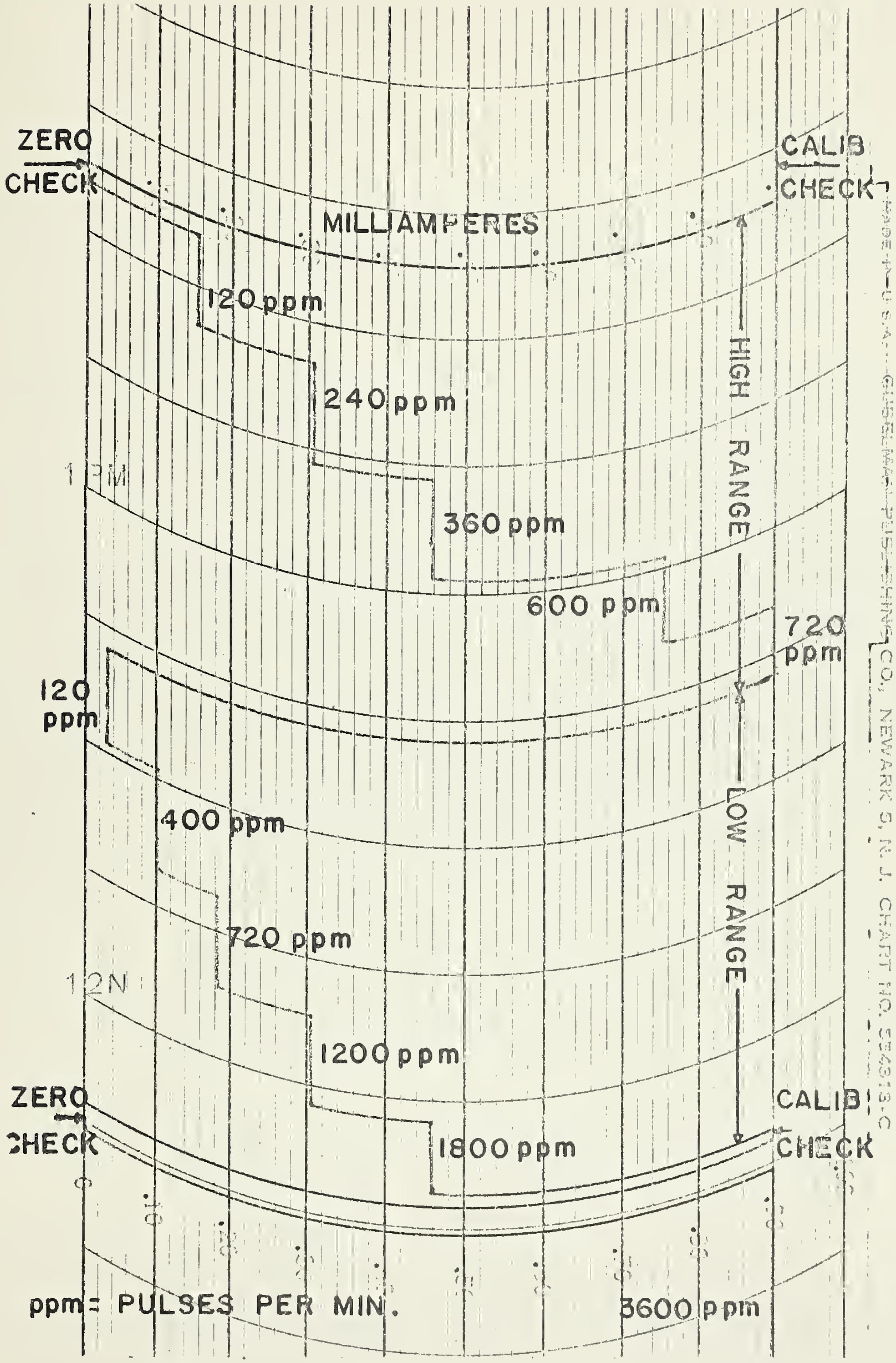

Figure 5. Test of linearity of response of the 1-milliampere modified indicator.

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