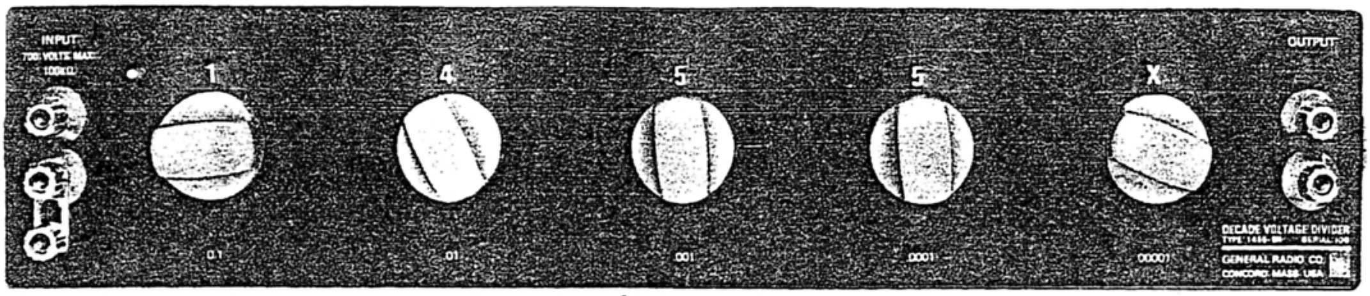

Figure 1-1. The Type 1455-BH Decade Voltage Divider.

SPECIFICATIONS

Type:	1455-AH	—A	—AL	—BH	—B
Dials:	4	4	4	5	5
Input Resistance:	100 kΩ	10 kΩ	1 kΩ	100 kΩ	10 kΩ
Input Voltage Rating: May be 20 ppm linearity change at full rating (see below)	700 V	230 V	70 V	700 V	230 V
Frequency Response (f_o at 3 dB down): (unloaded, at max output resistance setting)	85 kHz	850 kHz	7.5 MHz	69 kHz	690 kHz
Resolution (in ppm of input):	100	100	100	10	10
Linearity					
Absolute Linearity (in ppm of input): Output taken with respect to output zero setting at low audio frequencies with input voltage < ½ rating.					
Ratio					
0.00001 to 0.00010	—	—	—	± 0.02	± 0.03
0.00010 to 0.00100	± 0.2	± 0.3	± 0.7	± 0.2	± 0.3
0.00100 to 0.01000	± 2	± 2	± 3	± 2	± 2
0.01000 to 0.10000	±15	±15	±20	±10	±10
0.10000 to 1.00000	±30	±30	±50	±20	±20
Terminal Linearity (in ppm of input) (add to absolute linearity):					
Four-terminal (output with respect to low output terminal):	± 0.004	± 0.04	± 0.4	± 0.004	± 0.04
Three-terminal (low terminals common, or output with respect to low input terminal):	± 0.02	± 0.2	± 2	± 0.02	± 0.2
Max Output Resistance: (input shorted)	27.9 kΩ	2.79 kΩ	333 Ω	28.8 kΩ	2.88 kΩ
Effective Output Capacitance: (typical, unloaded)	67 pF	67 pF	67 pF	80 pF	80 pF

Frequency Characteristic:

Acts like simple RC circuit below f_o so that

$$\frac{E_o}{E_{in}} \approx \frac{\text{reading}}{\sqrt{1 + \left(\frac{f}{f_o}\right)^2}}.$$

Tabulated value of f_o is at setting that gives max output resistance so that f_o at all other settings is higher. At $0.044 f_o$, response is down $< 0.1\%$.

Accuracy of Input Resistance: +0.015%, except for 1455-AL, which is +0.025%.

Temperature Coefficient: < 20 ppm for each resistor. Since voltage ratios are determined by resistors of similar construction, net ambient temperature effects are very small.

Dimensions (width × height × depth): Rack models, 19 × 3½ × 4⅝ in. (485 × 89 × 120 mm); 4-dial bench models, 14¾ × 3½ × 6 in. (375 × 89 × 155 mm); 5-dial bench models, 17$\frac{15}{16}$ × 3½ × 6 in. (455 × 89 × 155 mm).

Net Weight: Bench models, 4-dial, 6¾ lb (3.1 kg); 5-dial, 7¾ lb (3.6 kg).

Shipping Weight (est): Bench models, 4-dial, 7½ lb (3.5 kg); 5-dial, 8½ lb (3.9 kg).

Add approx 1 lb (0.5 kg) to net and shipping weights for rack models.

INTRODUCTION

1.1 PURPOSE.

The Type 1455 Decade Voltage Divider is a convenient means of obtaining accurately known voltage ratios. Among its many uses are the calibration of voltmeters, linearity measurements on continuously adjustable transformers and potentiometers, measurement of gain and attenuation, the precise measurement of frequency-response characteristics of audio-frequency networks, and the determination of turns ratios in transformers.

Five models are available in order to provide a choice in resolution and impedance level. The high-impedance models, Types 1455-AH and -BH, permit greater applied voltage (up to 700 V), while the lowest-impedance model, Type 1455-AL, has useful accuracy in the radio-frequency range.

1.2 DESCRIPTION.

These voltage dividers are housed in a 3 1/2"-high cabinet. All models are available for either bench use or for installation in a relay rack. Refer to Table 1-1.

The panel binding posts are for general use, and connection to the instrument may also be made at the rear, as is often preferred for rack-mounted equipment.

The Types 1455-AH, -A, and -AL have four selector switches for four-digit readout. The Types 1455-BH and -B have five decade switches for five-digit readout. These switches indicate the voltage-ratio setting in an in-line readout with the decimal point always before the first digit (refer to paragraph 2.3).

1.3 ACCESSORIES AVAILABLE.

Panel-Adaptor Sets are supplied with the Type 1455 relay-rack models listed in Table 1-1. Panel-Adaptor Sets are also available for mounting Type 1455 bench instruments in a standard 19-inch relay rack (refer to Table 1-2).

Refer to the Appendix for details on other equipment recommended for use with the Type 1455 Decade Voltage Dividers.

Table 1-2
TYPE 1455 PANEL-ADAPTOR SETS

Catalog Number	*Description*
0480-2070	Panel-Adaptor Set for Types 1455-A, -AH, and -AL.
0480-2010	Panel-Adaptor Set for Types 1455-B and -BH.

Table 1-1
TYPE 1455 DECADE VOLTAGE DIVIDERS

Catalog Number				
Bench	*Relay Rack*	*Type*	*No. of Decades*	*Ratio Range*
1455-9700	1455-9701	1455-A	4	0.0001 to 1.0
1455-9702	1455-9703	1455-AH	4	0.0001 to 1.0
1455-9704	1455-9705	1455-AL	4	0.0001 to 1.0
1455-9706	1455-9707	1455-B	5	0.00001 to 1.0
1455-9708	1455-9709	1455-BH	5	0.00001 to 1.0

OPERATING PROCEDURE

2.1 INSTALLATION.

To install a Type 1455 Decade Voltage Divider in a standard 19-inch relay rack using the appropriate Panel-Adaptor Set, refer to Figure 2-1 and proceed as follows:

a. Remove the black nylon buttons from the holes in the side panels of the instrument. These buttons are press fitted and are easily removed with a small screwdriver.

b. Install the adaptor panel (A) on each side of the instrument, using the 3/8-inch locking screws (B) supplied. The holes in the side panels are tapped to receive these screws.

c. Mount the assembly in a standard 19-inch relay-rack cabinet, using the 5/8-inch No. 10-32 screws (C) and nylon washers (D) supplied.

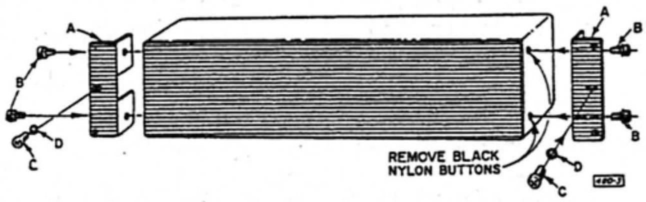

Figure 2-1. Relay-rack installation of a Type 1455 Decade Voltage Divider.

2.2 CONNECTIONS.

2.2.1 FRONT-PANEL CONNECTIONS.

Connect the external voltage source to the two insulated INPUT terminals. If grounded operation is to be used, connect the ground link between the lower INPUT grounded terminal and the middle (insulated) terminal. Connect the device to be supplied to the OUTPUT terminals.

2.2.2 REAR CONNECTIONS.

To make connections at the rear of the instrument, refer to Figure 2-2 and proceed as follows:

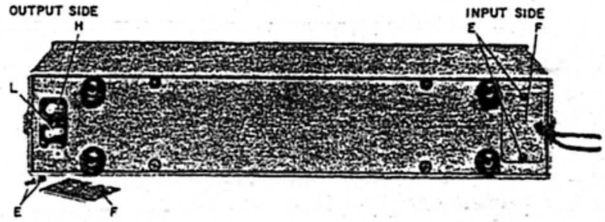

Figure 2-2. Rear view of Type 1455 showing OUTPUT terminals and INPUT side fully connected.

a. Remove the two 6-32 screws (E) and the small rectangular plate (F) from the INPUT side of the rear panel. (The terminals on the front panel, except for the lower INPUT grounded terminal, extend directly to the rear and are available for connection when the rear plates are removed.)

b. Connect the voltage source to the recessed INPUT terminals at the rear. If grounded operation is desired, connect the ground link between the lower INPUT grounded terminal and the middle (insulated) terminal on the front panel.

c. Remount plate (F) on the rear panel, using the two screws (E) previously removed.

NOTE

In order to provide an opening for the connection leads, plate (F) must be mounted with its slot facing toward the side panel of the instrument. To seal the instrument from outside dust and dirt when connections are not required at the rear, mount plate (F) with its slot facing away from the side panel.

d. At the OUTPUT side of the rear panel, repeat step a above, connect the device to be supplied to the rear OUTPUT terminals (H and L), and remount plate (F) as described in step c.

2.3 OPERATION.

Remember that the voltage divider, like any potentiometer, should be used only with high resistance loads. Refer to paragraph 2.7.

Set the selector switches to indicate the desired voltage ratio. When setting the switches remember that X = 10, and the decimal point is always placed before the first digit. For example, if the output voltage is to be 0.1240 times the input voltage, the switches can be set (from left to right, respectively) to:

1, 2, 4, 0 = 0.1240

or

1, 2, 3, X = 0.1240

And if a ratio of 1.0000 is desired, set the switches to:

9, 9, 9, X = 1.0000

2.4 TYPICAL USES.

2.4.1 CALIBRATION OF A VTVM.

The simple circuit of Figure 2-3 is useful for checking electronic, low-frequency ac or dc voltmeters which have an input impedance much higher than the output impedance of the divider. The Type 1455-AL is particularly useful for low-voltage ac calibration because of its lower output impedance and better frequency characteristics. In this circuit, the standard meter should be used with a reading near full scale to obtain the best accuracy.

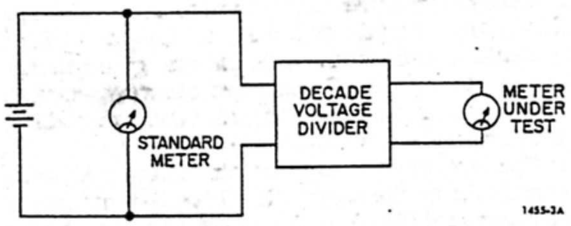

Figure 2-3. Circuit for vacuum-tube voltmeter calibration and test, using a Type 1455 Decade Voltage Divider.

2.4.2 LINEARITY CHECKS OF POTENTIOMETERS.

The linearity of potentiometers and other voltage dividers can be checked using the circuits shown in Figure 2-4 and Figure 2-5. Both circuits are essentially Wheatstone bridges.

The circuit of Figure 2-4 is preferable if the potentiometer or divider under test has a resistance higher than that of the divider.

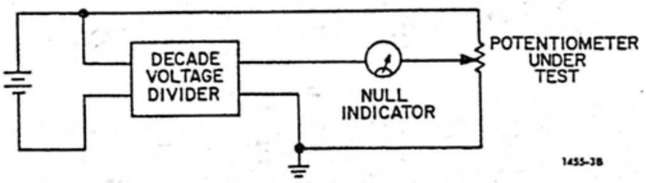

Figure 2-4. Type 1455 Decade Voltage Divider in null circuit used for linearity test of a high-resistance potentiometer.

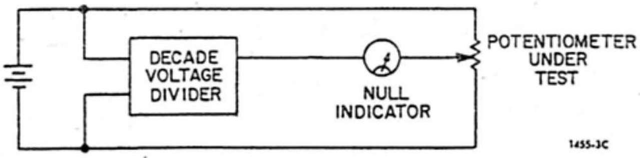

Figure 2-5. Null circuit for linearity test of a low-resistance potentiometer, using a Type 1455 Decade Voltage Divider.

The circuit of Figure 2-5 is preferable if the impedance of the device under test is lower than that of the divider. In either of these circuits, when the divider is adjusted to give a null indication, no current is drawn from the divider and the open-circuit calibration is correct.

These circuits may also be useful at audio frequencies, but capacitive-loading effects must be considered in order to obtain a null, and to obtain the desired accuracy at a null. The null detector should either be battery-operated and floating (GR 1232 Tuned Amplifier and Null Detector) or isolated from the circuit by a shielded transformer (GR 578 Shielded Transformer). In either case, the larger output capacitance should be placed across the device with the lower output impedance in order to reduce loading and phase-shift errors. It may be necessary to add additional capacitance to obtain a null.

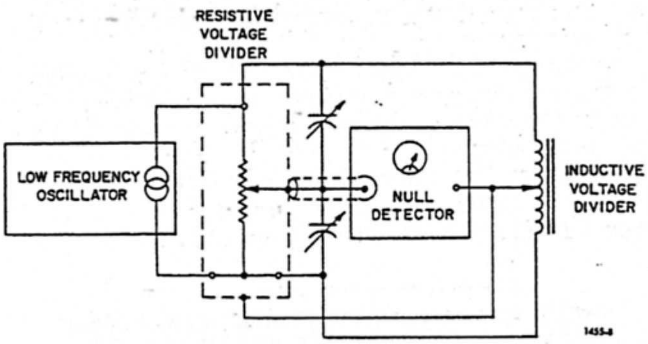

Figure 2-6. An ac null circuit for linearity test of an inductive voltage divider, using a resistive (Type 1455) voltage divider.

An example of an ac circuit is shown in Figure 2-6. Here, the transformer-type divider has a much lower output impedance than that of the resistive divider, so that the low-side of the detector and the case of the resistive divider are both tied to the output.

2.5 EFFECTS OF TEMPERATURE.

Since all resistors are of similar construction and have more or less equal temperature coefficients, the effects of changes in ambient temperature are very small. The effects from self-heating are not balanced out, however. In Figure 3-1, note that in the first decade between contacts 7 and 9, which are bridged by the second decade, only half of the input current is carried. The resistors between these points will have only one-quarter of the temperature rise of other resistors in the decade, causing an error in the output voltage. The temperature rise of the following decades is negligible. The temperature effect is greatest at the zero position of the first decade.

To keep the self-heating error at the first decade within specifications, limit the input voltage to the divider to one-half of the maximum voltage rating.

In dc measurements at very low levels, substantial error can result from thermal emf's at the junctions of dissimilar metals. The Type 1455 Decade Voltage Dividers use gold-plated copper binding posts to minimize these voltages when connections are made with copper wire.

2.6 FREQUENCY RESPONSE.

The Type 1455 Decade Voltage Dividers act very much like simple RC low-pass filters at frequencies below their 3-dB cutoff frequency (f_o). Thus, attenuation at any frequency below f_o can be determined from the expression:

$$\frac{E_{out}}{E_{in}} = \frac{N}{\sqrt{1 + \left(\frac{f}{f_o}\right)^2}}$$

where:

N = divider setting
f = operating frequency

In the specifications, the value of f_o is given for the setting which gives the maximum output resistance (refer to paragraph 2.7), with no additional capacitance on the OUTPUT terminals, and with the case connected to the low INPUT terminal. For any other setting, f_o is higher, and additional capacitance on the output will reduce f_o which is inversely proportional to $R_{out} \times C_{out}$. The effective internal-loading capacitance is also given in the specifications to facilitate the calculation of values of f_o when external capacitance is added.

In some measurement circuits, such as the circuit shown in Figure 2-6, it is possible to connect the divider case to a voltage equal to the output voltage. This greatly reduces the effect of stray capacitance and makes it possible to obtain extremely precise ac measurements even with the high-resistance models (Types 1455-AH and -BH).

At settings near zero, the inductance of the wiring (approximately 0.7 µH) introduces a small error which is proportional to frequency and is equal to approximately 0.1 ppm at 10 kHz.

2.7 OUTPUT RESISTANCE.

The decimal ratio in the Type 1455 dividers is the ratio of the open-circuit output voltage to the input voltage. The divider is intended primarily for use with high-impedance loads, such as a null indicator or high-impedance voltmeter. For finite load resistances, it is necessary to know the output resistance in order to determine the actual output voltage of the divider. The loaded output voltage (E_o) can be determined by the expression:

$$E_o = N \frac{R_L}{R_L + R_o}$$

where:

N = divider setting
R_L = load resistance
R_o = output resistance

To the first approximation, the output resistance is that of a simple divider (see Figure 2-7). For this circuit, with the input shorted, the output resistance (R_o) is:

$$R_o = N(1-N)R_{in}$$

where:

N = divider setting
R_{in} = input resistance

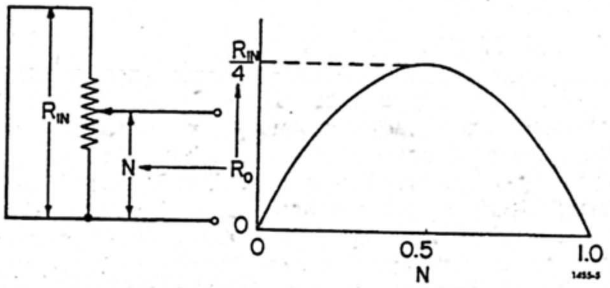

Figure 2-7. Output-resistance characteristic of a simple divider.

Actually, the Type 1455 divider circuit is substantially more complicated than a simple divider; and the actual output resistance for any given setting is difficult to calculate. Output resistance values for combinations of the first two digits (with other digits set at zero) are given in Table 2-1 for Type 1455-A and -B. The output resistance values for the Types -AH and -BH are those given in Table 2-1 but multiplied by a factor of 10. For the Type 1455-AL, multiply by 0.1.

Note that it is not possible to interpolate between values given in Table 2-1. The resistance is always increased if subsequent digits are set to other than

Table 2-1
OUTPUT RESISTANCE* FOR TYPES 1455-A, -B

First Selector – Switch Setting \ Second Selector – Switch Setting	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	189	356	501	624	725	804	861	896	909
0.1	900	1069	1216	1341	1444	1525	1584	1621	1636	1629
0.2	1600	1749	1876	1981	2064	2125	2164	2181	2176	2149
0.3	2100	2229	2336	2421	2484	2525	2544	2541	2516	2469
0.4	2400	2509	2596	2661	2704	2725	2724	2701	2656	2589
0.5	2500	2589	2656	2701	2724	2725	2704	2661	2596	2509
0.6	2400	2469	2516	2541	2544	2525	2484	2421	2336	2229
0.7	2100	2149	2176	2181	2164	2125	2064	1981	1876	1749
0.8	1600	1629	1636	1621	1584	1525	1444	1341	1216	1069
0.9	900	909	896	861	804	725	624	501	356	189

*Values given are for combinations of settings for first two digits, with other digits set at zero.

zero. The highest output resistance (given in the specifications) is at settings 5455 for the four-digit dividers, and 54545 for the five-digit models. Output resistance for other settings may be most easily found by resistance measurement.

If the generator has a finite impedance, and the voltage is measured before this impedance instead of at the divider, the ratio with respect to this generator voltage will be in error. However, if the load impedance is infinite, the ratio of any two settings will be correct because the input impedance of an unloaded divider of this type is constant.

If both the generator and load impedances are finite and relative ratios are desired, the equivalent output impedance should be measured with the INPUT terminals connected through an impedance equal to that of the generator, and corrections should be made as shown above.

SECTION 3

PRINCIPLES OF OPERATION

3.1 CIRCUIT DESCRIPTION.

The method of voltage division, which is attributed to Kelvin and Varley, is shown by the schematic diagram for the Type 1455-A, Figure 3-1. Eleven equal resistors are used in all but the last decade. Two of these resistors are shunted by the next decade which uses resistors of one-fifth the value of those in the preceding decade. In this manner, each decade effectively becomes a string of ten equal resistors giving the desired decimal readout on the dial.

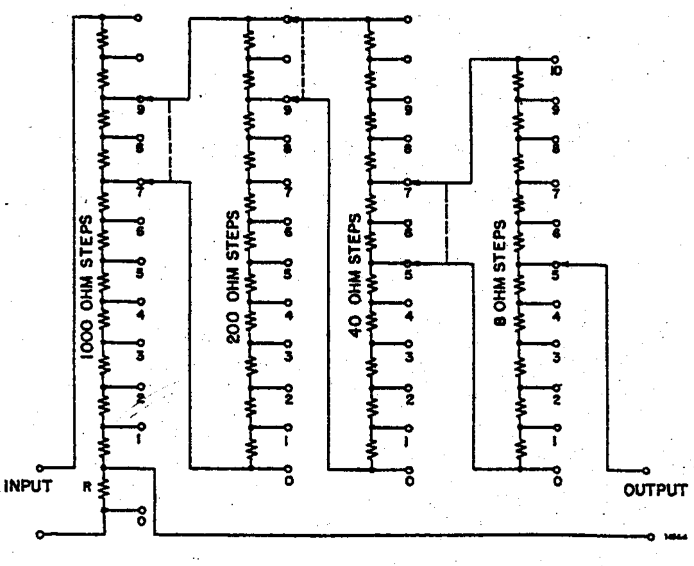

Figure 3-1. Elementary schematic diagram of Type 1455-A Decade Voltage Divider.

The Type 1455-AH uses resistors of ten times the values shown in Figure 3-1. On the Types 1455-AL, -B, and -BH, additional fixed resistors are added across the input of the later decades in order to avoid the necessity of using very low-value resistors which would be less accurate and stable.

3.2 INTERPRETATION OF LINEARITY SPECIFICATIONS.

3.2.1 LINEARITY AND ACCURACY.

The linearity specification for the Type 1455 is given in ppm (parts-per-million) of the input voltage. This specification is similar to a voltmeter accuracy specification given in percent-of-full scale. At any setting, the difference between the output voltage and the input voltage multiplied by the setting will be less than the specified ppm of the input voltage.

In terms of percentage of setting, the accuracy is equal to the specified linearity divided by the setting. Because the setting is never greater than unity, the accuracy, as a percent of setting, is always a larger number than the linearity specification. For very low settings the linearity, as a fraction of input, becomes a very small number. The accuracy, as a percent, of these low settings is actually poorer than that of higher settings, because somewhat lower tolerance resistors are used on the higher digits.

3.2.2 ABSOLUTE LINEARITY.

For very low settings, the resistance of the wiring and switches add small, but noticeable errors, because at the zero setting the output is not exactly zero. This error can be ignored if the output at any setting is taken with respect to the actual output voltage at the zero setting. This is shown in Figure 3-2 where the errors are greatly exaggerated for the purpose of illustration. Here, the output voltage at zero setting is substantial. Also, the output at full scale does not equal the input. Absolute linearity is a measure of how far the output voltage differs from a straight line drawn between the output voltages at the zero and full-scale settings, even though the voltages at these points are not exactly equal to zero and unity.

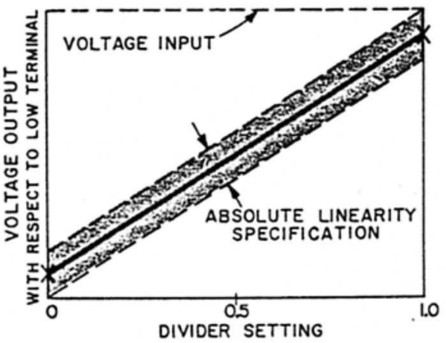

Figure 3-2. Exaggerated illustration of absolute linearity of a Type 1455.

An example of the use of absolute linearity is the calibration of dividers using lead-compensation correction as in Figure 3-3. Here, potentiometers A and B are adjusted so that the 0 (zero) and 1 (one) settings of both dividers coincide.

3.2.3 TERMINAL LINEARITY.

The linearity of a voltage actually present at two terminals of a divider is called the terminal linearity.

When the output is taken across both OUTPUT terminals, all four divider terminals are in use. An example of a measurement using this four-terminal connection is shown in Figure 2-3. The error due to switch resistance (refer to paragraph 3.2.2) is compensated for when such a measurement is made. A small resistor (R, Figure 3-1) is added in series with the divider so that the low OUTPUT terminal is at very nearly the same voltage as the high OUTPUT terminal when the divider setting is at zero. This resistor is of the order of 0.001 Ω and it will not affect calibration of the divider.

In some cases, the input and output connections must be tied together, or the output must be taken with respect to the low INPUT terminal. In such three-terminal applications, the compensating resistor (R, Figure 3-1) is not effective and an additional error is given in the specifications under Terminal Linearity. Examples of three-terminal operation are the comparison of two dividers and checking the linearity of potentiometers using the circuit shown in Figure 2-6. However, if the potentiometer under test is of high resistance (greater than the input resistance of the divider), there will be less error if it is connected to the low OUTPUT terminal of the divider as shown in Figure 2-4.

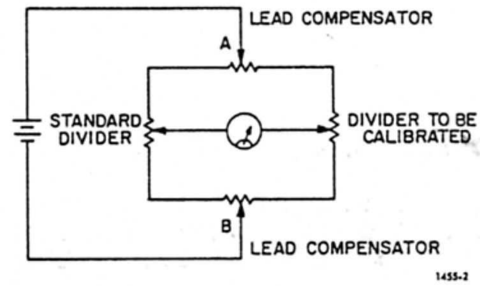

Figure 3-3. Divider calibration, using lead-compensation circuit.