4737-A20 AND 4737-A21
GUARDED WHEATSTONE BRIDGES

Surge Tech #

LEEDS & NORTHRUP

NOTE

This direction book is also applicable to the 4737-A22 and 4737-A23 Guarded Wheatstone Bridges. The 4737-A22 and 4737-A23 differ from the 4737-A20 and 4737-A21, respectively, in that they are wired for operation on 230-volt 50/60 Hz line voltage.

These instruments have 4737-A20 screened on the top plate since that is the basic model.

The plug has been cut from the line cord and none is provided owing to the variety of shapes in use. Attach a plug suitable for use with your outlets.

CONTENTS

SPECIFICATIONS

OPERATING CONDITIONS
Reference Conditions (Best Accuracy):
Ambient temperature of 25°C ±1°, relative humidity of less than 80%, and calibration cycle of one year.
Rated Conditions (Reduced Accuracy):
Ambient temperature between 15°C and 35°C with other conditions the same as for reference conditions.

STORAGE CONDITION
Ambient temperature between -20°C and 50°C.

MEASURING RANGE
0.1 ohm to 11,111 megohms.

LIMITS OF ERROR*
Reference Conditions:
±0.01% of reading +0.0005 ohm up to 10 megohms.
±0.02% of reading from 10 to 100 megohms.
±0.2% of reading from 100 to 1111 megohms.
±2% of reading from 1111 to 11,111 megohms.
Rated Conditions:
±0.01% of reading +0.0005 ohm up to 10 megohms, derated 10 ppm/°C for each °C outside reference conditions.
±0.02% of reading from 10 to 100 megohms, derated 10 ppm/°C for each °C outside reference conditions.
±0.2% of reading from 100 to 1111 megohms.
±2% of reading from 1111 to 11,111 megohms.
Percent Deviations:
±3% of full scale of detector meter for both reference and rated conditions.

RANGE MULTIPLIER SWITCH
10^{-1} to 10^{9} in powers of 10. Switch also changes bridge voltage to proper value for each range. Blank position useful for calibration (see Section 3A).

READOUT DIALS
Six rheostat decades:
First decade has 10 steps of 1000 ohms.
Second decade has 10 steps of 100 ohms.
Third decade has 10 steps of 10 ohms.
Fourth decade has 10 steps of 1 ohm.
Fifth decade has 10 steps of 0.1 ohm.
Sixth decade has 10 steps of 0.01 ohm.
Blank position is electrically the same as the 10 or X position.

NULL DETECTOR
L&N 2437 DC Null Detector** with following specifications:
Sensitivity—about 10 µV for full scale deflection of meter.
Input Resistance—greater than 50 kΩ (detector input resistance is always below 10 kΩ in Bridge Circuit).
Sensitivity Control—sensitivity increases from minimum to maximum with clockwise rotation; a setting of 1 provides approximately a 100-fold reduction in sensitivity.
Zero Control—0 to ±20 µV.
Meter—Current Range: 50 to 0 to 50 µA ±2 µA.
Scale: marked 10, 8, 6, 4, 2, 0, 2, 4, 6, 8, 10 with 5 subdivisions between each number; left end of scale marked "+ ADD" and right end marked "− SUB".
Accuracy: ±2% of full scale.
Zero Dead Band: less than 1% of full scale of 1/2 division.
Resistance: 750 ohms ±10%.
Mechanical Zero Adjustment: 3% of full scale.

POWER SUPPLIES
Guarded (PS1): Provides 1 to 50 volts dc to bridge circuit.
Unguarded (PS2): Provides 12.5 volts dc at 3.5 mA to null detector.

LINE VOLTAGE REQUIREMENT
120 volts, 50-60 Hz, 2 volt-amperes.

DIMENSIONS
4737-A20 (Bench-Type): 19" long, 10-1/2" wide, 9-1/2" deep with legs retracted or 11" deep with legs extended.
4737-A21 (Relay-Rack-Type): 19" long, 10-1/2" wide, 8-3/8" deep.

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* See Appendix for error analysis.
** For additional information, refer to Directions 177416.

4737-A20 AND 4737-A21
GUARDED WHEATSTONE BRIDGES

1. GENERAL DESCRIPTION

The 4737-A20 and 4737-A21 Guarded Wheatstone Bridges are laboratory-type measuring instruments for making precise measurements of dc resistances having values between 0.1 ohm and 11,111 megohms.

These bridges can be used to make percent deviation measurements, thereby allowing the making of quick and accurate tolerance checks of production-line resistors. The rheostat arms of these bridges can be used as resistance boxes.

The 4737-A20 Bridge, shown in Fig. 1, is designed for bench mounting and the 4737-A21 Bridge for mounting in a standard 19-inch relay rack.

All bridge readout dials, controls, indicators, and switches as well as the ground, X2, X1, and guard binding posts are mounted on the front panel. The line cord, calibration terminals, external detector binding posts, and the external power supply binding posts are mounted at the rear of the bridge as shown in Fig. 2.

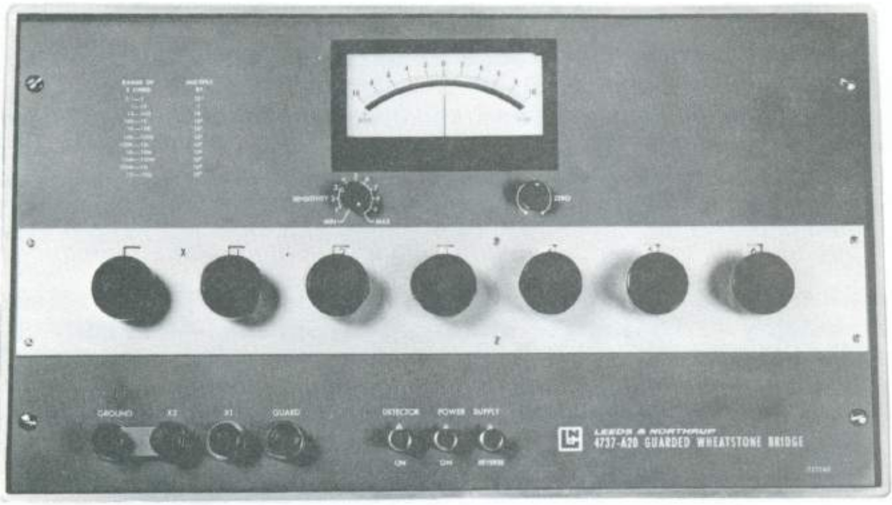

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Fig. 1—4737-A20 Guarded Wheatstone Bridge.

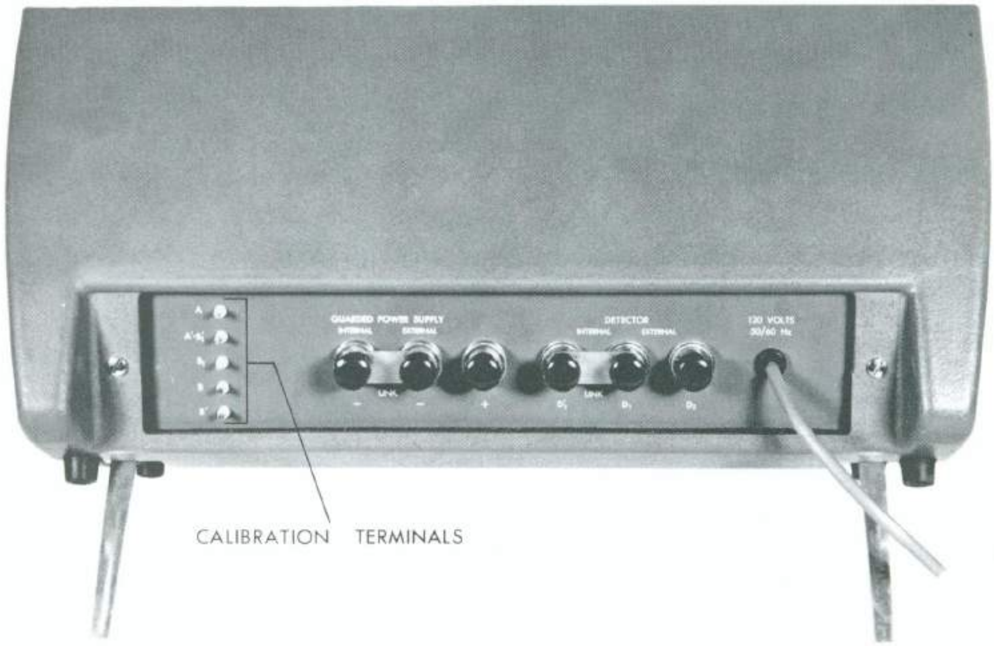

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Fig. 2–Rear view of 4737-A20 Guarded Wheatstone Bridge.

2. DESIGN FEATURES

Each bridge has a built-in null detector which can be disconnected from the bridge circuit by removing the metal link from the D'_1 and D_1 (INTERNAL DETECTOR) binding posts at the rear of the bridge. A more sensitive null detector—such as an L&N 9834 or 9834-1 Detector —can be connected to this bridge by means of the D_1 and D_2 (EXTERNAL DETECTOR) binding posts. The use of such a detector facilitates making measurements of resistances having values below 100 ohms and above one megohm. For such measurements the greater detector sensitivity could be useful in taking full advantage of the ppm resolution of the bridge.

The internal guarded power supply can also be disconnected from the bridge circuit by removing the metal link from the – INTERNAL and – EXTERNAL (GUARDED POWER SUPPLY) binding posts at the rear of the bridge. An external power supply can then be connected to the bridge by means of the – EXTERNAL (GUARDED POWER SUPPLY) and + binding posts. Do this when bridge voltages other than those selected by the range multiplier dial are desired. Refer to Section 5A for additional information about the use of an external power supply.

Five calibration terminals (A, A'-B'_2, B_1, B, and B') are provided at the rear of the bridge, as shown in Fig. 2. These terminals permit checking of the internal resistors of the bridge.

3D. DETECTOR ON Key

This key is a single-pole, double-throw switch that connects the null detector across the bridge when it is depressed. The key locks in the depressed position when turned 180 degrees. When the key is in the up or normal position, a 1000-ohm load resistor is connected across the null detector.

3E. POWER SUPPLY ON Key

This key is a single-pole, single-throw switch that connects the PS1 power supply across the bridge circuit when it is depressed. This key locks in the depressed position when turned 180 degrees.

3F. POWER SUPPLY REVERSE Key

This key is a guarded, double-pole, double-throw, polarity-reversing switch. When depressed, this key reverses the direction of the current flowing through the bridge circuit to detect undesirable thermal emf's and to eliminate the effects of such emf's. This key locks in the depressed position when turned 180 degrees.

3G. Binding Posts and Calibration Terminals

Ten binding posts are provided on the bridge: four are mounted on the front panel and six at the rear of the bridge. The front panel binding posts are marked GROUND, X2, X1, and GUARD, respectively; three of the rear binding posts are marked GUARDED POWER SUPPLY and the other three are marked DETECTOR.

Five calibration terminals are provided at the rear of the bridge for making accurate four-terminal measurements of the resistances of the internal resistors without removing the bridge chassis from the bridge case. These terminals are mounted in a vertical row and are marked A, A'-B'_1, B_1, B, and B', respectively.

3H. Power Supplies

Two power supplies, PS1 and PS2, are used in the bridge. They are mounted and wired internally and do not require any readjustment. The PS1 is a guarded supply that provides 1 to 50 volts to the bridge circuit. The PS2 is an unguarded supply that provides power to the null detector.

4. INSTALLATION

Install the bridge at a location having a reasonably constant temperature with no sudden temperature changes. For example, sudden changes can occur near heating or air conditioning vents. Make sure that the location is free from strong electrostatic and magnetic fields and vibrations.

Locate the 4737-A20 Bridge on a bench or other level surface. Then extend the two rear legs of the bridge as shown in Fig. 2.

Mount the 4737-A21 Bridge in a standard 19-inch relay rack or existing L&N facility in accordance with Dwg. A-DIM-822-25.

5. CONNECTIONS

5A. External Power Supply

If an external power supply is to be used instead of the internal power supply, remove the link from the – INTERNAL and – EXTERNAL (GUARDED POWER SUPPLY) binding posts. Then connect the external power supply to the – EXTERNAL (GUARDED POWER SUPPLY) and + binding posts as indicated in Fig. 3.

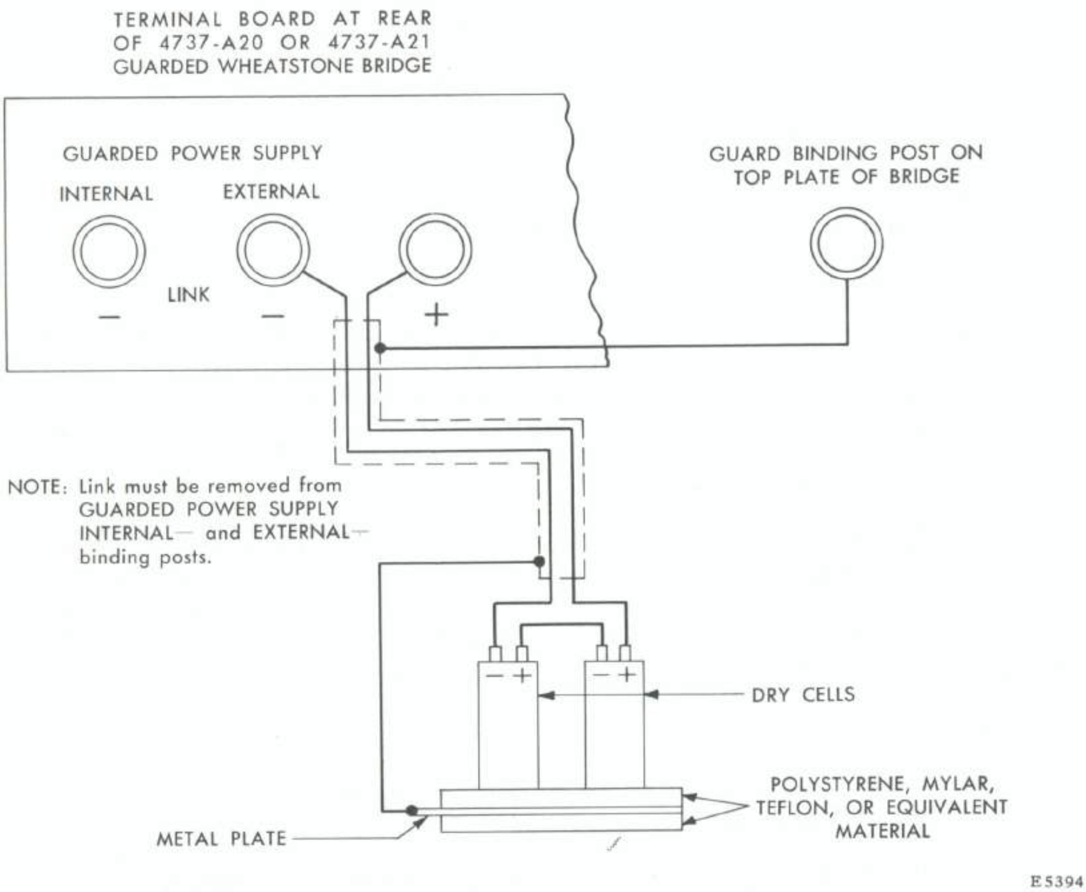


Fig. 3—Wiring connections between external guarded power supply and 4737-A20 or 4737-A21 Guarded Wheatstone Bridge.

CAUTION: The power dissipated by the bridge resistors must not exceed the power ratings of the resistors. Therefore, a maximum of 7.5 volts dc may be applied to the bridge by an external power supply for any setting of the range multiplier switch without damaging the bridge resistors, providing the 1000-ohm-per-step dial is set at 1 or higher. Never allow the external power supply to exceed 7.5 volts dc to the bridge until the approximate settings of the bridge dials have been determined and the dials adjusted accordingly. Table I lists the maximum dc voltages that may be applied for the various settings of the range multiplier switch.

TABLE I—MAXIMUM EXTERNAL POWER SUPPLY DC VOLTAGES

NOMINAL VALUE OF UNKNOWN RESISTANCE (OHMS)	SETTING OF RANGE MULTIPLIER SWITCH	MAXIMUM EXTERNAL POWER SUPPLY DC VOLTAGE (VOLTS)
0.1 - 1	10^{-1}	15
1 - 10	1	7.5
10 - 100	10	7.5
100 - 1K	10^2	7.5
1K - 10K	10^3	7.5
10K - 100K	10^4	15
100K - 1M	10^5	15
1M - 10M	10^6	15
10M - 100M	10^7	50
100M - 1G	10^8	50
1G - 10G	10^9	50

5B. Null Detector

If an external null detector is to be used instead of the internal null detector, disconnect the link from the D'_1 and D_1 (INTERNAL DETECTOR) binding posts. Then connect the external detector to the D_1 and D_2 (EXTERNAL DETECTOR) binding posts.

5C. Electrostatic Shielding

To make the metal case and top panel of the bridge effective as a shield against electrostatic disturbances, ground the case. The three-prong plug of the line cord grounds the case when the plug is plugged into a grounded receptacle. If such a receptacle is not available, connect the GROUND binding post to a good earth ground.

5D. Resistance To Be Measured

Connect the resistance to be measured (unknown resistance) between binding posts X1 and X2.

When the unknown resistance is ungrounded, the low potential junction of the bridge (X2) may be connected to the case and panel through the link connecting the GROUND and X2 binding posts. This connection helps to reduce "pickup" when the leads from the unknown resistance are long.

When measuring an unknown resistance that is grounded, remove the link connecting the GROUND and X2 binding posts. When measuring an unknown resistance that is ungrounded, the link may be either connected to or disconnected from the GROUND and X2 binding posts.

When the leads from the unknown resistance are short and the resistance is unmounted, connect the resistance directly to the X1 and X2 binding posts. When making such connections, make sure that the unknown resistance and its leads are air insulated.

When the unknown resistance is located several feet away from the bridge, use shielded leads; connect the bridge ends of the shields to the GROUND binding post.

If the unknown resistance has a resistance value in excess of one megohm and has long leads, it may be necessary to replace the X_1 lead with guarded-shielded leadwire. The L&N part number of leadwire suitable for such an application is #22-36.11. This leadwire consists of a pair of twisted, polyethylene-insulated, untinned, stranded-copper conductors with two conductive vinyl shields, each shield provided with a drain wire and insulated from the other shield by polyethylene insulation. The leadwire has an outside diameter of 0.23 inch. Connect as shown in Fig. 4 using the twisted pair of conductors as a single conductor connected to X_1. The X_2 conductor can be any available copper wire whose resistance is not a significant portion of the unknown.

If the unknown resistance is mounted on anything which could significantly shunt its value, use a metal guard ring as indicated on Fig. 4.

6. OPERATING PROCEDURES

6A. Approximate Value of Resistance To Be Measured Unknown

To measure a resistance whose approximate value is not known, proceed as follows:

Lock the DETECTOR ON key in its ON position.

Set the pointer of the null-detector meter at zero using the ZERO control, then set the SENSITIVITY dial to MIN.

Set the range multiplier switch (left-hand dial) to its 10^{-1} position.

Set the 1000-ohm-per-step dial (2nd from left) to 1 and the remaining dials to 0.

Tap the POWER SUPPLY ON key and observe the direction of the deflection of the pointer of the null-detector meter, which should be to the left. If the pointer deflects to the right, the resistance value of the unknown resistance is below the range of this bridge and should be measured with a Kelvin bridge. If the pointer deflects to the left, advance the range

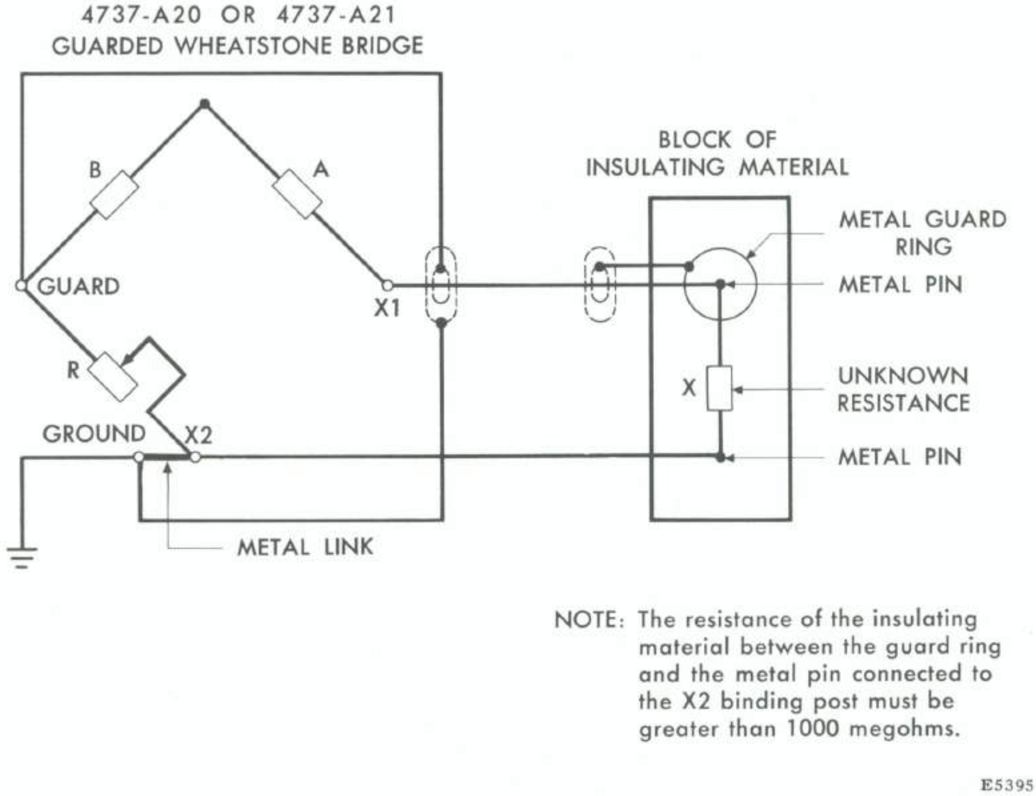


Fig. 4—Schematic diagram showing connections between a guarded unknown resistance and 4737-A20 or 4737-A21 Guarded Wheatstone Bridge.

multiplier switch one step at a time, tapping the POWER SUPPLY ON key after each step, until the pointer deflects to the right. If the pointer still doesn't deflect to the right, advance the 1000-ohm-per-step dial one step at a time, tapping the POWER SUPPLY ON key after each step, until it does.

> NOTE: If the pointer deflection decreases with progressively higher settings of the 1000-ohm-per-step dial up to the highest setting on the dial but does not reverse direction, the resistance value of the unknown resistance is beyond the range of this bridge.

After the pointer deflection reverses direction, move the range multiplier switch back one step to the next lower setting and tap the POWER SUPPLY ON key. The pointer will now deflect to the left.

Advance the 1000-ohm-per-step dial, one step at a time, tapping the POWER SUPPLY ON key after each step, until the pointer deflects to the right. Then return the dial to the next lower setting.

Repeat the preceding step with the remaining dials until this step is being executed with the last (0.01-ohm-per-step) dial, increasing the null-detector sensitivity, as required. Adjust the last dial for minimum deflection rather than reversal of direction of the pointer.

When a balance is obtained—that is, when the pointer rests at zero or when the pointer deflection is minimal—the settings of the range multiplier switch and the six dials indicate the resistance value of the unknown resistance in the form of a seven-window in-line readout.

A multiplication sign is engraved between the range multiplier switch and the 1000-ohm-per-step dial; a decimal point is engraved between the 1000-ohm-per-step and the 100-ohm-per-step dials. To obtain a readout, expressed in ohms, multiply the reading obtained from the six dials by the multiplier indicated in the window of the range multiplier switch.

One or more of the last five dials may show an X in their respective windows. Each X indicates that the dial reading is equal to 10—that is, the reading should be read as 0 with 1 carried over to the next dial. For example, assume that the last three dials indicate 8, X, and X, respectively; the reading of these dials is, therefore, 910.

Reference to Table II will facilitate the reading of this bridge, as the table lists a representative number of sample readouts.

TABLE II–SAMPLE READOUTS

READING IN WINDOW									OHMIC VALUE OF READOUT
1		2		3	4	5	6	7	
10^9	X	10	·	X	X	X	X	0	11,111.00M
10^5	X	1	·	2	3	4	5	6	123.456K
10^3	X	3	·	X	1	1	1	2	4,011.12
10	X	7	·	6	3	2	5	X	76.3260
1	X	10	·	X	X	X	X	1	11.11101
10^{-1}	X	1	·	0	0	0	0	0	0.100000

After obtaining a balance as indicated in the preceding steps, it is good measurement practice to obtain a balance with the POWER SUPPLY REVERSE key depressed. One advantage that such a balance provides is that the observable sensitivity is doubled. However, the most significant advantage provided is that any increase in thermal emf's which may occur during the measurement due to a change in temperature of the unknown resistance is "zeroed out". Depress the key and then adjust the rheostat dials until the deflection noted is the same as the deflection obtained when the key was in its up position. Usually, with the key depressed, no change in the settings of the rheostat dials will be required. A change in the dial settings may be required when small low-wattage resistors are measured, due to self-heating of the resistors and the resulting thermal emf's. A change in the dial settings may also be required when the resistor being measured has been recently touched or handled to such an extent that body heat has changed the resistor temperature, causing thermal emf's in the resistor.

Note that, when measuring resistors which are inductive, it is desirable to lock down the POWER SUPPLY ON key to avoid the time consuming kicks of the detector-meter pointer.

6B. Approximate Value of Resistance To Be Measured Known

Lock the DETECTOR ON key in its ON position.

Set the pointer of the null detector at zero using the ZERO control; then set the SENSITIVITY dial to MIN.

Set the range multiplier switch (left-hand dial) to the setting corresponding to the approximate value of the unknown resistance as determined from the table engraved above the range multiplier switch.

Set the 1000-ohm-per-step dial (2nd from left) to 1 and the remaining dials to 0. Tap the POWER SUPPLY ON key and observe the direction of the deflection of the pointer of the null-detector meter, which should be to the left.

Advance the 1000-ohm-per-step dial, one step at a time, tapping the POWER SUPPLY ON key after each step, until the pointer deflects to the right. Then return the dial to the next lower setting.

Repeat the preceding step with the remaining dials until this step is being executed with the last (0.01-ohm-per-step) dial, increasing the null-detector sensitivity, as required. Adjust the last dial for minimum deflection rather than reversal of direction of the pointer.

When a balance is obtained—that is, when the pointer rests at zero or when the pointer deflection is minimal—the settings of the range multiplier switch and the six dials indicate the resistance value of the unknown resistance.

After obtaining a balance as indicated in the preceding steps, it is good measurement practice to obtain a balance with the POWER SUPPLY REVERSE key depressed. Refer to the last two paragraphs of Section 6A for the procedure.

6C. Lead Resistance Measurements

If the leads connecting the unknown resistance to the bridge have an ohmic value equivalent to a significant fraction of the ohmic value of the unknown resistance, then the ohmic value of the leads should be measured and subtracted from the total ohmic value measured to obtain the correct value of the unknown resistance. That is—first, measure the ohmic value of the unknown resistance in the usual manner; then, disconnect the unknown resistance from the leads, short-circuit the leads, and measure their ohmic value; finally, subtract the latter (second) value from the former (first) value to obtain the correct value of the unknown resistance.

TABLE III–PERCENT DEVIATION MEASUREMENTS

NOMINAL VALUE OF UNKNOWN RESISTANCE (OHMS)	SETTING OF RANGE MULTIPLIER SWITCH	PERCENT DEVIATION				
		10%	1%	0.1%	0.01%	0.001%
0.1 1	10^{-1}	* *				
1 10	1	* ***	* *	 *		
10 100	10	*** ***	* *	* *		
100 1K	10^2	*** ****	** ***	* **	* *	 *
1K 10K	10^3	**** ****	*** ***	** **	* *	* *
10K 100K	10^4	**** ****	*** ***	** **	* *	* *
100K 1M	10^5	*** ***	** **	* *	* *	
1M 10M	10^6	** **	* *	* *		
10M 100M	10^7	* *	* *			
100M 1G	10^8	* *				
1G 10G	10^9					

*Use SENSITIVITY control.
**Use MIN position of SENSITIVITY control.
***Use MIN position of SENSITIVITY control and 270-kilohm resistor.
****Use MIN position of SENSITIVITY control and 2.7-megohm resistor.
NOTE: The blank spaces in this table indicate that the corresponding percent deviations cannot be obtained with this bridge.

6D. Percent Deviation Measurements

Before attempting to use this bridge to make production- or inspection-type percent deviation measurements of a number of resistors having the same nominal resistance value, refer to TABLE III. This table serves as a guide in determining the adjustments necessary to obtain the listed full scale percent deviations.

The following four adjustments provide the required sensitivity for obtaining the various percent deviations. These adjustments involve the SENSITIVITY control of the null detector and the insertion of a 270 kilohm or 2.7 megohm resistor in series with the power supply.

(1) Sensitivity Control: This control permits the maximum sensitivity of the null detector to be reduced by 1/100 when it is set at 1.

(2) MIN Position of Sensitivity Control: This (extreme counter-clockwise) position of the sensitivity control closes a switch mounted on

the rear of the control. The closed position of this switch shunts a 100-ohm resistor across the null detector to reduce the sensitivity by an additional factor of 1/10 or 1/100, depending on whether the 1000-ohm-per-step dial is set at 1 (1000 ohms) or 10 (10,000 ohms), respectively, and the range multiplier switch is in position 10^2, 10^3, 10^4, 10^5, 10^6, 10^7, 10^8, or 10^9. For some instruments, use of this MIN position may provide too great a reduction in sensitivity. In this case return to the 1 or 2 position until the desired deflection is achieved.

> NOTE: With the sensitivity control in the MIN position, the sensitivity is not reduced further when the range multiplier switch is in positions 10, 1, or 10^{-1}, since the bridge resistance at the null-detector binding posts is less than 100 ohms.

(3) 270 Kilohm Resistor: Replacement of the link connected to the INTERNAL GUARDED POWER SUPPLY binding posts with a 270-kilohm resistor (1/4 watt ± 20% carbon-type) reduces the sensitivity by decreasing the power supply voltage. This reduction is about 1/270 or 1/27 of the sensitivity produced by the normal voltage, depending on whether the bridge resistance at the power supply binding posts is 1000 ohms or 10,000 ohms, respectively.

(4) 2.7 Megohm Resistor: Replacement of the link connected to the INTERNAL GUARDED POWER SUPPLY binding posts with a 2.7-megohm resistor (1/4 watt ± 20% carbon-type) reduces the sensitivity by decreasing the power supply voltage. This reduction is about 1/2700 or 1/270 of the sensitivity produced by the normal voltage, depending on whether the bridge resistance at the power supply binding posts is 1000, or 10,000 ohms, respectively.

To arrange the bridge for a specific percent deviation measurement for a selected resistance, proceed as follows:

(1) Select a resistor having a value within ± 10% of the value to be checked; connect this resistor to the X1 and X2 binding posts.

(2) Measure the value of this resistor as indicated in Section 6B.

(3) Upset the bridge balance by a known amount. Then adjust the sensitivity as indicated in Table III until the meter pointer deflects to exactly 10. This technique calibrates the meter scale to indicate deviations in percentage, parts per million, or ohms, as desired. The arbitrary calibrations of the SENSITIVITY control permit future resetting of the control to reestablish the desired calibration.

6E. Use of Bridge as Resistance Box

The decade arm of this bridge (six right-hand dials) may be used as a resistance box for settings varying from 0.01 ohm to 11,111.10 ohms.

Make sure that, for any resistance setting, the current flowing through the resistors of the decade arm does not have a value in excess of the maximum-current value listed in Table IV for the highest decade in use—that is, the highest decade set to any position except zero. For example: for a resistance setting of 9906.54 ohms, the current should not exceed 0.011 ampere; and for a resistance setting of 7.19 ohms, the current should not exceed 0.35 ampere.

TABLE IV–MAXIMUM CURRENT FLOW THROUGH DECADE RESISTORS

DECADE (Ohms-per-step)	MAXIMUM CURRENT (Amperes)	ACCURACY (%)
1000	0.011	± 0.006
100	0.035	± 0.006
10	0.110	± 0.060
1	0.350	± 0.300
0.1	1.000	± 1.000
0.01	3.500	±10.000

7. TECHNICAL INFORMATION

7A. Bridge Circuit

Dwg. L-D-822-24 is a schematic diagram of the 4737-A20 or 4737-A21 Guarded Wheatstone Bridge. Fig. 5 is a simplified diagram of the bridge circuit.

As indicated by Fig. 5, the circuit of this bridge is basically that of a conventional Wheatstone bridge. The bridge is balanced—that is, no current flows through the null detector—when the resistances of the four arms are selected so that the potentials at points 1 and 3 are equal. The unknown resistance and the bridge resistances are related by the following expression:

$$X = \frac{A}{B}R$$

where:

X = the resistance to be measured (unknown resistance),
A and B = the ratio arms, and
R = the rheostat or balancing arm.

7B. Guarding and Shielding

It is essential that the term guarding should not be confused with the term shielding. Shielding provides protection against electrostatic effects (especially prevalent in dry atmospheres). Guarding reduces the effect of leakage currents (especially prevalent in humid atmospheres).

(1) Guarding

Leakage currents across the power supply or the null detector do not adversely affect the accuracy of measurement. The only effect of these two leakage currents is a negligible decrease in sensitivity. Leakage currents across the rheostat arm shunt a maximum of 10,000 ohms and so can be much higher than leakage currents which would shunt the unknown resistance if guarding was not provided.

Dwg. L-D-822-24 shows the guard circuit as that portion of the bridge circuit enclosed within the heavy broken lines marked GUARD. This includes range multiplier switch S1, the X1 and GUARD terminals, the POWER SUPPLY ON and REVERSE keys, and all portions of power supply PS1 except the primary side of transformer T1.

The critical corner of an unguarded bridge, Fig. 6, is the high potential (X1) binding post. With the X2 binding post normally grounded, leakage from the X1 binding post to ground will directly shunt the unknown resistance. For example: If the ohmic value of the unknown resistance were 1000 megohms, the required insulation resistance from this binding post to ground would be 10^{14} ohms for negligible error due to leakage. When binding post X1 is guarded as shown in Fig. 7, leakage from the X1 binding post will shunt a maximum of 10,000 ohms in the rheostat arm. For negligible error, the shunt resistance across this arm must be at least 10^{9} ohms. This shunt resistance is obtained by the use of adequate insulating material between the guard circuit and ground.

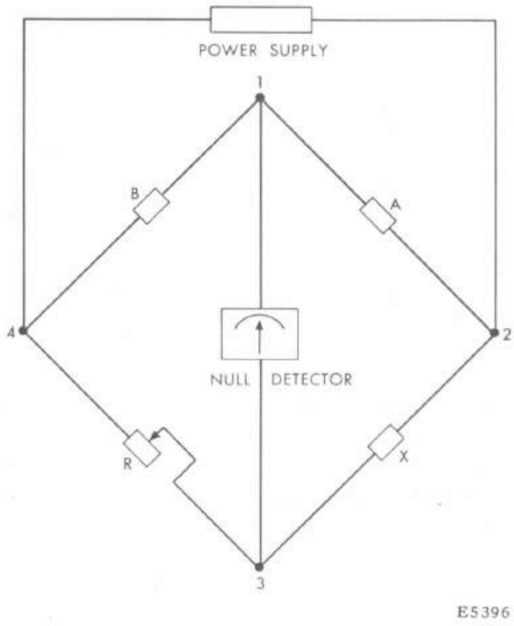


Fig. 5–Simplified diagram of bridge circuit.

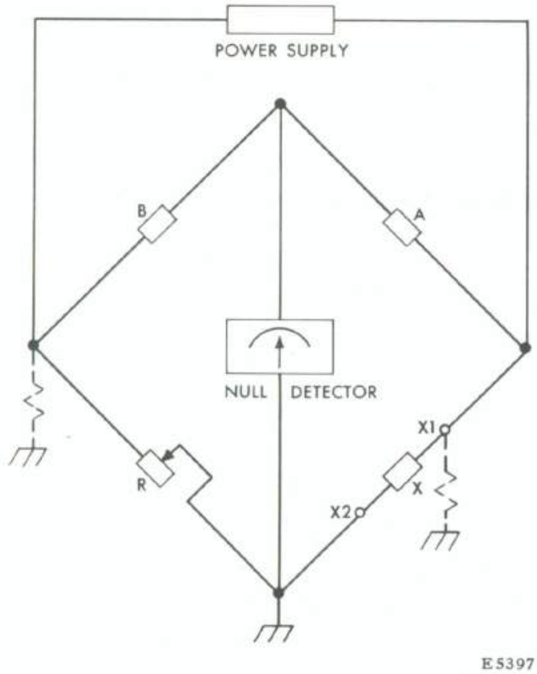


Fig. 6—Electrical leakage in bridge circuit without guarding.

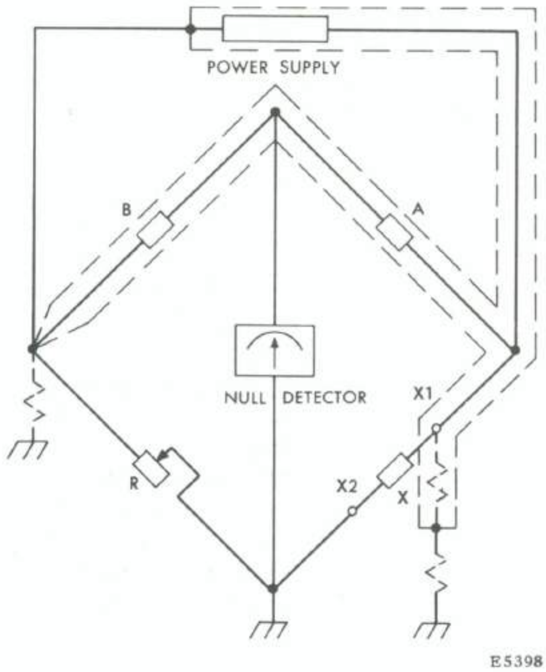


Fig. 7—Electrical leakage in bridge circuit with special guard circuit.

(2) Shielding

As indicated in Section 5C, the metal case and top panel serve as an electrostatic shield when grounded. Critical detector components and leads are furthermore shielded internally.

8. MAINTENANCE

No special maintenance is required for this bridge as long as the voltage and current ratings are not exceeded and as long as the bridge is handled with reasonable care. The top plate of a bench-type bridge should be protected with a dust cover (Part No. 095148) to prevent the accumulation of dust when the bridge is not being used.

Under normal laboratory conditions the insulating parts of the bridge binding posts will not require cleaning. If the binding posts become contaminated, clean them thoroughly with a mild detergent solution. Drying of the binding posts may be accelerated by the use of clean isopropyl alcohol.

9. CALIBRATION

The calibration procedure for checking the internal resistors of this bridge by means of the five calibration terminals, Fig. 2, is contained in Directions 177496, available on request.

10. REPLACEMENT PARTS

Various parts of the bridge that might require replacement are listed in Table V.

TABLE V–REPLACEMENT PARTS

DESCRIPTION	PART NO.
Metal Link	074062
Dust Cover	095148
Binding Post Head	002199
Key Head	042073
Key Index	048098
Dial Knob	002204
Sensitivity Control Knob	002269
Case (4737-A20)	239064
Case (4737-A21)	067933
Mounting Bracket (4737-A21)	273025

11. REPAIR SERVICE

For repair service that doesn't involve the parts listed in Table V, return the bridge to the Leeds & Northrup Company, Sumneytown Pike, North Wales, Pa. 19454.

APPENDIX

Table AI lists the bridge parameters when using the internal power supply and null detector. Table AII lists an analysis of the system errors at reference conditions.

TABLE AI–BRIDGE PARAMETERS

UNKNOWN RESISTANCE (ohms)	SETTING OF RANGE MULTIPLIER SWITCH	BRIDGE VOLTAGE FROM INTERNAL POWER SUPPLY (volts)	SENSITIVITY $\left(\frac{\Delta X}{1/8'' \text{ deflection}}\right)$	DISSIPATION IN X (milliwatts)	BRIDGE ARM WITH MAXIMUM HEATING	
					ARM*	(milliwatts)
0.1 1	10^{-1}	1 5	0.5% 600 ppm	10^{-4} 2.5×10^{-3}	R B	1 2.5
1 10	1	1 5	500 ppm 60 ppm	10^{-3} 2.5×10^{-3}	R B	1 2.5
10 100	10	1 5	50 ppm 10 ppm	10^{-2} 2.5×10^{-2}	R B	1 2.5
100 1K	10^2	2 10	3 ppm 0.7 ppm	0.4 1	R B	4 10
1K 10K	10^3	4 15	0.6 ppm 0.2 ppm	4 5.5	X, R A, B, X	4 5.5
10K 100K	10^4	10 15	0.6 ppm 0.5 ppm	10 2.2	A, X A	10 25
100K 1M	10^5	15	3 ppm 4 ppm	2.2 0.22	A	25
1M 10M	10^6	15	30 40	0.22 2.2×10^{-2}	A	25
10M 100M	10^7	50	100 125	0.25 2.5×10^{-2}	A	250
100M 1G	10^8	50	0.1% 0.15%	2.5×10^{-2} 2.5×10^{-3}	A	250
1G 10G	10^9	50	1% 1.5%	2.5×10^{-3} 2.5×10^{-4}	A	250

*Refer to Fig. 5 for identification of bridge arms.

TABLE AII—ANALYSIS OF SYSTEM ERROR

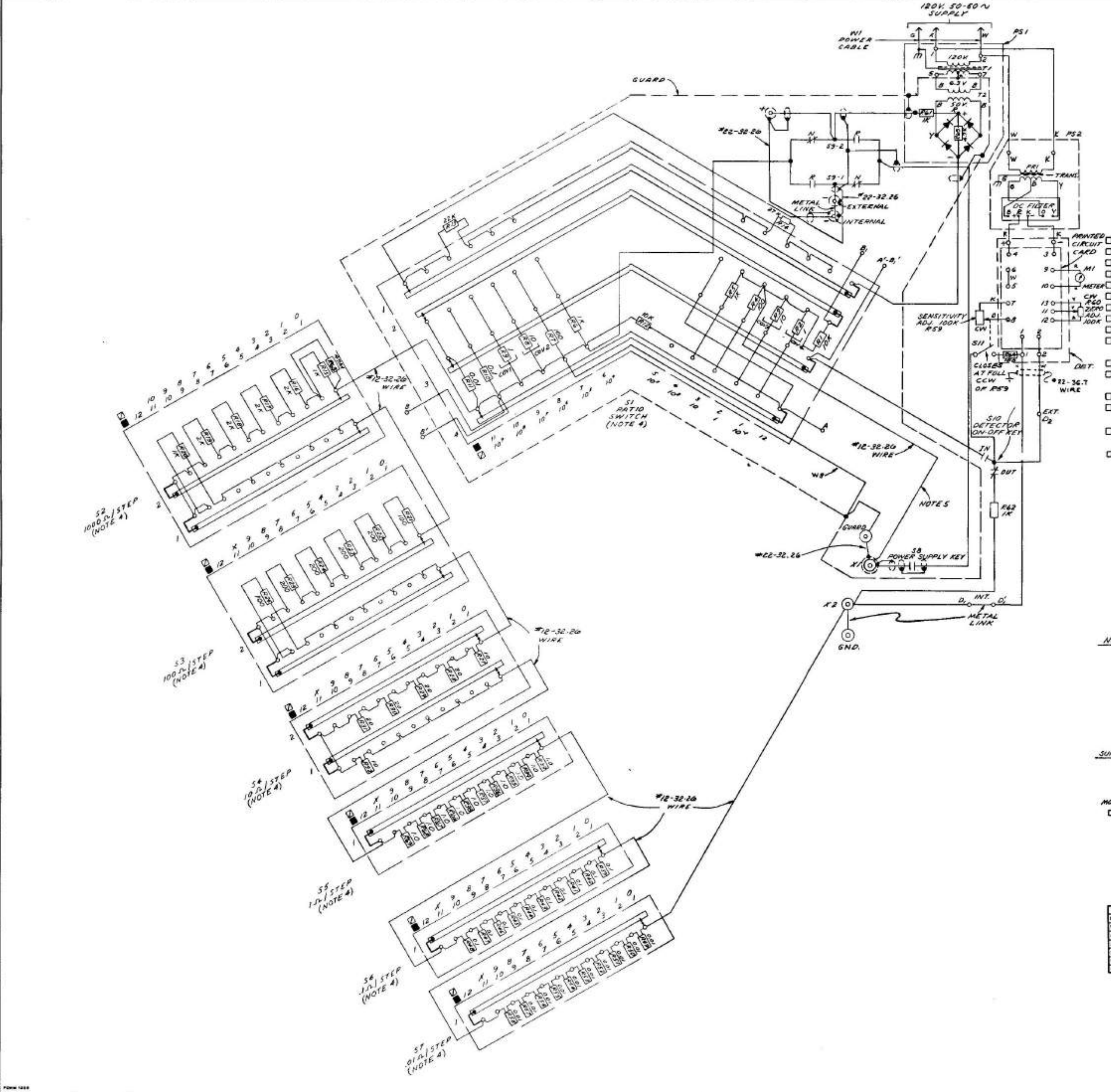
ERROR COMPONENTS*	SETTING OF RANGE MULTIPLIER SWITCH			
	10^{-1} TO 10^{6}	10^{7}	10^{8}	10^{9}
	(ppm of reading)			
Arm A	20	20	20	20
Arm B	20	50	1500***	5000***
Arm R**	30	30	30	30
Temperature Coefficient	10	10	10	10
Stability	10	10	10	10
Self Heating (at maximum rated voltage)	10	70	70	70
Binding Post Resistance (2 binding posts)	0.0002 Ω	--	--	--
Possible Error****	0.0002 Ω + 100 ppm	190 ppm	1640 ppm	5140 ppm

*The individual error components are worst-case values based on random checks. Since not every error component of every bridge is checked, the guarantee applies only to the LIMITS OF ERROR (Reference Conditions) listed in the Specifications.

**With the 1000-ohm-per-step dial set to 1 or higher.

***The resistors involved in these positions of the range multiplier switch are not adjusted closely because of the absence of accurate multi-megohm resistance standards for verification of a smaller possible error. These two positions of the range multiplier switch were checked using delta-wye transformations (refer to A.I.E.E. Transactions Paper 58-556).

****The sensitivity of a bridge using the internal power supply and null detector is sufficient to detect changes having magnitudes smaller than or equal to the magnitude of these possible errors.



PARTS LIST				
SYMBOL	DESCRIPTION	PART NO.		REMARKS
R1, R12	10 K, ± 20 PPM ¼ W RESISTOR	310558		
R2, R9	1, -0.1 TO -0.2%	310569		
R3, R8	10, -0.03 TO -0.06%	310564		
R4, R7	100, ± 10/60 PPM	310570		PART OF 031473
R5, R6	1K, ± 20 PPM	310560		
R10	0.1, 0 TO -2%	010192	10-13-13-2	
R11	0.01, 0 TO -10% ¼ W	310568		
R13	22 K, ± 10% ½ W	011160	11-1-0-60	
R14	27K, ± 10% ½ W	011161	11-1-0-61	
R15, R20	1K, ± 20 PPM ¼ W	310560		PART OF 031468
R16 TO R19	2K, ± 20 PPM	310559		
R21, R26	100, ± 10/60 PPM	310570		PART OF 031477
R22 TO R25	200, ± 20 PPM	310571		
R27, R32	10, ± 0.01 %	310565		PART OF 031470
R28 TO R31	20, ± 0.01 %	310563		
R33 TO R38	1.0, ± 0.05 %	310728		PART OF 031475
R66 TO R68	1.0 ± 0.05 %	310728		
R39 TO R48	0.1, 0 TO -2%	010192	10-13-13-2	PART OF 031472
R49 TO R58	0.01, ± 10% ¼W RESISTOR	310575		PART OF 031467
S1	11 POSITION, 4 POLE SWITCH	031473		
S2	2	031468		
S3	2	031477		
S4	2	031470		
S5	1	031475		
S6	1	031472		
S7	11 POSITION, 1 POLE	031467		
S8	S.P.S.T. GUARDED	031166		
S9	D.P.D.T. GUARDED	031165		
S10	S.P.D.T. GUARDED SWITCH	031619		
S11	DETECTOR SENSITIVITY SWITCH			PART OF 013460
PS1	POWER SUPPLY	099086		
PS2	" "	099087		
W1	POWER CABLE	237350		PART OF 316059
R59	SENSITIVITY ADJ. 100K	013460		
R60	ZERO ADJ. 100 K	013460		
R61	1K ± 5% 3W RESISTOR	011855		PART OF 099086
M1	METER	021156		
R62	1 K ± 10% ¼ W RESISTOR	011934		
W2	CABLE	237588		
W3	WIRE (#22-32.43-D), WHITE	037558		
R63	47M ± 20% ½ W RESISTOR	011201		PART OF 031468

LEGEND

- ☒ INDICATES DIAL MARKINGS.
- ■ INDICATES SWITCH POSITIONS.
- ☐ INDICATES PARTS CALLED FOR ON MECHANICAL ASSEMBLY.
- ⓞ INDICATES FRONT PANEL TERMINAL.
- o INDICATES REAR PANEL TERMINAL.
- ◎ INDICATES GUARDED FRONT PANEL TERMINAL.
- ⊙ INDICATES GUARDED REAR PANEL TERMINAL.
- ⏀ INDICATES SHIELDED WIRE (#22-35.15)

NOTES:

1. ALL RESISTANCE IS IN OHMS.
2. HEAVY LINES INDICATE SWITCH INTERNAL WIRING.
3. USE #22-32.43-SERIES WIRE EXCEPT WHERE OTHERWISE SPECIFIED.
4. WAFER #1 OF ALL SWITCHES IS NEAREST PANEL.
5. AIR INSULATED, DO NOT SUPPORT EXCEPT AT ENDS.

SUPPLY WITH INSTRUMENT

1 DIRECTION BOOK 177472

1 DIRECTION BOOK 177416

MOD					
	COV1 TO COV4	COVER FOR RESISTOR	067741		
☐	DET	DETECTOR	101199		
	R64	100 ± 10%, ½W RESISTOR	011132		
	R65	4.7 ± 10%, ½W RESISTOR	011152		PART OF 099086

COLOR CODE	
K - BLACK	Y - YELLOW
W - WHITE	A - GRAY
G - GREEN	V - VIOLET
R - RED	P - PINK
B - BLUE	S - SLATE
N - BROWN	T - TAN
O - ORANGE	

NO.	DATE	AUTH	REVISIONS
3	[illegible]	C.B.	B8899
2	[illegible]	C.B.	B8863
1	[illegible]	C.B.	B7030

SCHEMATIC WIRING FOR CAT. # 4737-A 20 & A 21 WHEATSTONE BRIDGE

DRAWN PRZASNYSKI | CHECKED DC | APPROVED PJC

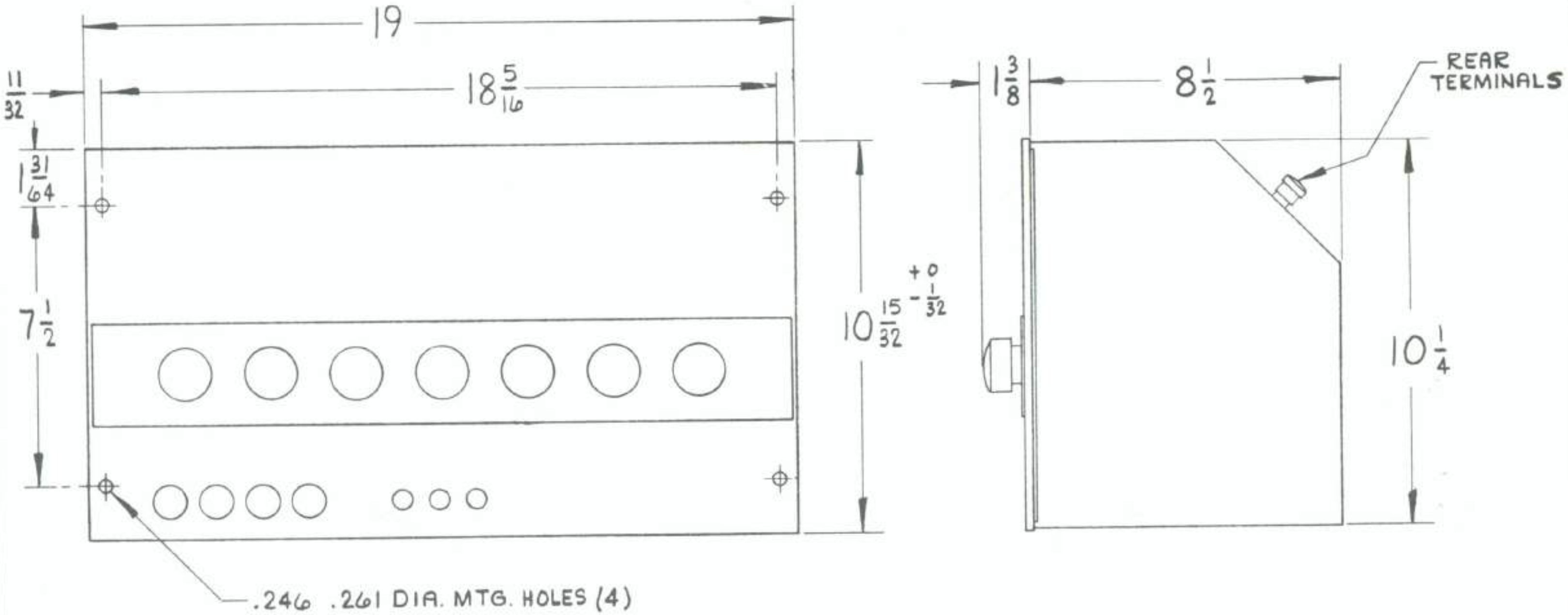
DESIGNED DC | DESIGN APPROVED | DATE 3-15-67

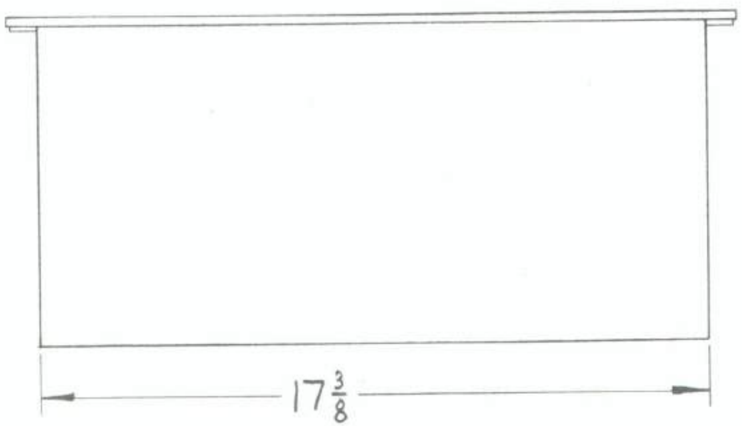
FIRST MADE FOR L&N ORDER NO. LN

DWG. NO. L-D-822-24

LEEDS & NORTHRUP CO.

FORM 1259





NO.	DATE	APPD.	REVISIONS

OUTLINE & DIMENSION DWG.
CAT. 4737-1 & 4737-A21
RELAY RACK MTD. WHEATSTONE BRIDGE

DRAWN 11-24-67 T. MOREE | CHECKED C. Bell | APPROVED C. Bell
DESIGNED | DESIGN APPROVED | DATE 11-24-67

FIRST MADE FOR L&N ORDER NO. LN

DWG. NO. A-DIM-822-25

LEEDS & NORTHRUP CO.
PHILADELPHIA, PA., U.S.A.

REFERENCE: CAT. 4737-1 ASSEMBLY – H-822-34
CAT. 4737-A 21 ASSEMBLY – H-822-25

UNLESS OTHERWISE STATED ALL DIMENSIONS IN INCHES
TOL. ON DECIMAL DIM. ±.005"
TOL. ON OTHER DIM. ±.010"

SCALE 1/4" = 1.0"
DO NOT SCALE DWG.

FORM 1316