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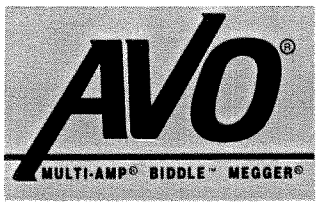
Instruction Manual
AVTM 72-439Ja

For the

Portable, High Precision Kelvin Bridge

Catalog No. 72-439



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ILLUSTRATIONS

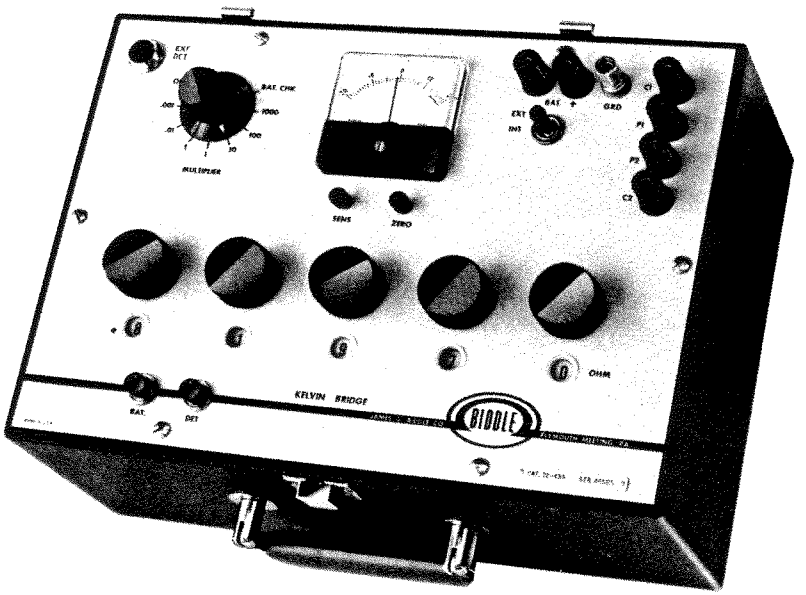


Figure 1: The Cat. No. 72-439 Five-Dial Kelvin Bridge.

Section A

INTRODUCTION

The Catalog No. 72-439 instrument is a direct reading, high-precision, 5-dial Kelvin Bridge designed for wide range low resistance measurements in the laboratory, field and production line. The circuit is of the Kelvin Bridge form which permits four-terminal measurement of resistance elements thereby eliminating lead and contact resistance errors that occur in the use of a conventional Wheatstone Bridge when measuring low resistance.

The bridge is fully self-contained being equipped with its own batteries and solid state null detector. It includes individual battery and detector push keys for control of circuit closure sequence and has four binding posts for connection of the unknown resistance, an auxiliary pair of binding posts for connection of an external battery, and a receptacle for connection of an external null detector.

Applications include the measurement of electrical conductivity and temperature coefficient of wires and rods; checking the quality of welds in copper or aluminum bus bars; the checking and calibration of low-value resistance standards, current carrying shunts and power type resistors; the measurement of switch and relay contact resistance; and the measurement of the resistance, as well as change in resistance as an index of temperature rise, of the windings of motors, generators and transformers.

The top panel view of the Kelvin Bridge shown in Figure 2 locates and identifies the top panel components and controls.

Section B

SAFETY PRECAUTIONS

The Catalog No. 72-439 operates solely from dry batteries of low voltage and, therefore, meets the classification of "extra-low energy source" (ANSI C39.5-1974), "Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation", Para. 3. It does not present a shock hazard in itself, but as with all electrical equipment, safety rules must be observed. Particular care should be taken that wires carrying high voltages or power are not connected to the instrument binding posts. Such connections can cause shock hazard to the operator and damage the instrument.

RECEIVING INSTRUCTIONS

Your Kelvin Bridge has been thoroughly tested and inspected to rigid inspection specifications before being shipped and is ready for use when received. Check the equipment received against the packing list. Notify Biddle Instruments, Blue Bell, Pa. of any shortage of materials. The instrument should be examined for damage received in transit. If any damage is found, file a claim with the carrier at once and notify Biddle Instruments or its nearest sales representative giving a detailed description of the damages observed.

Section C
SPECIFICATIONS

A. Range:

0.01 microhm to 1111.1 ohms in 7 ranges.

B. Limit of Error:

±(0.03% of reading + 0.03 microhm).

C. Measuring Dial:

The measuring circuit consists of two fixed arms and two adjustable arms which form the ratio arms of the bridge. The two arms are mechanically linked so that they can be adjusted simultaneously. The measuring dial consists of 5 decades giving resistance steps equivalent to 10 (0.1 + 0.01 + 0.001 + 0.0001 + 0.00001) ohm, for a total range of 1.1111 ohms in steps of 0.00001 ohm.

D. Multiplier Dial:

A nine-position rotary switch (item 6, Figure 2) permits selection of the following multipliers and functions:

1. OFF: Connects a short circuit across the meter, disconnects the amplifier and batteries.

2. .001, .01, .1, 1, 10, 100 and 1000: Seven positions for selecting the resistance multiplier value. These positions contain the fixed standard resistances of the bridge circuit and provide automatic current limiting for each setting of the multiplier dial.

3. Battery Check: Sets instrument to indicate state of charge of the measuring circuit battery directly on the meter.

E. Detector:

The null detector consists of a rugged zero center meter (item 7, Figure 2) and a solid state high gain differential amplifier which drives the meter. The characteristics are as follows:

SPECIFICATIONS (Cont'd.)

1. Sensitivity: 0.5 microvolt (approximately 1/2 division).

2. Input resistance: 5000 ohms

3. Noise (0.1Hz to 10 Hz): Less than 1 μV peak-to-peak.

4. Resolution: Sufficient to detect the following resistance changes:

   0.0001 ohm or less - 0.05 μΩ
   at 0.001 ohm - 0.01%
   0.01 ohm to 1111 ohms - 0.005% with first measuring dial at step 1, improving to 0.001% with 5 measuring dials at maximum setting.

5. Drift: Typically less than 1.0 μV per hour at constant ambient temperature after 30-minute warm-up.

6. Response Time: Less than 1.2 seconds.

7. Overload: 35 V dc continuous without permanent damage.

8. Zero Control: Provides minimum adjustment of ±100 μV to compensate for thermal and drift voltages.

9. Sensitivity Control: Continuously adjustable from full sensitivity to at least 40:1 reduction of sensitivity. This permits calibration of the detector meter when using the instrument as a limit bridge for production testing.

F. External Detector:

Resistance resolution is improved to 0.01 microhm for measurements below 0.0011 ohm when bridge is used with an external null detector having a sensitivity of ±1 microvolt full scale.

G. Meter:

2-1/2" with rugged Taut-Band suspension. The meter will withstand 50 g shock. The scale has 40 divisions and is zero center.

SPECIFICATIONS (Cont'd.)

H. Binding Posts and Connector:

Seven 5-way binding posts (item 9, Figure 2) with standard 3/4" spacing. Four provided for connection of unknown resistance, two for connection of optional external battery and one for case ground. A receptacle is provided for connection of an optional external null detector.

I. Keys:

Separate battery and detector keys (items 1 and 2, Figure 2) are provided to permit choice of circuit closure sequence. Both keys can be locked down when desired. An additional lever switch (item 8, Figure 2) is provided for selection of internal or external battery.

J. Leads:

A pair of black leads (Part No. 1693-60) is furnished with each instrument for use as potential leads. Each lead has a length of 5 ft., is provided with tellurium copper, gold-plated spade lugs at both ends and has a resistance of 0.008 ohm.

K. Battery Requirements:

1. Measuring circuit: Two 1-1/2 volt No. 6 dry cells (NEDA 906) connected in parallel. Normal battery life for resistance measurements above 0.01 ohm is in excess of 200 hours (10 weeks at 20 hours per week). For resistance measurements below 0.01 ohm battery life decreases.

2. Null Detector: Two 9V Carbon Zinc batteries - Burgess 2U6 or Eveready 216 (NEDA 1604). Battery life is approximately 430 hours.

L. External Battery:

The use of an external 2-volt storage battery (or several 1-1/2 volt No. 6 dry cells connected in parallel) is recommended for prolonged resistance measurements below 0.01 ohm in order to avoid frequent dry cell replacement.

SPECIFICATIONS (Cont'd.)

M. Enclosure:

The top panel is aluminum with off-white enamel finish. The case, with lid and carrying handle, is aluminum with charcoal gray texture finish.

Dimensions: 13" x 9-1/4" x 7" high, (33 x 23.5 x 17.8 cm)

Weight: 15 lbs., (6.8 kg.)

N. Accessories:

1. Catalog No. 241005-5 Kelvin Clip Leads:
   Composed of specially designed alligator clips having gold-plated jaws insulated from each other. Jaws open to 1/2". The leads are 4 ft. long with spade lugs for connecting to the Bridge.

2. Part No. 13098 Shielded Cable Assembly:
   Used for connecting Bridge to Keithley 155 Null Detector.

Section D
DESCRIPTION

A. General:

The schematic diagram of the Catalog No. 72-439 Kelvin Bridge is shown in Figure 3. The measuring circuit consists of two fixed arms (B and b) and two mechanically-linked adjustable arms (A and a) which form the ratio arms of the Kelvin Bridge, plus a multiple step standard arm S. The adjustable ratio arm (measuring dial) consists of 5 decade giving resistance steps equivalent to 10 (0.1 + 0.01 + 0.001 + 0.0001 + 0.00001) ohms, for a total range of 1.1111 ohms in steps of 0.00001 ohm. The multiplier switch selects the seven fixed standard resistances of the bridge circuit and its dial is marked to provide equivalent multiplier values of .001, .01, .1, 1, 10, 100 and 1000. The multiplier switch also automatically selects the proper current limiting resistor which is in series with the fixed standard resistor, and thus prevents damage to the bridge by overheating. The contact resistance of the multiplier switch is in series with the 10K ohm resistor of the main ratio arm (B) and has negligible effect on accuracy. The unknown resistance, which is connected to the C1, P1, P2 and C2 binding posts, is measured in ohms at the balanced condition of the bridge.

B. Connections:

1. Unknown Resistance:

The schematic diagram, Figure 3, illustrates the bridge circuit and external connections to the bridge. The unknown resistor, designated by X, must be measured as a four-terminal resistor, that is, it must contain two current terminals and two potential terminals or branch points.

a. Connect the two current terminals of the X resistor (C1 and C2) to the corresponding C1 and C2 binding posts of the Bridge.

NOTE: The lead connecting C1 of the X resistor to the C1 binding post of the Bridge should be a heavy copper wire or strap and should be as short and low in resistance as possible, as this lead is part of the yoke. Increases in the yoke

resistance causes more current to pass through the yoke (auxiliary) ratio arm resistors and may cause a slight increase in the bridge error. If the ratios of the two arms (main and auxiliary) were identical, the resistance of the yoke would make no difference.

However, there are slight unavoidable differences in the adjustment of the ratios of the two arms and this is accentuated as the value of measured resistance decreases, since any appreciable current in the auxiliary ratio arm resistors then becomes more significant. The C2 connecting lead may be any convenient wire size with sufficient current carrying capacity. Refer to Table 1 for test current for each multiplier setting.

b. Connect the two potential terminals of the X resistor (P1 and P2) to the corresponding P1 and P2 binding posts of the Bridge using the potential leads furnished with the bridge.

NOTE: The potential leads L1 and L2 which are used to connect the X resistor to the bridge are not true potential connections as they carry very small currents even when the bridge is at null balance. The resistance of these leads as well as the connection resistance becomes a part of the resistance of the ratio resistors in series with them (refer to Figure 3). This bridge is calibrated for use with the 5 ft. Potential Leads furnished with the bridge, and use of these leads will result in negligible potential lead resistance error over the entire measurement range.

2. External Battery:

If use of an external battery is desired, connect the battery to the BAT. binding posts of the Bridge observing proper polarity. Refer to Section C-K for recommended external battery.

3. External Detector:

If use of an external detector is desired, connect the detector to the EXT DET receptacle of the Bridge using Biddle Part No. 13098 Shielded Cable Assembly. The cable assembly has a length

of 5 feet, is provided with tellurium copper, gold plated spade lugs at one end, and with Amphenol Part No. 80-MC2M plug at the other end. For best results, connect pin 2 (red wire of cable assembly) to terminal of detector which is most highly insulated from chassis.

4. Grounding:

For best results, connect the GRD binding post of the Bridge to a good earth ground.

Section E

OPERATION

A. General:

The instrument can be operated in any position and is relatively free from the effects of vibration.

B. Test Current:

Table 1 indicates the test current through the unknown resistance and bridge for each setting of the MULTIPLIER dial as well as the maximum continuous current rating. The test current is based on using the internal battery or an external 1-1/2 volt battery.

TABLE 1

RESISTANCE RANGE "X" OHMS	MULTIPLIER SETTING	TEST CURRENT (AMPS)	MAXIMUM CURRENT (AMPS)
0 to 0.00111	.001	3.4	5
0.001 to 0.0111	.01	1.5	2.2
0.01 to 0.111	.1	.5	.8
0.1 to 1.11	1	.1	.2
1 to 11.1	10	.015	.06
10 to 111	100	.0015	.02
100 to 1111.1	1000	.00015	.006

NOTE: If the external battery voltage exceeds two volts or if it is desired to reduce the test current to a value less than that stated in column 3, it will be necessary to connect a current limiting rheostat and ammeter in series with the external battery to adjust the bridge current to the desired value.

C. Meter Zero Adjustment:

1. Rotate the MULTIPLIER switch to the OFF position and adjust the meter to the mechanical "0" of its scale, if required, by rotating the slotted head screw on the meter cover.

2. Rotate the MULTIPLIER switch to the .001, .01, or .1 position (for maximum resolution), the SENS control to the extreme clockwise position (maximum sensitivity), then rotate the ZERO control until the meter pointer indicates "0".

NOTE: When the pointer cannot be adjusted to "0" or the detector sensitivity is significantly less than that stated in Section C-E replace the amplifier batteries.

D. Battery Check:

Check the state of charge on the measuring circuit battery prior to making measurements. Proceed as follows:

1. Adjust the meter to the mechanical "0" of its scale, if required, as described in Section E-C.

2. Rotate the MULTIPLIER Switch to the BAT. CHK position.

3. Depress the BAT. key and note the meter deflection. A new battery (nominal 1.5 volts) will cause the meter pointer to deflect to the right at least full scale. If the meter pointer deflects in the section marked by the green line, the battery has sufficient charge, whereas, if the deflection is below the green line (equivalent to 14 divisions or 1.05 volts) the measuring circuit battery should be replaced as this is the approximate service life end point.

NOTE: The SENS and ZERO controls as well as the DET key are not in the circuit when in the BAT. CHK position.

E. Measuring a Resistance:

To measure a resistance, proceed as follows:

1. Connect the Unknown Resistance (X) to the Kelvin Bridge as described in Section D-B.

2. If an external battery or null detector is to be used, connect as described in Section D-B.

3. Set the BAT. lever switch to the INT (internal) position. If an external battery is to be used set this switch to the EXT (external) position.

4. Adjust the meter to "0" of its scale as described in Section E-C.

5. Rotate the MULTIPLIER dial to the desired resistance range. If the approximate value of X resistance is unknown select the 1000 multiplier setting.

   NOTE: This dial is marked so that each multiplier value is also equivalent to the maximum resistance range with the measuring dials at their maximum setting (excluding the 10% over-range).

6. Rotate the measuring dials to the maximum resistance setting (1.1111 ohms).

   NOTE: The tenth switch position is represented by the Roman Numeral X. This numeral is used in preference to the number 10 to simplify the recording of data. When an X appears in the window consider the setting of that dial to be 0 and add 1 to the preceding digit.

7. Depress the BAT. key, then the DET key and note the meter deflection. If the deflection is to the right, the bridge dial settings are too high; if to the left, too low.

8. Increase or decrease the setting of the multiplier dial as dictated by Step 7, one step at a time, until the meter deflection reverses, then set the multiplier dial to the higher value position where reversal occurs.

9. Adjust the bridge measuring dials for null meter deflection, starting with the highest value dial.

10. Lock down the DET key and re-adjust the last measuring dial, if necessary, for null meter deflection while depressing and releasing the BAT. key.

    NOTE:

    a. For precise resistance measurements, with minimum thermal emf errors, it is recommended the meter be adjusted to

"0" of its scale when connected directly across the bridge circuit under measurement conditions, approximate bridge balance, full detector sensitivity, with the DET key depressed, and with the BAT. key in the open position.

b. Some users may find it convenient to reduce detector sensitivity during preliminary balancing until operating experience is acquired. After balance is achieved, adjust the SENS control to obtain optimum detector sensitivity or to calibrate the meter deflection in terms of ohms deviation from nominal. Clockwise rotation of the SENS control increases sensitivity; counterclockwise rotation decreases sensitivity.

c. If excessive noise is encountered in the null detector due to electrostatic pick-up, connect the bridge to a good earth ground.

d. If the unknown resistance is inductive, it may be necessary to depress the BAT. key for a short time before depressing the DET key. This procedure will permit stabilization of the current, facilitating bridge balancing, and will avoid an inductive "kick" in the meter. In releasing the keys, always release the DET key first.

e. When an external detector is connected to the bridge it is in parallel with the internal detector. Normally, no interaction will occur, however, if it does, it can be eliminated by removing the two batteries of the interal detector.

11. Read the value of measured resistance in ohms, by taking the sum of the measuring dial switches and then multiplying by the setting of the multiplier dial.

NOTE: If the measuring dial reading is less than 0.1111 ohm, excluding the lowest resistance range, the resistance can be measured with higher accuracy by using the next lower multiplier setting.

F. Use of Bridge for 2-Terminal Resistance Measurements:

The bridge may be used for 2-terminal resistance measurements when the value of the unknown resistance is above 20 ohms, since the contact resistance at the X binding posts will have a relatively insignificant effect upon the measurement accuracy. Short circuit the C1 - P1 binding posts and also C2 - P2 binding posts with a heavy copper wire or strap then proceed to balance the bridge as described in Section E-E.

NOTE:

1. The unknown 2-terminal resistance measurement is between the P1 and P2 binding posts.

2. Do not use the potential leads supplied with the bridge.

3. The decrease in bridge accuracy should not exceed 0.01%.

Section F
MAINTENANCE

A. General:

With normal use the only maintenance required will be replacement of the batteries and an occasional cleaning of the push keys after long periods of disuse. Instruments having only periodic use should have their measuring dials rotated several times over their full travel previous to making a measurement.

B. Removal of Bridge From Case:

1. Remove the six panel screws.

2. Carefully lift the instrument from the case then disconnect the three-lead cable at the batteries, if necessary.

3. Replace the bridge in the case by reversing the procedure described above.

C. Battery Replacement:

Replace the measuring circuit battery when the meter pointer deflection is below the green line (less than 14 divisions) when checking the battery as described in Section E-D.

Replace the null detector batteries when the meter pointer cannot be adjusted to "0" as described in Section E-C. The battery compartment for the measuring circuit is in the bottom of the instrument. Remove the panel assembly from the case as described above in "B".

The battery requirements and their connections are as follows:

1. Measuring Circuit: Two 1-1/2 volt, #6 dry Cells (NEDA 906) connected in parallel. Red lead connection to positive (+) terminal of either battery. Red jumper lead from positive (+) terminal of one battery to positive (+) terminal of second battery. White/Black lead connection to negative (-) terminal of one battery. Remaining White/Black lead connection to negative (-) terminal of second battery. Refer to Figure 3.

2. Null Detector: Two 9V Carbon Zinc batteries, Burgess 2U6 or Eveready 216 (NEDA 1604).

NOTE: Incorrect installation of the null detector batteries, defective batteries, or failure to make contact with the battery holders will cause the meter pointer to deflect violently off scale or result in failure of the pointer to move when the ZERO control is rotated with the Multiplier Selector Switch set at any of the seven multiplier positions.

D. Push Keys:

Failure of the push keys to make contact will be indicated by the failure of the meter pointer to deflect when an unbalance is known to exist.

Key contacts may be cleaned by inserting a thin strip of bond paper or business card between the contacts and applying pressure to the contacts by depressing or releasing the key button as required while withdrawing the paper. Repeat three or four times, or as necessary.

E. Amplifier Assembly:

No maintenance of the amplifier assembly is required under normal use, due to its solid-state construction, other than battery replacement which is described in Section F-C. After several years, however, it may be necessary to re-adjust the amplifier zero balance circuit to compensate for long term drift voltages beyond the range of the ZERO control. If the meter cannot be adjusted to "0" of its scale as described in Section E-C proceed as follows:

1. Remove the Bridge from the case as described in Section F-B.
2. Short circuit the P_1 - P_2 binding posts with a piece of copper wire.
3. Rotate the Multiplier dial to the X0.1 position.
4. Rotate the first Measuring dial to the X position.
5. Rotate the SENS control to the extreme clockwise position (maximum sensitivity).

6. Set the ZERO control to its approximate mechanical center position and adjust amplifier trimmer R12 to bring the meter pointer to "0".
7. Depress the DET key and observe any change in the meter pointer deflection. If the change exceed 1/4 division adjust amplifier trimmer R11 to bring the pointer to "0".

   NOTE: The R11 and R12 adjusting screws are accessible through openings in the amplifier shield box.

   There is some interaction between the adjustments of the R12 and R11 trimmers; therefore, after making any changes in the setting of R11 always reset the meter pointer to exact "0" using the ZERO control, with the DET key released.
8. Repeat Step 7 until the meter pointer change is less than 1/4 division.

On rare occasions gross long-term drift may occur which cannot be corrected by the above procedure because the range of R12 is not great enough. In such cases the total resistance of R5, R6 must be modified to make the correction possible. If the meter pointer remains to the right side of "0" when R12 is completely counter-clockwise, the total resistance of R5, R6 must be reduced. If the meter pointer remains to the left side of "0" when R12 is completely clockwise, the total resistance of R5, R6 must be increased. Changes of resistance should be made in increments of 50K ohms. (50K ohms is equal to 1/2 of the span of trimmer R12).

After correcting the total of R5, R6 so that R12 is effective, repeat the above adjustment procedure.

NOTE: Locations of resistors R5 and R6 are marked on the reverse side of the PC board. Use metal film resistors when replacing R5 or R6.

Remove the 2 screws which hold the amplifier assembly in place to gain access to the PC board assembly. When replacing the assembly make sure the PC board is seated on the two bent up edges of the shield base and all access wires are brought out at the corners

of the assembly. Also make sure the trimmers and access holes face the top of the panel.

F. Meter Replacement:

Meter failure usually occurs by suspension breakage due to a severe shock. It is indicated by the failure of the meter pointer to deflect when an unbalance is known to exist. To detect, rotate the Multiplier Switch to the OFF position, then impart a slight rotational motion to the instrument in a plane parallel to the panel. If the suspension is broken, the pointer will not swing.

To replace the meter proceed as follows:

1. Remove the bridge from the case as described in Section F-B.

2. Remove the two screws which hold the amplifier assembly in place then carefully roll back the assembly away from the meter.

3. Remove the two nuts which hold the amplifier base bracket in place then carefully remove the bracket, wire and washers.

4. Remove the four nuts which hold the meter in place, then lift the meter out of the panel.

5. Remove the piece of wire (short) from the terminals of the new meter and install the meter and amplifier assembly by reversing the procedure described above.

   NOTE:

   a. Install the insulated washer and sleeve on the positive (+) meter terminal with the amplifier base bracket sandwiched between the meter housing and insulated washer, then mount the lug of the white/gray wire on top of the insulated washer. Install the metal washer on the minus (-) meter terminal.

   b. The amplifier base bracket must make electrical contact with the negative (-) meter terminal and must be insulated

from the positive (+) meter terminal. The amplifier printed circuit card must also make electrical contact with the base bracket.

6. Replace the bridge in the case by reversing procedure described in Section F-B.

G. Measuring Circuit:

Calibration and repair of the measuring circuit should only be attempted in the laboratory under controlled conditions. For those operations not described above, or the replacement of parts not listed in Section G, it is recommended that the instrument be returned to the factory.

H. Calibration:

1. General:

The calibration check should be performed in a laboratory free from drafts and where temperature is stable and maintained at $25^{0}C \pm 2^{0}C$. The Bridge should be placed in the calibration room 8 hours prior to the calibration check to allow normalization to room temperature.

If maximum accuracy and resolution is desired over the entire resistance range of the Bridge, it is recommended that the Bridge be used with an external null detector having a sensitivity of ±1 microvolt full scale.

Check the state of charge on the measuring circuit battery, as described in Section E-D, and check the internal detector for proper zero adjustment as described in Section E-C before attempting to make any calibration checks.

A complete overall accuracy check should be performed before attempting to readjust any of the Bridge precision resistors.

2. Equipment Recommended:

   a. Precision Resistance Standards:

   .0001Ω Reichsanstalt Resistor, J.G.B. Cat. No. 71-641.
   .001 Ω Reichsanstalt Resistor, J.G.B. Cat. No. 71-639.
   .01 Ω Reichsanstalt Resistor, J.G.B. Cat. No. 71-637.
   .1 Ω Reichsanstalt Resistor, J.G.B. Cat. No. 71-635.
   1 Ω NBS Resistor, J.G.B. Cat. No. 71-6311.
   10 Ω NBS Resistor, J.G.B. Cat. No. 71-6313.
   100 Ω NBS Resistor, J.G.B. Cat. No. 71-6315.
   1K Ω NBS Resistor, J.G.B. Cat. No. 71-6317.

   b. Keithley Null Detector, Model 155 or equivalent, sensitivity of 1 μV full scale.

   c. Shielded cable assembly (P/N 13098) for connecting Bridge to Keithley 155 Null Detector.

3. Overall Accuracy Check:

   a. Connect the C_1 and C_2 binding posts of the Cat. No. 72-439 Bridge to the Current Terminals of the desired Resistance Standard using heavy copper straps which have a resistance of less than 500 microhms.

   b. Connect the P_1 and P_2 binding posts of the Cat. No. 72-439 Bridge to the Potential Terminals of the Resistance Standard using the two 5-foot long potential leads (P/N 11966) furnished with Bridge. Observe the connection polarity as shown in Figure 3.

   c. Connect the external Null Detector, if used, to the Bridge EXT DET receptacle. When using an external Detector rotate the internal detector sensitivity control to its fully counterclockwise position.

   d. Obtain a resistance reading on the Cat. No. 72-439 for each multiplier range, using the appropriate standard resistor and measuring dial setting as indicated below.

Multiplier Setting	Resistance Standard	Measuring Dial Setting		Limit of Error (%)
		1st	2nd	
.001	.0001Ω	1	0	±0.03%
.001	.001 Ω	X	0	±0.03%
.01	.001 Ω	1	0	±0.03%
.01	.01 Ω	X	0	±0.03%
.1	.01 Ω	1	0	±0.03%
.1	.1 Ω	X	0	±0.03%
1.	.1 Ω	1	0	±0.03%
1.	1. Ω	X	0	±0.03%
1.	1. Ω	9	X	±0.03%
1.	1. Ω	9	9 X	±0.03%
1.	1. Ω	9	9 9X	±0.03%
1.	1. Ω	9	9 99X	±0.03%
10	1. Ω	1	0	±0.03%
10	10. Ω	X	0	±0.03%
100	10. Ω	1	0	±0.03%
100	100. Ω	X	0	±0.03%
1000	100. Ω	1	0	±0.03%
1000	1K Ω	X	0	±0.03%

Section G

REPLACEMENT PARTS LIST

JGB PART NO.	QUANTITY PER INSTRUMENT	DESCRIPTION
72-439J	1	Instruction Manual
11884	1	Case
13093	1	Panel
11912	1	Sub Panel
11964-1	1	Bracket, Battery Holdown, Case Bottom
16643	1	Label, Battery Check
11166-2	6	Binding Posts, Insulated (Superior #DF31BC)
11166-4	1	Binding Post, Ground (Superior #GP30NC)
11883	1	Meter
7184	1	Knob, Multiplier Dial (Raytheon #90-3-2 with pointer)
7184-1	5	Knob, Measuring Dial (Raytheon #125-2-2)
11868	2	Knob, Zero & Sens, (Stockwell Rubber #LC9250-1)
11360	3	Window, Dial 1, 3 & 5
11360-1	2	Window, Dial 2 & 4
11754	5	Retainer, Window
11965	1	Push Key, Det
11357-4	1	Push Key, Bat
11186-4	1	Lever Key, Internal-External Battery
13096-1	1	Receptacle, Ext. Det.
13097	1	Receptacle Cap (Niagara Plastics #C6)
11383-10	1	Potentiometer, Zero Control
11507-12	1	Potentiometer, Sens Control
11358-1	5	Dial Assembly, O-X Bottom Index
13218-3	1	Amplifier P-C Board Assembly
13390	1	Amplifier Shield Box
11974	1	Bottom Plate, Amplifier Box
11975	1	Insulating Sleeve, Amplifier Mounting
11035-1	1	Insulating Washer, Amplifier Mounting
7470-3	1	Ring Terminal, Amplifier Mounting
13354	2	Snap-Terminal Connector, 9V Amplifier Battery

REPLACEMENT PARTS LIST (Cont'd.)

JGB PART NO.	QUANTITY PER INSTRUMENT	DESCRIPTION
13356	2	Retainer, 9V Amplifier Battery
12074-21	1	Zener Diode, 12V, IN4960
13090-1	1	Resistor - Switch Assembly (Dial 1)
13090-2	1	Resistor - Switch Assembly (Dial 2)
13090-3	1	Resistor - Switch Assembly (Dial 3)
13095-1	1	Resistor - Switch Assembly (Dial 4)
13095-2	1	Resistor - Switch Assembly (Dial 5)
13094	1	Resistor - Switch Assembly (Multiplier)
10000-174	12	Resistor, 400 Ohms (R1 to R12)
10000-45	12	Resistor, 40 Ohms (R13 to R24)
10000-51	12	Resistor, 4 Ohms (R25 to R36)
10018-11	2	Resistor, String of Five 0.4 Ohm (R37 to R41 & R43 to R47)
10010-21	2	Resistor, 0.4 Ohm (R42 & R48)
10018-10	2	Resistor, String of Five 0.04 Ohm (R49 to R53 & R55 to R59)
10010-20	2	Resistor, 0.04 Ohm (R54 & R60)
10004-10	5	Resistor, 5k Ohm (R71)
10002-58	1	Resistor, 500 Ohms (R70)
10002-57	1	Resistor, 50 Ohms (R69)
10002-56	1	Resistor, 5 Ohms (R68)
10002-55	1	Resistor, 0.5 Ohm (R67)
10010-19	1	Resistor, 0.05 Ohm (R66)
10010-18	1	Resistor, 0.005 Ohm (R65)
-	1	Resistor, 13" of #17 Manganin (R72)
11025-6	2	Resistor, W.W., 1.5Ω ±10%, ½W (R73, R74) (IRC TYPE BWH)
11025-4	2	Resistor, W.W., 2Ω ±5%, ½W (R75,R76) (IRC TYPE BWH)
4501-181	1	Resistor, Carb, 8.2Ω ±5%, ½W (R77) (MIL TYPE RI1)
4501-148	1	Resistor, Carb, 51Ω ±5%, ½W (R78) (MIL TYPE RI1)

REPLACEMENT PARTS LIST (Cont'd.)

JGB PART NO.	QUANTITY PER INSTRUMENT	DESCRIPTION
4501-149	1	Resistor, Carb, 510Ω ±5%, ½W (R79) (MIL TYPE RI1)
4501-137	1	Resistor, Carb, 5.1kΩ ±5%, ½W (R80) (MIL TYPE RI1)
4501-123	1	Resistor, Carb, 15kΩ ±5%, ½W (R81) (MIL TYPE RI1)
4501-179	1	Resistor, Carb, 39Ω ±5%, ½W (R82) (MIL TYPE RI1)
11922-3	5	Switch (Dial 1 thru Dial 5)
11922-4	1	Switch (Multiplier Dial)
13091	3	Mounting Plate, Resistor (Dial 1, 2 & 3)
11963	1	Mounting Plate, Resistor (Multiplier Dial)
11212	2	Battery, 1½V, #6 Dry Cell, BT3 & BT4 (Eveready Ignition, NEDA 905 or 914 with Screw Terminals)
1482	2	Battery, 9V, BT1 & BT2 (Eveready 216 or Burgess 2U6, NEDA 1604)
11966	2	Test Leads, 5 Ft lg. (Pomona Electronics # 1693 - 60 Black)
13098	1	Shielded Cable Assembly, for use with Keithley 155 External Detector

Section H

WARRANTY & REPAIRS

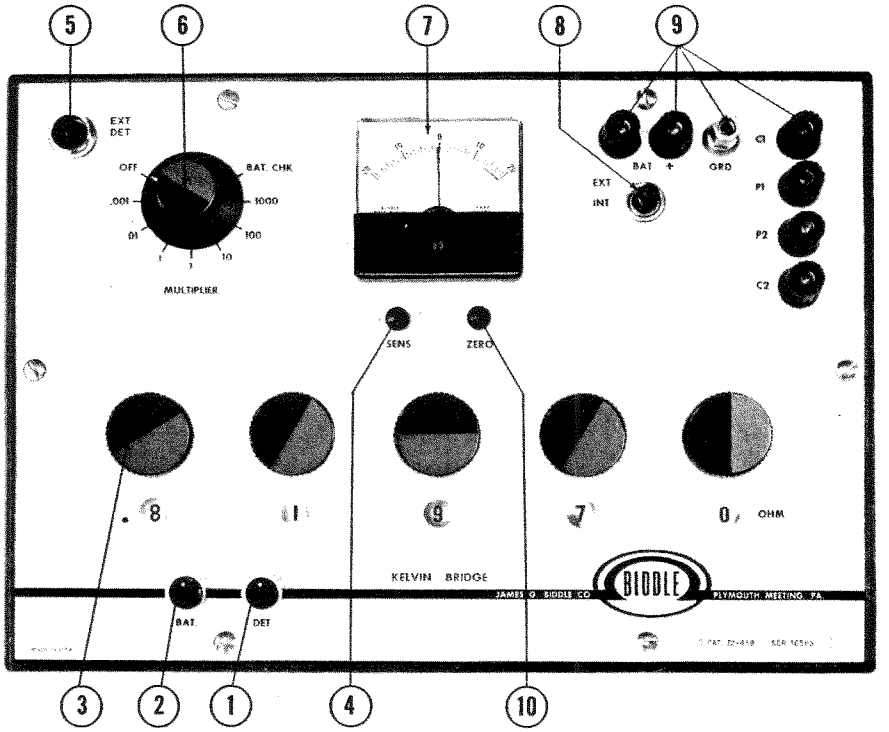
A. Warranty:

All products supplied by Biddle Instruments are warranted against all defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair will be shipped Prepaid and Insured. The warranty does not include batteries, lamps or tubes, where the original manufacturer's warranty shall apply. WE MAKE NO OTHER WARRANTY.

The warranty is void in the event of abuse or failure by the customer to perform specified maintenance as indicated in the manual.

B. Repairs:

Biddle Instruments maintains a complete instrument repair service. Should this instrument ever require repairs, we recommend it be returned to the factory for repair by our instrument specialists. When returning instruments for repairs, either in or out of warranty, they should be shipped Prepaid and Insured and marked for the attention of the Instrument Service Manager.



1. Detector Key
2. Battery Key
3. Measuring Dials
4. Meter Sensitivity Adjust
5. External Detector Receptacle
6. Multiplier Dial
7. Meter
8. Bat. Selector Switch
9. Binding Posts (7)
10. Meter Zero Adjust

Figure 2: Panel View of Cat. No. 72-439 Kelvin Bridge

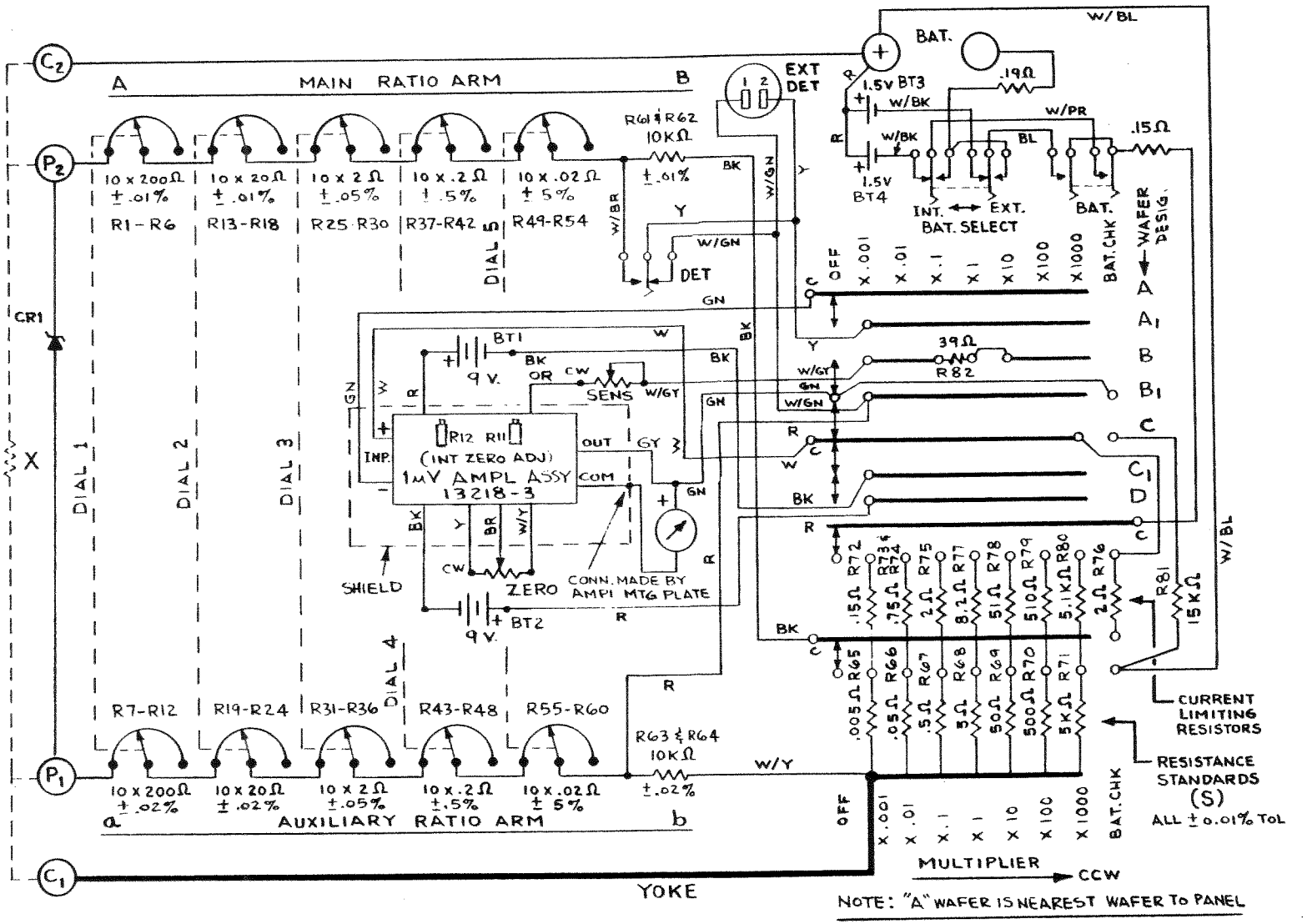


Figure 3: Schematic Diagram of Cat. No. 72-439 Kelvin Bridge