

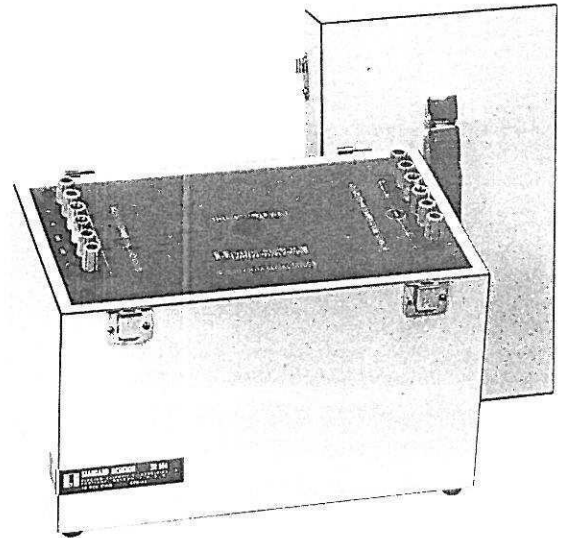
MODEL SR 104

TRANSPORTABLE STANDARD RESISTOR

Instruction Manual

OCTOBER 1972

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SERIAL NUMBER: _____

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esi®

Electro Scientific Industries

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SECTION I

INTRODUCTION

1.1 DESCRIPTION

ESI Model SR 104 Transportable Standard Resistor has nominal values of 10 kilohms (SR 104U), 1 kilohm (SR104T) or 100 ohms (SR 104S). It is enclosed in a hermetically sealed thermal mass with a resistance thermometer having the same nominal value as the standard. The assembly is isolated from ambient temperature changes by foam insulation. The standard and the resistance thermometer are both connected to binding posts on the panel of the container so that they can be measured or calibrated or can serve as the resistance standard for two-, three-, four-, or five-terminal measurements.

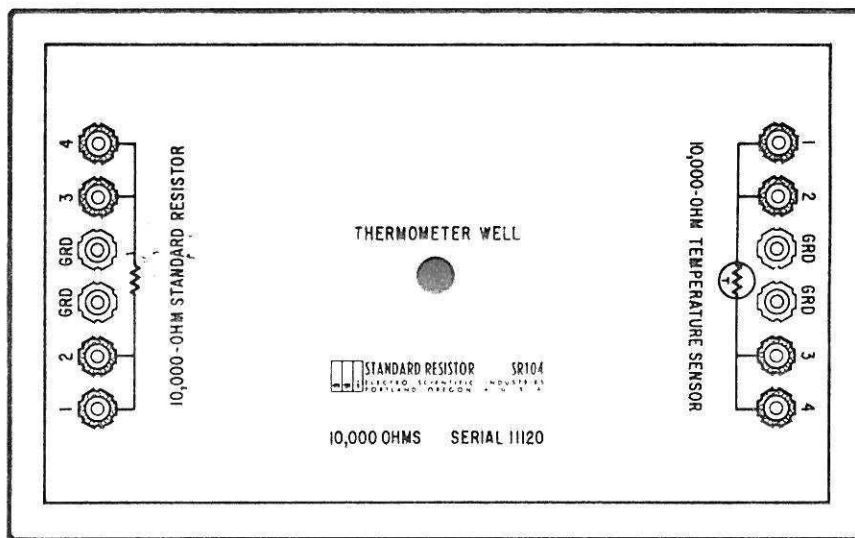


Figure 1-1. Model SR 104U (10 Kilohms), Panel View

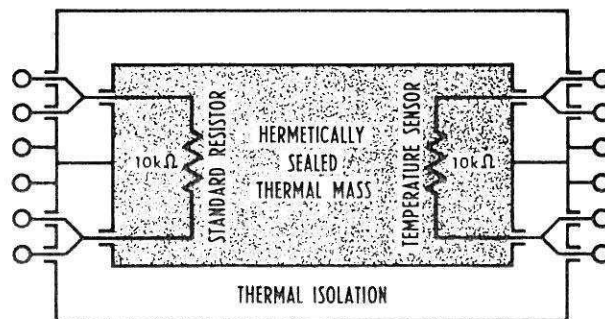


Figure 1-2. Model SR 104U (10 Kilohms), Schematic Diagram

1.2 SPECIFICATIONS

Standard Value: 10 k Ω , 1000 Ω , or 100 Ω .

Accuracy

Initial: ± 3 ppm.

Calibration: ± 1 ppm.

Stability: ± 1 ppm/yr the 1st 2 years. ± 0.5 ppm/yr thereafter.

Temperature Coefficient: Alpha (temperature coefficient) better than ± 0.1 ppm/ $^{\circ}\text{C}$ at 23 $^{\circ}$ for 10 k Ω and 1000 Ω . ± 0.2 ppm/ $^{\circ}\text{C}$ for 100 Ω value.

Beta (1/2 rate of change of temperature coefficient) - does not exceed ± 0.03 ppm/ $^{\circ}\text{C}^2$ over the range of 18 $^{\circ}\text{C}$ to 28 $^{\circ}\text{C}$ for 10 k Ω and 1000 Ω . ± 0.05 ppm/ $^{\circ}\text{C}^2$ for 100 Ω .

Performance listed above is as a passive device with no ovens or external power requirements.

Power Rating: 1 watt, momentary 100 W overloads will not cause failure.

Breakdown Voltage: 500 V peak to case.

Construction: Matched set of highly stabilized unifiler resistors.

Internal Temperature Sensor: 10 k Ω , 1000 Ω or 100 Ω resistor with 1000 ppm/ $^{\circ}\text{C}$ temperature coefficient. Thermometer well provided for calibration.

Power Coefficient: Less than 1 ppm/W.

Calibration Data: ESI test report supplied with unit gives resistance calibration traceable to standards of NSL in Australia and NBS in Washington, D.C., and temperature coefficient.

Dielectric Soakage Effect: Resistance stabilizes to within ± 0.1 ppm of final value within 5 seconds with 10 volts applied to the resistor.

Current Reversal: Resistance value changes less than ± 0.1 ppm with reversal of current through the resistor.

Insulation Resistance: All resistor terminals maintain at least 10^{12} ohms to ground.

Termination: 5-terminal construction (4-terminal resistor with ground intercept) on both standard resistor and temperature sensor. Dual ground terminals are employed.

Terminals: All terminals are gold plated tellurium copper.

Hermetic Sealing: Resistor is completely hermetically sealed in oil with metal-to-glass seals. The resistor changes value less than ± 0.1 ppm with normal atmospheric pressure and humidity changes.

AC-DC Difference: Does not exceed ± 5 ppm from 0 to 1,592 Hz.

Shock Effect: Resistor does not change more than ± 0.2 ppm when subjected to two drops of 3 feet each to a concrete floor on each of three mutually perpendicular faces (6 drops total).

Thermal Lagging: The resistor is provided with thermal lagging which has a time constant of one hour minimum ($1 - \frac{1}{e}$ of total change in one hour).

Packaging: Resistor is mounted in a sturdy white Formica[®] covered box having a removable lid. All the exposed outside and inside surfaces and exposed edges are laminated with 1/16 in. thick Formica[®] bonded to a wood core. All walls are at least 3/8 in. thick. All corners are braced with a 1/2 in. aluminum angle the entire length of the corner and the corners are bonded with epoxy resins under heat and pressure to make a waterproof joint. The lid is gasketed with a neoprene gasket. The lid is mounted with two slip hinges and two latches. A carrying handle is mounted on the lid.

Dimensions: Height 10.00 in. (25.40 cm), Width 8.10 in. (20.57 cm), Depth 12.25 in. (31.12 cm).

Weight: Net 10.5 lbs (4.73 kg), Packed for Shipping 12 lbs (5.4 kg).

1.3 TYPICAL PERFORMANCE

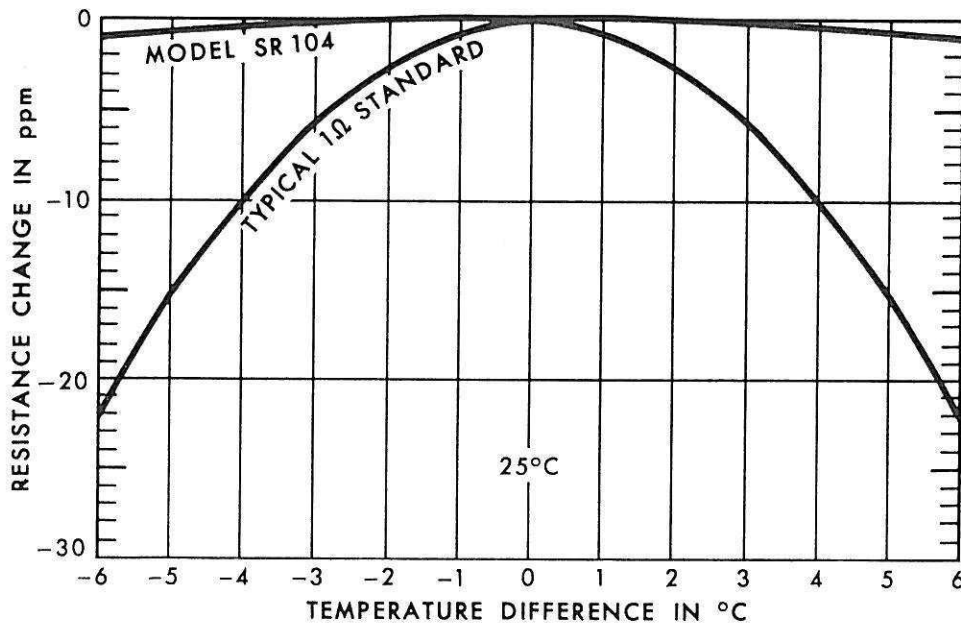


Figure 1-3. Comparison of Temperature Coefficients of Model SR 104 and Typical 1-Ohm Standard Resistor

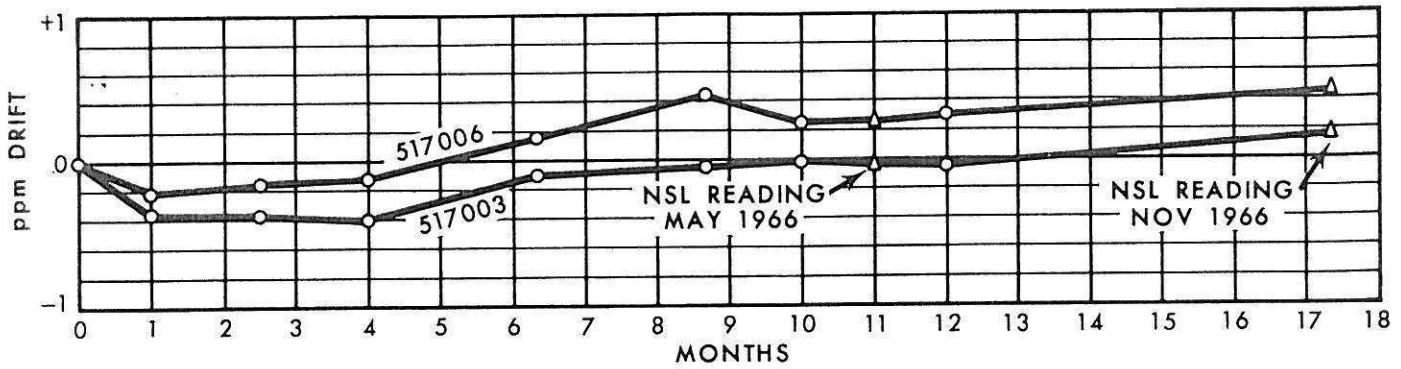
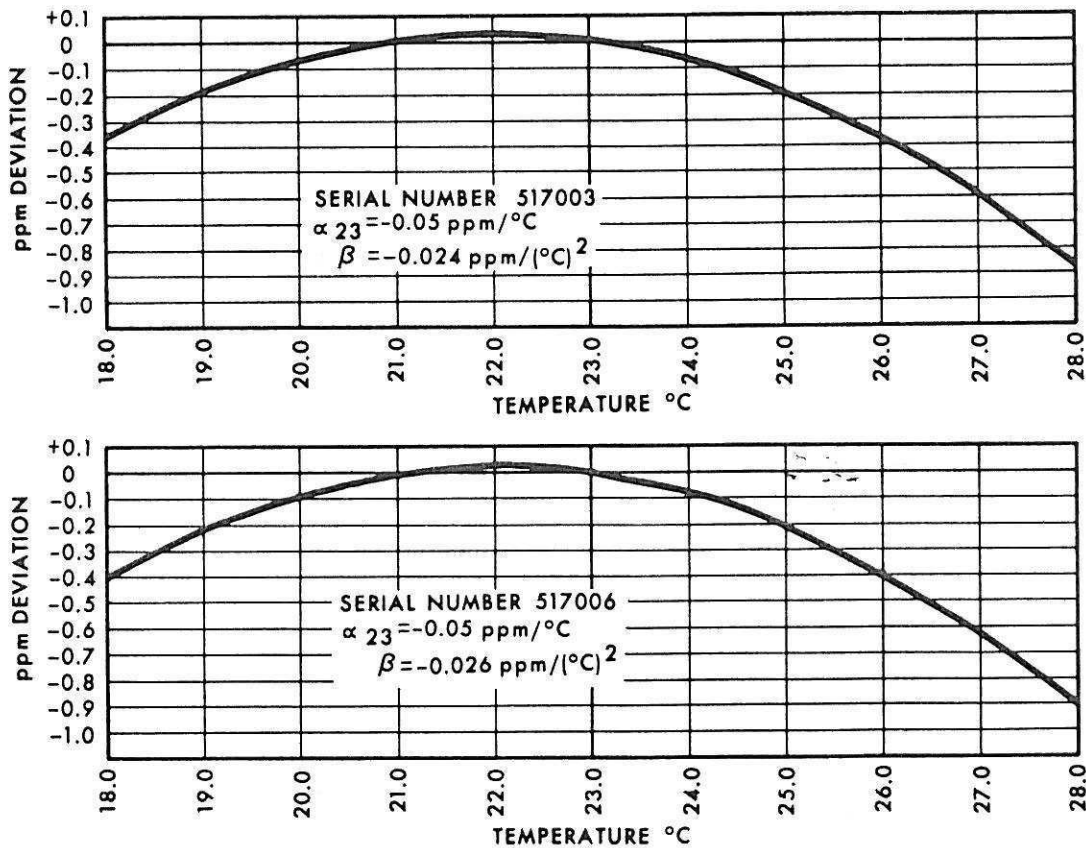


Figure 1-4. Typical Stability for 10 Kilohm Model*



α AND β GIVEN FOR EACH RESISTOR APPLY IN THE FORMULA:

$$R = R_{AT\ 23^{\circ}C} [1 + \alpha_{23} \Delta t + \beta (\Delta t)^2]$$

WHERE Δt = ACTUAL TEMPERATURE MINUS $23^{\circ}C$

Figure 1-5. Typical Temperature Coefficients

*All values are made of 1 k Ω resistors connected in series, parallel, or series-parallel. Therefore, typical stability should be the same for all values.

SECTION II

OPERATION

2.1 CALIBRATION OF OTHER STANDARD RESISTORS

The Model SR 104 can be used as the basis for calibrating resistors of other values. Transfer standards consisting of ten equal resistors can be connected in series or parallel to obtain either 10 times or 100 times the resistance of the individual resistors. With a precision bridge these resistors can be compared to the Model SR 104 Standard Resistor to calibrate them. With the proper values of transfer standards, all comparisons can be one-to-one for highest accuracy.

The transfer standards recommended are ESI Models SR 1010 (10 ohms per step, 100 ohms, 1 kilohm, and 10 kilohms per step) and SR 1050 (100 kilohms, 1 megohm, and 10 megohms per step). With these transfer standards, values of resistance from 1 ohm to 100 megohms can be calibrated. The Model SR 1010 is recommended for values below 10 kilohms because of the four-terminal connection that preserves accuracy between series and parallel connections. The Model SR 1050 is recommended above 10 kilohms because of the three-terminal guarded construction that eliminates errors due to leakage.

Bridges recommended are ESI Model 242 Resistance Measuring System or ESI Model 123 Resistance Comparison System. Both systems use five-terminal measurements (combination of four-terminal and three-terminal guarded) in order to eliminate errors from lead and contact resistance and from leakage resistance.

ESI Model 123 Resistance Comparison System which includes a high-sensitivity detector (ESI Model 900 Nanovolt Galvanometer) is capable of performing the resistance transfers from 10 kilohms to 1 ohm and to 100 megohms with an accuracy of better than a part per million.

2.2 BRIDGE CONNECTIONS

A standard resistor can be used either as an interchange standard or as a comparison standard, depending on the type of bridge. An interchange standard is most commonly used because it is either the most accurate or, at least, its accuracy is the easiest to verify. Many bridges have internal standards and can use the standard resistor only for interchange comparisons. Other bridges have external standard connections and can be used to compare the ratio of two resistors. The interchange technique in this case uses a tare resistor for the external standard of the comparison bridge. The tare resistor is adjusted so that the bridge reading is correct for the value of the standard resistor and other resistors can be compared to the standard.

2.2.1 Wheatstone Bridges

Wheatstone bridges do not generally have provision for external standards. The connections shown in the following examples are for typical Wheatstone bridges to be used for interchange comparisons.

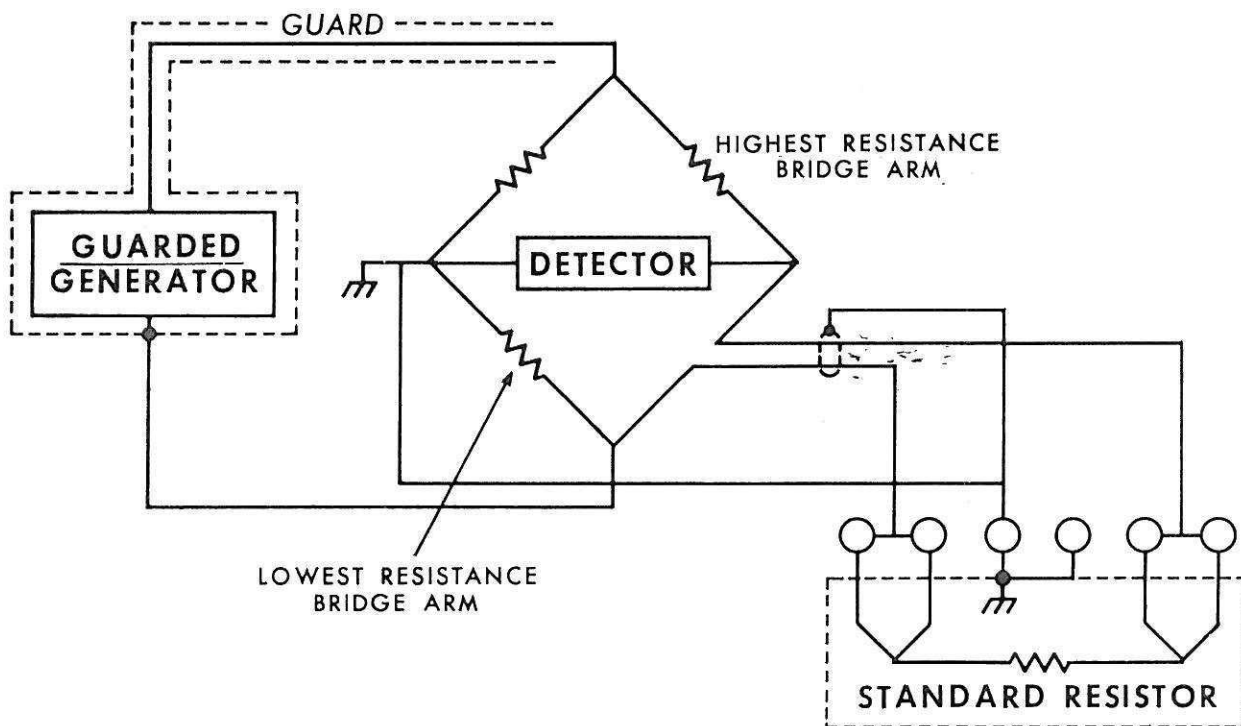


Figure 2-1. Wheatstone Bridge Connections

NOTE: Since 1 k Ω and 100 Ω standards have approximately 5 m Ω resistance in the wire between the posts and the effective ends of the standard resistor, Wheatstone bridge measurements are not recommended except with the 10 k Ω value.

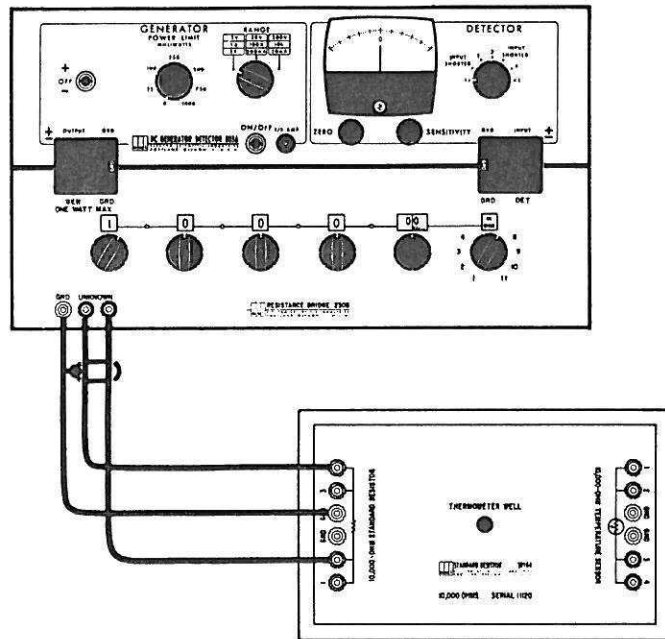


Figure 2-2. ESI Model 230 Bridge Connection

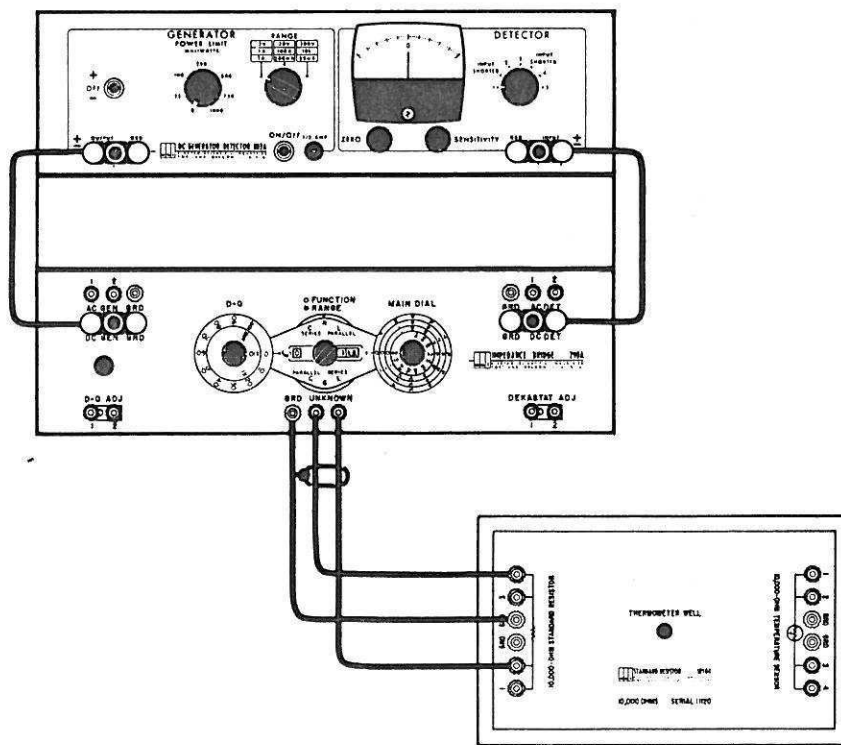


Figure 2-3. ESI Model 290 Bridge Connection

2.2.2 Kelvin Bridges

Many Kelvin bridges can be used for comparison measurements. The connections in the following examples show the bridge connected for interchange measurements. The tare resistor, where optional, is connected to the terminals indicated.

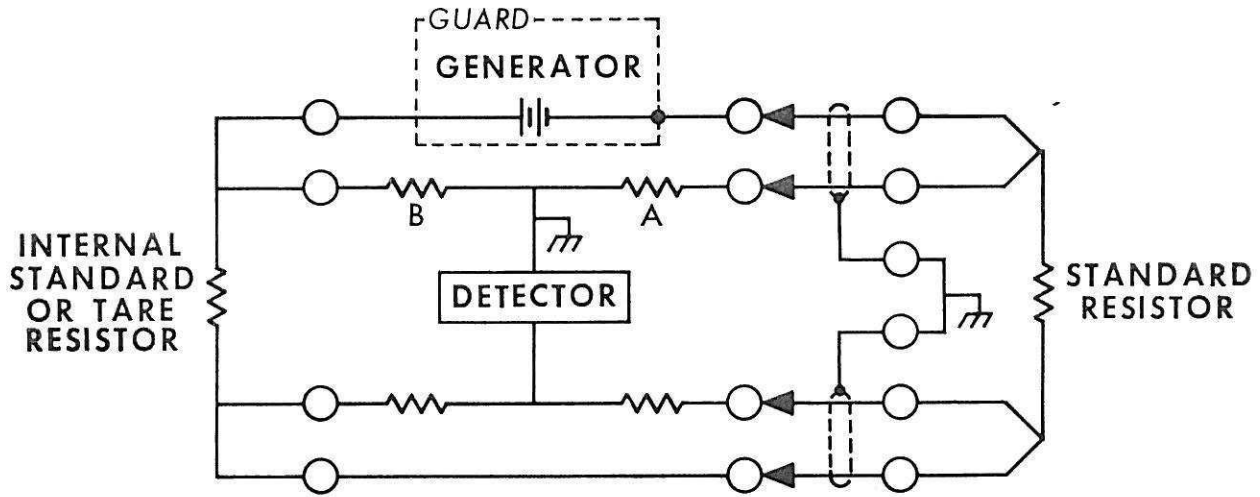


Figure 2-4. Kelvin Bridge Connections

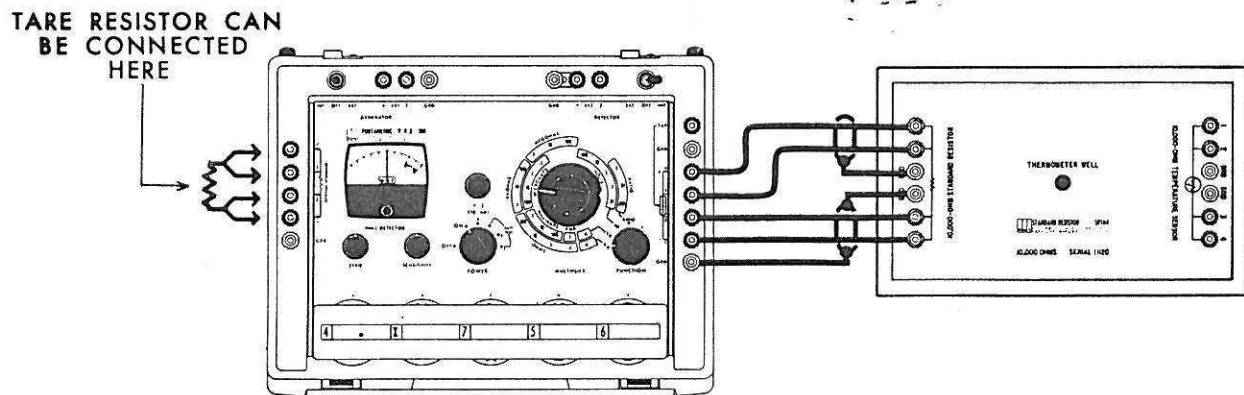


Figure 2-5. ESI Model 300 PVB® Connections

TARE RESISTOR CAN
BE CONNECTED
HERE

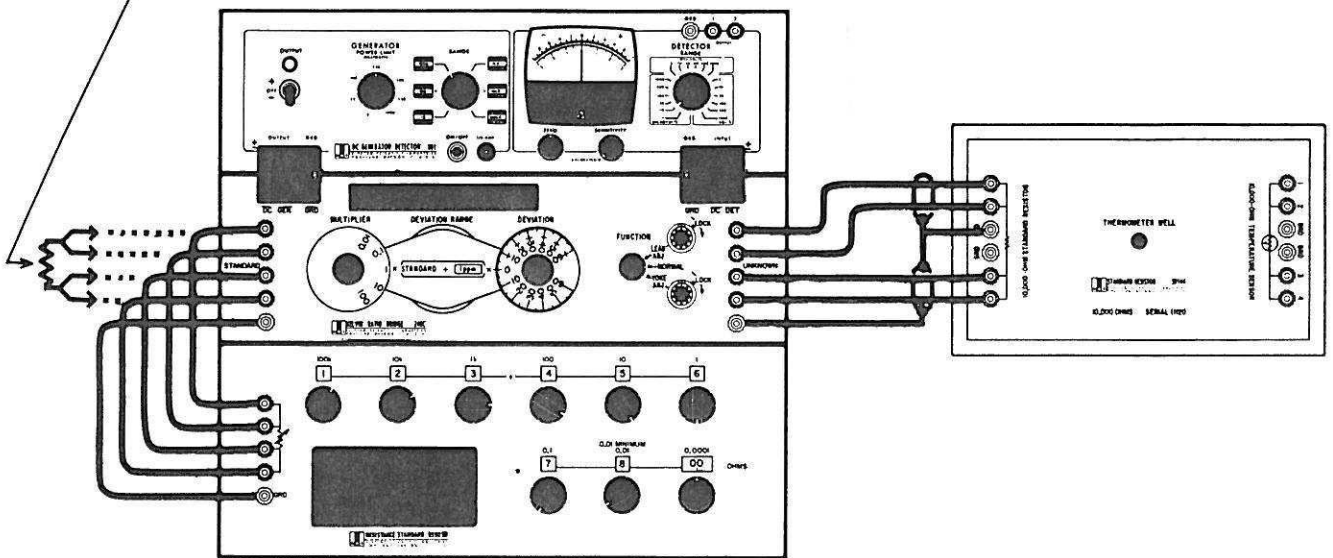


Figure 2-6. ESI Model 242 Resistance Measuring System Connection

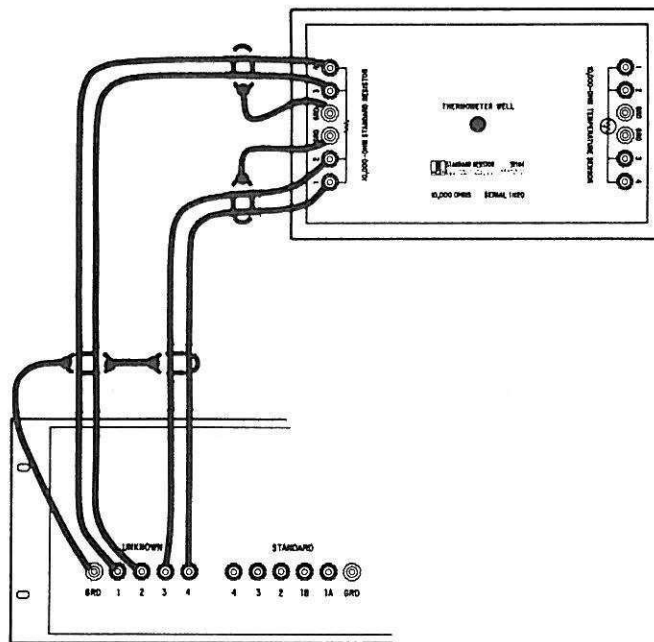


Figure 2-7. ESI Model 501 Resistance Deviation Bridge Connection

2.2.3 Direct-Reading Double Ratio Sets

A direct-reading double ratio set is similar to a Kelvin bridge in principle. Adjustments on the ratio set make it versatile and accurate enough to allow comparison of standard resistors to accuracies of 0.1 part per million. Connection of the Model SR 104 Transportable Standard Resistor to ESI Model 120 Direct-Reading Ratio Set are shown in the following illustrations.

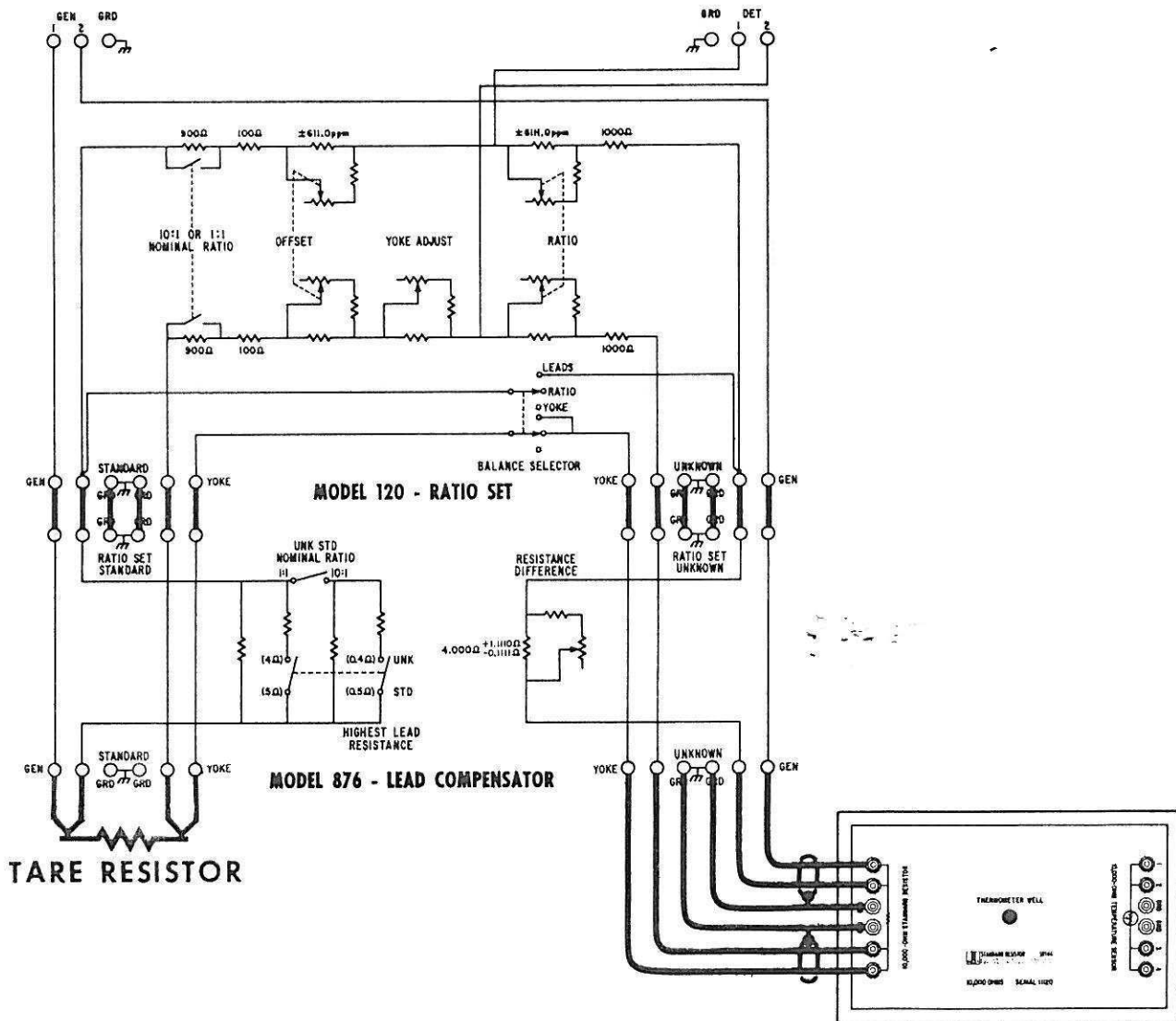


Figure 2-8. Direct-Reading Double Ratio Set Connection

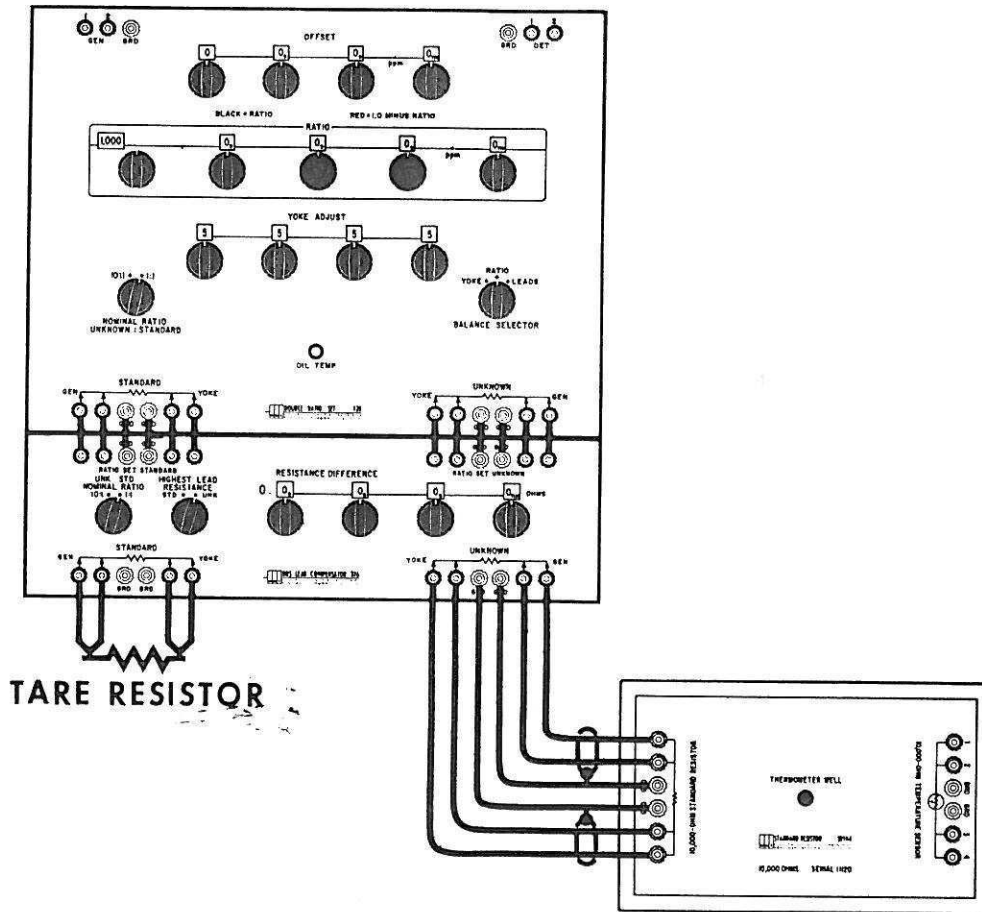


Figure 2-9. ESI Model 120 Connection

2.3 TEMPERATURE COMPENSATION

2.3.1 Temperature Sensor

The temperature sensor resistance network consists of a copper resistor in series with a low temperature coefficient resistor. The resistance of the network at 23°C has a temperature coefficient of 1000 ppm (0.1%) per °C.

The temperature sensor is mounted in the same oil tank as the standard resistor and thus is at the same temperature. Since the standard resistor and the temperature sensor have the same nominal resistance, they can be measured on the same bridge.

2.3.2 Temperature Connection

The temperature sensor can be connected to the same bridges in the same manner as the standard resistor. The bridge can be the same one used to measure the standard resistor, but generally the accuracy does not need to be as high.

2.3.3 Calculating the Correction

The temperature correction chart (in the lid of the unit) can be used to correct the resistance of the Model SR 104 Transportable Standard Resistor for temperature effects. Figure 2-10 is a sample correction chart.

To calculate the true resistance of the standard, first compare the resistance of the temperature sensor with the standard resistor, then find the deviation due to temperature effect from the curve on the temperature correction chart (2). In the sample, the difference between the standard and temperature sensor is +0.17%, corresponding approximately to 24.7°C from the curve; the deviation is -0.28 parts per million. This number is added to the nominal deviation (1), which is -0.15 ppm. The total deviation is -0.43 ppm.

The actual temperature of the temperature sensor can be determined from its deviation at 23°C (3). In this case, the deviation is -0.006%. All temperatures are thus 6/10 of a minor division to the right of the corresponding percentage scale.

The temperature correction curve follows the formula:

$$\frac{R_s}{(R_s \text{ at } 23^\circ\text{C})} = 1 + \alpha_{23} \Delta t + \beta (\Delta t)^2$$

where α_{23} and β are as noted at (4) and the other terms at (5).

es|i MODEL SR 104

SERIAL NUMBER 734003

NOMINAL VALUE: 10k Ω

DEVIATION IN PARTS PER MILLION OF NOMINAL VALUE: -0.15 ppm \pm

NOTE: ADD OR SUBTRACT TEMPERATURE CORRECTION TO DEVIATION

TEMPERATURE COEFFICIENT

IN THE FORMULA:

$$\frac{R_s}{[R_s \text{ at } 23^\circ\text{C}]} = 1 + \alpha_{23} \Delta t + \beta (\Delta t)^2$$

WHERE R_s = STANDARD RESISTANCE
 Δt = ACTUAL TEMPERATURE MINUS 23°C

α_{23} = -0.115 ppm/°C

β = -0.025 ppm/(°C)²

TEMPERATURE SENSOR RESISTANCE (R_T)

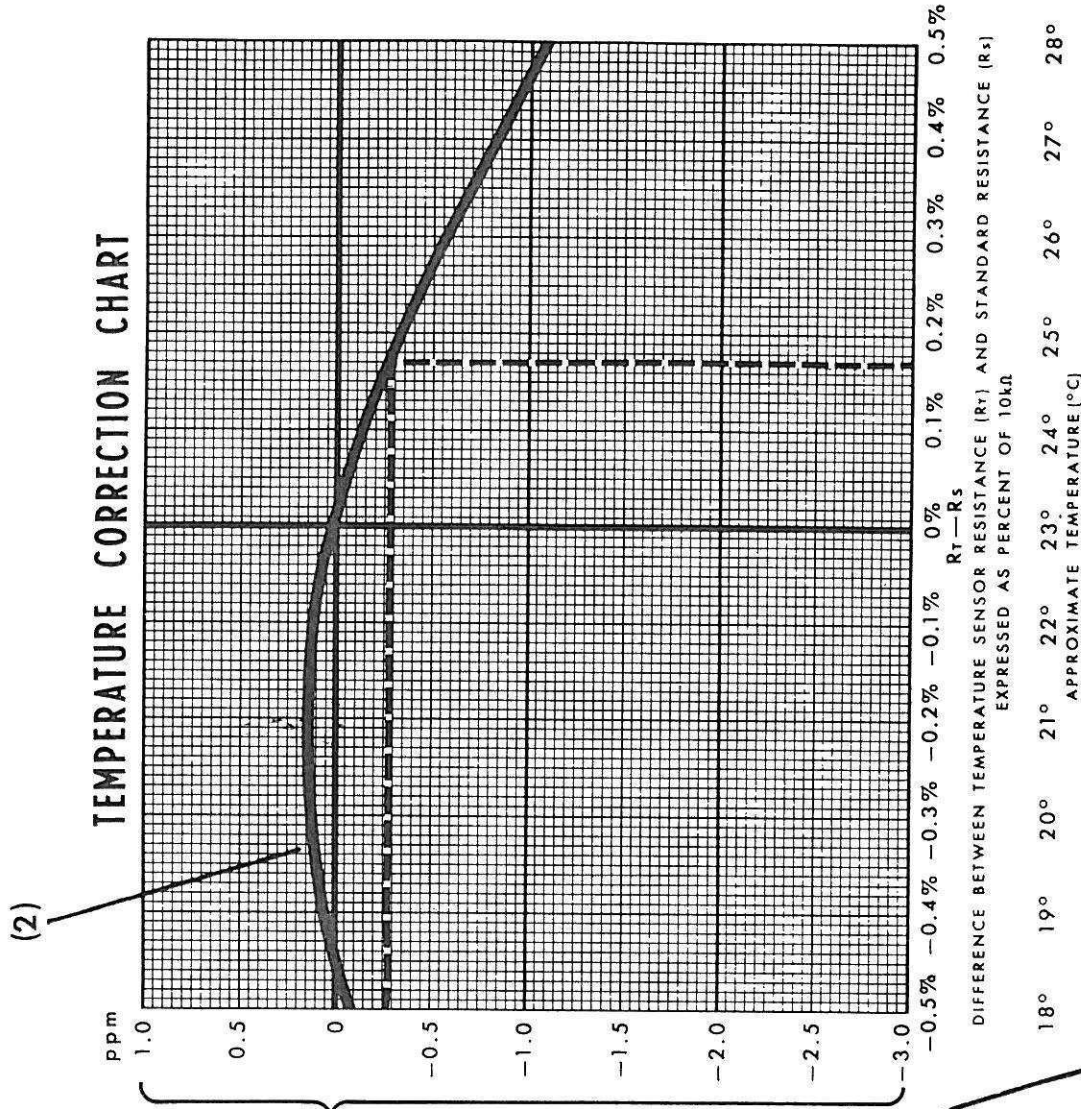
DEVIATION AT 23°C: -0.006 %
 TEMPERATURE COEFFICIENT: 0.1%/°C

BY MM

DATE 25 May, 1967

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TEMPERATURE CORRECTION CHART



PART NO. 13570

Figure 2-10. Sample Temperature Correction Chart

2.4 SELF-HEATING

To avoid self-heating in the bridge or resistor being measured, low power must be used in both the standard and temperature sensor of the Model SR 104. Self-heating, generally noticeable by a steady drift in the reading while power is being applied can be avoided if power is kept below 10 mW in the standard and 100 μ W in the temperature sensor. Voltages are given in Table 2-1.

RESISTOR VALUE	VOLTAGE	
	at 10 mW	at 100 μ W
10 k Ω	10 V	1 V
1 k Ω	3.3 V	0.33 V
100 Ω	1 V	0.1 V

Table 2-1