♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

SR 102, SR 102/DC,
SR 104, SR 104/DC

Transportable Resistance Standard

User and Service Manual

IET LABS, INC.
formerly manufactured by
esi/Tegam

534 Main Street, Westbury, NY 11590 www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTIBILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

WARNING

OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qulified personnel

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND KEEP UNREQUIRED PERSONNEL SAFELY AWAY.

CAUTION

DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

Safety Precautions

1. REVIEW MANUAL:

The ⚠ symbol on the instrument front panel denotes that the user should read the Instruction Manual before operating the instrument.

2. INSTALLATION CATEGORY:

In accordance with EN61010-1, the Models SR102 and SR104 are rated for Installation Category II.

3. ENVIRONMENTAL CONDITIONS:

The SR102 and SR104 are specified for operation at 23°C±1°C and zero power dissipation. Refer to specifications listed in the instruction manual for operation outside these limits.

4. MAXIMUM INPUT VOLTAGE:

The SR102 (100 ohms) is limited to 20V maximum and the SR104 (10 Kohms) is limited to 200V maximum input. Refer to the manual for the effects of self-heating.

5. POTENTIAL HAZARDS:

When in use with a potentially hazardous voltage, the front panel "GRD" terminal should be connected to a suitable safety ground.

WARNING

The instrument does not protect against hazards created by equipment to which it is connected.

WARNING

Upon loss of the protective ground connection, all accessible parts (including knobs and controls that appear to be insulated) can render an electrical shock.

6. MISUSE OF INSTRUMENT:

Misuse can result in unsafe operation and/or damage to the instrument. Do not use the instrument in any manner that is not specified in the Instruction Manual.

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SECTION I

INTRODUCTION

1.1 DESCRIPTION

SR102 100 Ω, and the SR104 10,000 Ω Standard Resistors are both designed as totally transportable bench top instruments. The SR102/DC and SR104/DC are also transportable and are designed to be used in an oil bath. All four versions have a five-terminal resistor configuration, an internal temperature sensor, and are hermetically sealed in an oil filled container. When the SR102/DC or SR104/DC is used in an oil bath it maintains a constant temperature of the resistance elements, thus providing outstanding short term stability which is especially important when making Quantum Hall Effect measurements.

The SR102, SR102/DC, SR104 and SR104/DC resistance standards offer an extremely low temperature coefficient, less than 0.1 ppm/°C, and power coefficient, less than 1ppm/watt. These characteristics facilitate precise laboratory comparisons without critical environmental controls. When external environmental controls, such as air or oil bath, are used, the stability and temperature coefficient specifications are enhanced. This is especially true with the SR102/DC and SR104/DC both designed for oil bath operation.

The oil filled resistor container of each model is designed to protect against shock of temperature and pressure gradients typically produced where standards are commercially transported from one region to another or across varying altitudes. The SR104's and SR104/DC's 10,000 Ω resistance value positions this standard in the center of the commonly used resistance range, four decades from 1 Ω and four decades from the100 M Ω. Accurate transfers can be made using the 100:1 transfer technique manifest in **IET Labs** SR1010, SR1030, SR1050, and SR1060 Resistance Transfer Standards. The combination of the SR104 or SR104/DC a transfer bridge and these transfer standards can establish resistance levels from 0.1 Ω to 100 M Ω. The five terminal construction allows four-terminal measurements which eliminate lead resistance, contact resistance, and leakage resistance effects. The four resistor terminals are gold plated tellurium copper on the SR102, and SR104 to reduce thermal emf.

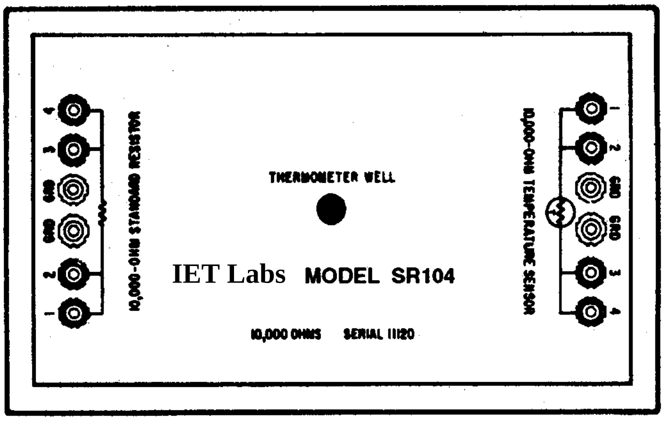


Figure 1-1. Model SR104 (10 Kilohm), Panel View
(for SR102 substitute 100Ω in place of 10,000Ω)

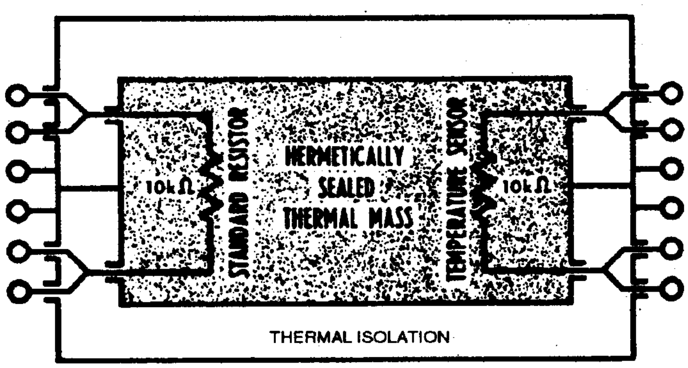


Figure 1-2. Model SR104 (10 Kilohm),
Internal Schematic View
(for SR102 substitute 100Ω in place of 10kΩ)

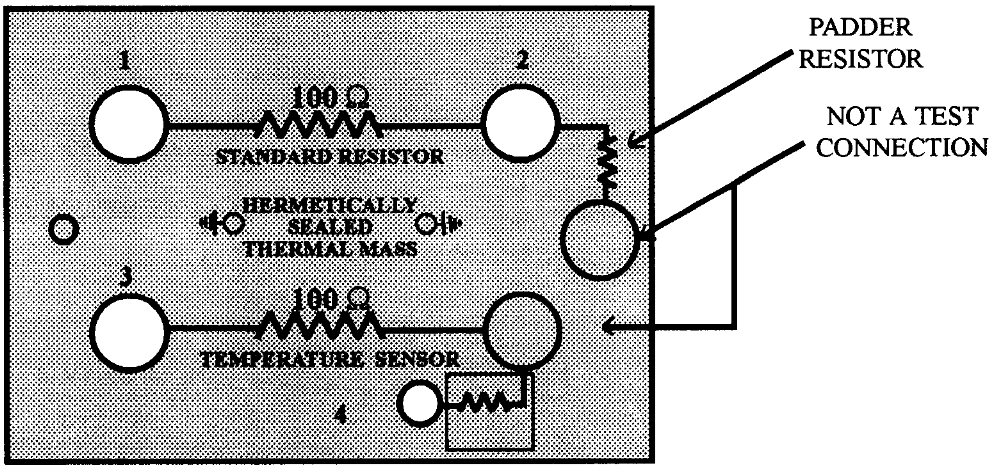


Figure 1-3. Model SR102 D/C (100Ω),
Schematic Diagram For Test Connections

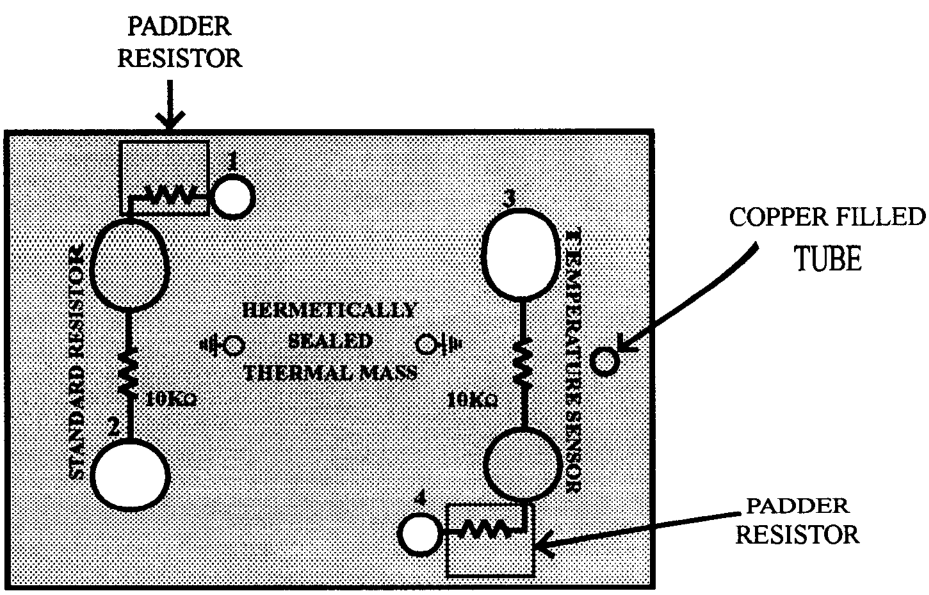


Figure 1-4. Model SR104 D/C (10KΩ),
Schematic Diagram For Test Connections

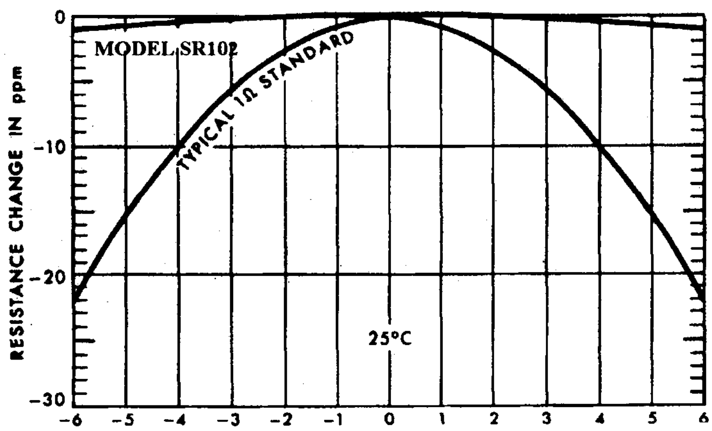
1.2 SPECIFICATIONS

Standard Value:	SR102	100 Ohms
	SR102/DC	100 Ohms
	SR104	10,000 Ohms
	SR104/DC	10,000 Ohms

Stability:	±1 ppm/yr the first 2 years; ±0.5 ppm/yr thereafter.
Temperature Coefficient:	Alpha (temperature coefficient) better than ±0.1 ppm/°C at 23° Beta (1/2 rate of change of temperature coefficient) does not exceed ±0.03 ppm/°C^2 over the range of 18°C to 28°C. This performance is as a passive device without ovens or external power requirements.
Power Coefficient:	less than 1ppm/W.
Initial Accuracy:	±2 ppm.
Calibration Accuracy :	±1 ppm.
Breakdown Voltage:	500 Volts peak to case.
Construction:	Matched set of highly stabilized unifilar resistors.
Internal Temperature Sensor	SR102, SR102/DC: 100 Ω resistor with 1,000 ppm/°C temperature coefficient. A thermometer well is provided for calibration. SR104, SR104/DC: 10,000 Ω resistor with 1,000 ppm/°C temperature coefficient. A thermometer well is provided for calibration.
Thermal emf	Under normal conditions thermal emf at the terminals does not exceed ±0.1μV.
Calibration Data:	IET Labs supplies a test report traceable to the National Institute of Standards and Technology with each unit. This report documents resistance calibration and temperature coefficient.
Thermal Lagging	The resistance standard is provided with thermal lagging which has a time constant of one hour minimum (1-1/e of total change in one hour).
Dielectric Soakage Effect:	Resistance stabilizes to within ±0.1 ppm of final value within 5 seconds with 1 volt for the SR102, and 10 volts for the SR104 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:	The four resistor terminals on the SR102 and SR104 are gold plated tellurium copper to reduce thermal emf, while the ground terminals are brass. The SR102/DC terminals are tin 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 O to 1,592 Hz.
Shock:	SR102, SR104: The resistor does not change more than 0.2 ppm when subjected to two drops of three feet each to a concrete floor on each of the three mutually perpendicular faces (six total drops)
Packaging:	SR102/DC, SR104/DC: Matched set of highly stabilized unifilar resistors, securely mounted and hermetically sealed in a deep drawn stainless steel container. The physical dimensions are: Height 5.0 in., Width 3.5 in., Depth 7.0 in. SR102, SR104: Matched set of highly stabilized unifilar resistors, securely mounted in a hermetically sealed in a deep drawn stainless steel container. This container is then enclosed in a sturdy portable chassis made of 1/16 in. thick Formica bonded to a 3/8 in. thick wood core. Corners are braced with 1/2 in. aluminum angle their entire length, and are bonded with epoxy resins under heat and pressure to make a waterproof joint. The physical dimensions are: Height 10.0 in., Width 8.10 in., Depth 12.25 in.

1.3 TYPICAL PERFORMANCE



TEMPERATURE DIFFERENCE IN °C

Figure 1-3. Comparison of Temperature Coefficients of Model SR102 and Typical 1-Ohm Standard Resistor

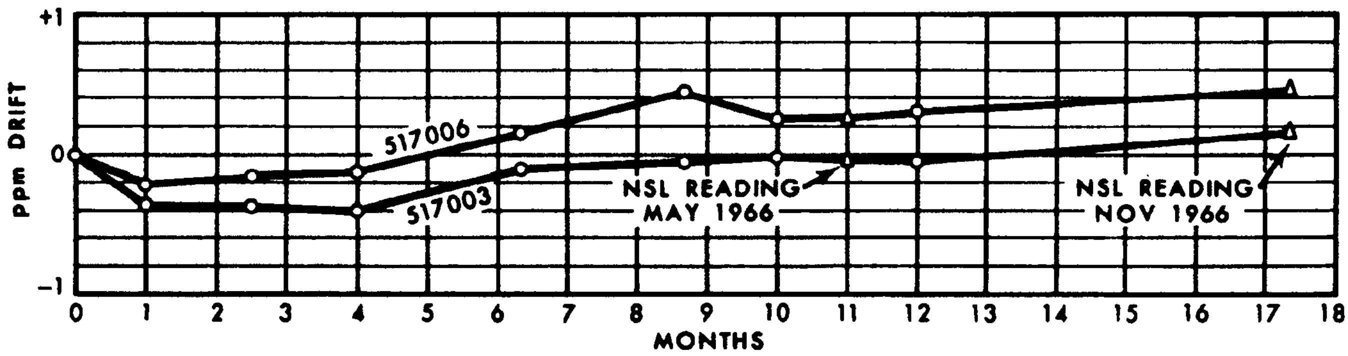
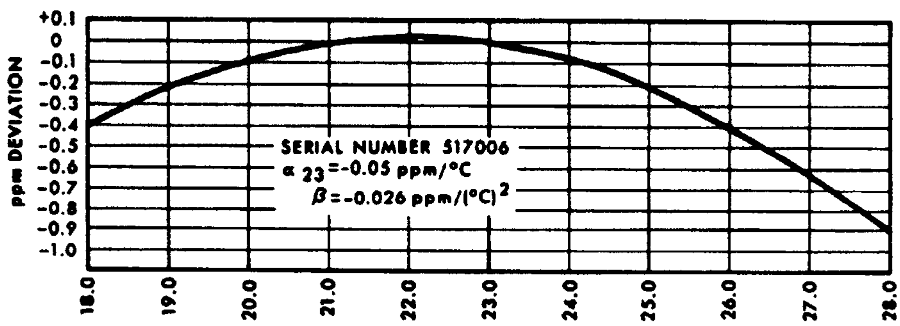


Figure 1-4 Typical Stability for 10 Kilohm Model



TEMPERATURE °C

α AND ß GIVEN FOR EACH RESISTOR APPLY IN THE FORMULA: $R=R$ AT 23°C $[1+ \alpha_{23}\Delta t + \beta(\Delta t)^2]$

Figure 1-5 Typical Temperature Coefficients

SECTION II

OPERATION

2.1 CALIBRATION OF OTHER STANDARD RESISTORS

Models SR102 and SR104 Transportable Resistance Standards are primary standards that establish the resistance levels in the laboratory. Working or secondary standards can be calibrated with these primary standards. Other necessary equipment would be a precision bridge and transfer standards.

The recommended bridge is IET Labs model 242D Resistance Measuring System. This system uses five-terminal measurements, combination of four-terminal and three-terminal guarded, in order to eliminate errors from leads, contact resistance, and leakage resistance.

Resistance transfer standards consists of at least 10 equal resistors (R) that can be connected in series, parallel, or series-parallel. This results in resistance values that are 10R, R/10, or R. The accuracy of these ratios is within 1 ppm.

Once a resistance level is established on a bridge, transfer standards can calibrate the remaining decades by transferring decades to decades above or below the established level. Using a set of transfer standards, users can establish and verify resistance decades on bridges from 0.1 Ω through 100M Ω.

Models SR1030 or SR1010 Transfer Standards are recommended for transfers below 1M Ω because of the four-terminal connection that preserves accuracy between series and parallel connections. Model SR1050 Transfer Standards are recommended for values above 1M Ω.

Consult manuals for 242D, SR1010, SR1030, SR1050, or SR1060 for details about the application of these products.

2.2 BRIDGE CONNECTIONS

A standard resistor can be used either as a 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.

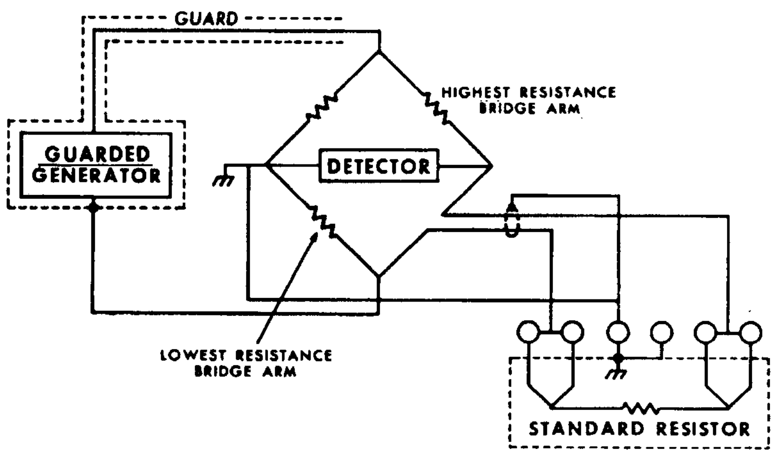


Figure 2-1 Wheatstone Bridge Connections

2.2.2 Kelvin Bridges

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

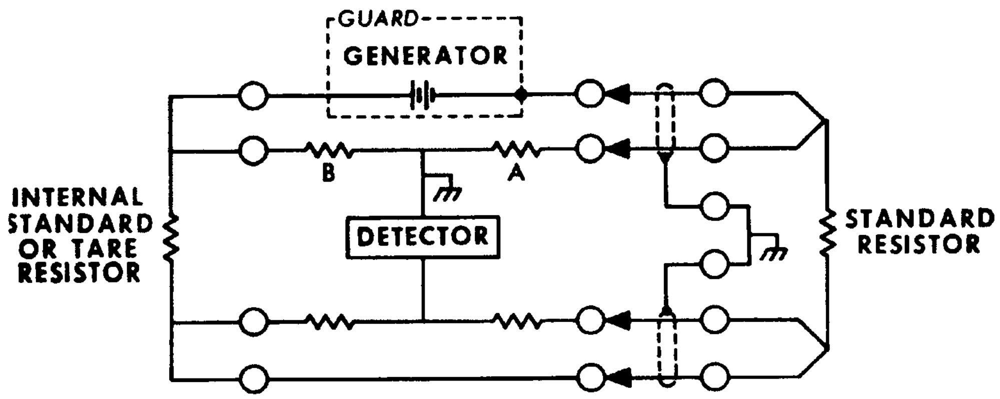


Figure 2-2 Kelvin Bridge Connections

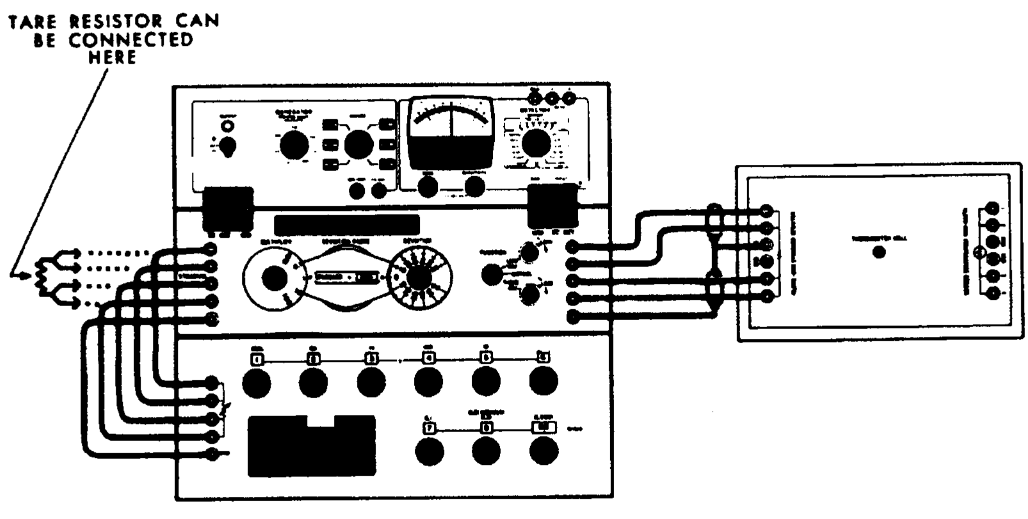


Figure 2-3 IET Labs Model 242D Resistance Measuring System Connection

2.4 TEMPERATURE COMPENSATION

2.4.1 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 1,000 ppm (0.1%) per °C.

The temperature sensor is mounted in the same oil filled container 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.

2.4.2 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.

2.4.3 Calculating the Correction

The temperature correction chart (in the lid of the unit) can be used to correct the resistance of the Model SR104, SR102, Transportable Standard Resistor for temperature effects. Figure 2-4 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:

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

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

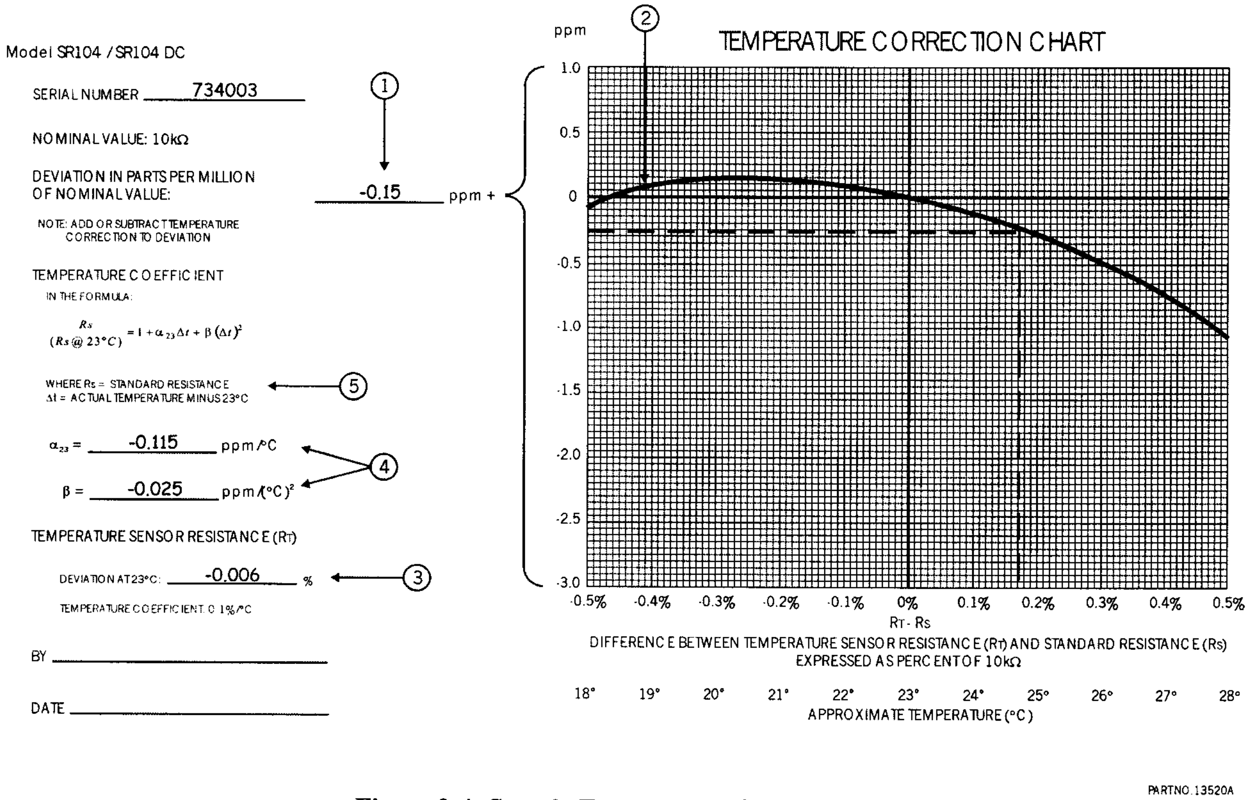


Figure 2-4: Sample Temperature Chart

2.6 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 Models SR104, SR102. 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 mW in the temperature sensor. Voltages are given in Table 2-1.

Resistor Value	**Voltage**	
	at 10 mW	at 100 mW
100Ω	1 V	0.1 V
10kΩ	10 V	1 V

Table 2-1

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