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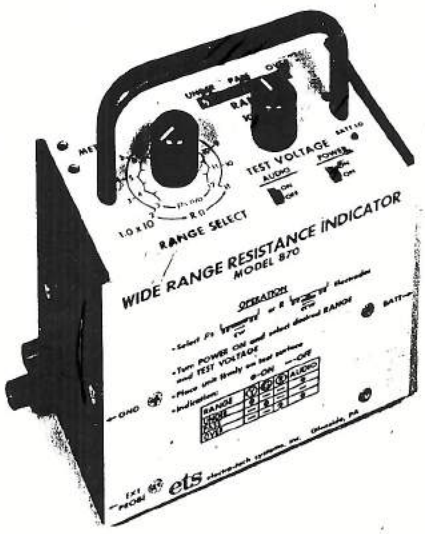
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MODEL 870

WIDE RANGE RESISTANCE INDICATOR

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1.0 INTRODUCTION

Many applications require a point to point surface resistance or a surface resistivity measurement to be made on a pass/fail basis. Products such as packaging material, work bench surfaces, chair mats, floor surfaces and conductive conveyor belts have resistive properties that may vary from less than 10^2 to greater than 10^{12} ohms. Current standards require that these products meet specific resistance requirements.

The Model 870 Wide Range Resistance Indicator is a compact, precision instrument that performs both resistance and resistivity measurements. Measuring accuracy in the 10^2 to 10^7 ohms range is ±2% and in the 10^8 to 10^{11} ohm range is ±5%.

It is an ideal instrument for checking the resistance/resistivity requirements specified in the ASTM D 257, EIA-541, NFPA 99, EOS/ESD STD 4, ASTM F 150 and applicable DOD standards.

The Model 870 incorporates user selectable test voltages of 10 and 100 volts. In the 10 volt range, the entire resistance range of 10^2 to 10^{11} ohms can be measured. In the 100 volt range only the resistance range of 10^4 to 10^{11} can be measured. By having user selectable test voltages, the instrument meets the measurement requirements specified in EOS/ESD and EIA specifications. The Model 870 can also be used for any measurement where 10 or 100 volts may be utilized.

2.0 EQUIPMENT DESCRIPTION

2.1 Standard Model

The Model 870 Wide Range Resistance Indicator is a compact, precision instrument that accurately indicates the resistance and/or resistivity characteristics

of material. The instrument incorporates a unique set of electrodes that enable a single instrument to measure both point to point resistance, surface resistivity and volume resistivity.

The resistance electrode consists of a 2.5 inch diameter conductive silicone rubber disc with a hardness of 65 durometer that is mounted on a threaded mounting plate. This electrode conforms to the requirements specified in NFPA 99, ASTM D 150 and EOS/ESD STD 4. When making a resistance measurement, the electrode is extended fully such that it is the only portion of the Model 870 to make contact with the material under test. An external jack is provided for connection to a ground point for resistance to ground measurements or to a Model 850 Surface Resistance Probe (optional), which also incorporates a 2.5 inch diameter conductive silicone rubber electrode for point to point measurements.

The 2.5 inch diameter carbon loaded electrode has a volume resistivity of 8 ohms-cm. When placed on a surface, the electrode adds approximately 25 ohms series resistance to the measurement. This additional resistance must be taken into account when using the lowest resistance range. However, current requirements usually specify a lower resistance limit of 10^3 to 10^5 ohms. At these levels, the error introduced by the electrode resistance is negligible.

A ground connection is located in the center of the left side panel. This banana jack output enables the case of the Model 870 Indicator to be grounded which helps in stabilizing the resistance measurement at the high ranges.

The resistivity electrodes consist of a pair of parallel bars 2.25 inches long and spaced 0.45 inches apart as shown in Figure 2.0-1.

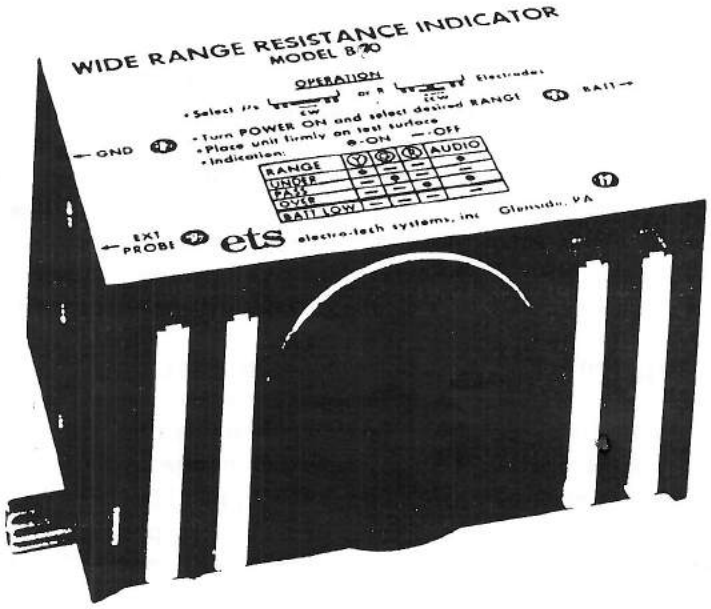


Figure 2.0-1

Model 870 Wide Range Resistance Indicator

The two outer bars are connected in series and the two inner bars are connected in series giving an effective electrode length of 4.5 inches. Using the parallel bar ratio specified in ASTM D 257, the surface resistivity, ρ_s, is simply

$$\rho_s = \frac{L}{d} R_m = \frac{4.5}{.45} R_m$$

$$= 10 R_m \text{ ohms/square}$$

Hence, the surface resistivity of the material under test is ten (10) times the measured resistance. The .45 inch electrode spacing reduces the fringing effects associated with parallel bars that are more widely separated. The parallel bars consist of .125" square conductive silicone rubber electrodes with a hardness of 65 durometer to ensure good instrument to material surface contact. These electrodes have a volume resistivity of .01 ohm-cm which adds approximately one (1) ohm series resistance to the measurement.

The Model 870 Wide Range Reistance Indicator is capable of accurately indicating resistance in (9) decade steps from 10^2 to 10^{11} ohms when using the 10 volt range. When using the 100 volt range, the two lower resistance decades (10^2-10^3 ohms and 10^3-10^4 ohms/sq.) are made inoperable. The 100 volt power supply is turned off when these ranges are selected. The maximum current output is thus limited to 10 milliamps.

Three LED point source readouts indicate whether the measured resistance is within the selected range (continuous green light), under the selected range (flashing yellow light) or over the selected range (flashing red light). A pulsating audio tone is also provided to indicate out of range measurements. This tone can be switched on or off by the user.

The Range Select switch has two scales. The black scale covers the nine (9) decade resistance range from 10^2 to 10^{11} ohms. The red scale covers the nine (9) decade resistivity range from 10^3 to 10^{12} ohms/square.

The total probe weight of the Model 870 is 5 pounds as required by applicable specifications. The unit measures only 5.25"W x 3.0"D x 6.50"H including the convenient carrying handle.

The instrument is powered by two (2) standard 9 volt alkaline batteries (Duracell type MN1604 or equivalent). that provide at least one (1) year of service under normal use. A built-in battery low detection circuit automatically indicates when the batteries are near the end of useful life.

2.2 Optional Accessories and Configurations

2.2.1 Analog Meter Readout

An optional plug-in module with a 2.5 inch analog meter is available to convert the Model 870 Wide Range Resistance Indicator to a Wide Range Resistance Meter. The face of the meter contains a three (3) decade scale that is colored in yellow, green and red, corresponding to the UNDER, PASS and OVER Range LED indicators. The UNDER and PASS scales are calibrated to measure resistance with two digit precision. The addition of the analog meter also expands the overall range of the Model 870 to a resistance range from 10 to $1x10^{12}$ ohms and to a resistivity range from $1x10^{2}$ to $1x10^{13}$ ohms/square.

2.2.2 Volume Resistivity

Volume resistivity may be calculated from the measurement of the resistance through a known thickness of material. The Model 870 can be used to measure this resistance; thus, an accurate calculation of its volume resistivity can be made. The ASTM D 257 formula for volume resistivity, ρ_v, can be used to calculate the volume resistivity as follows:

$$\rho_v = \frac{A}{t} R_m \text{ ohms-cm}$$

A = Area of measuring electrode in cm^2
t = Thickness of test specimen in cm
R_m = Measured resistance in ohms

For the Model 870 the area of the 2.5 inch diameter (6.35 cm) electrode is 31.67 cm^2, hence,

$$\rho_v = \frac{31.67}{t} \; R_m \text{ ohms-cm}$$

2.2.3 Surface Resistance Probe - Model 850

To accurately measure the point to point resistance on a flat surface requires a second circular probe whose weight, size and hardness are identical to the circular electrode in the Model 870.

The Model 850 Surface Resistance Probe is designed to meet these requirements as well as those set forth in NFPA 99, ASTM F 150 and EOS/ESD STD-4. The overall dimensions of the Model 850 Probe are 2.75 inches in diameter and 5.375 inches high, including the handle. The Probe has a weight of 5.0 pounds and contains a 2.5 inch diameter conductive silicone rubber electrode having a hardness of 65 durometer and as shown in Figure 2.2.3-1.



Figure 2.2.3-1

Model 850 Surface Resistance Probe

2.2.4 Personnel Resistance to Ground Configuration

The Model 870 can be used to accurately measure the resistance to ground of personnel grounding systems such as wrist and leg straps, conductive footwear, etc. A personnel resistance to ground configuration can be assembled by the user by using the 2.5 inch diameter electrode and placing the Indicator on a metal plate and connecting the external output to ground. Touching the metal plate will then give an accurate indication of the resistance to ground of the test subject.

3.0 OPERATION

The Model 870 Wide Range Resistance Indicator is an easy to use instrument for checking the resistive characteristics of material on a pass/fail basis. The instrument consists of four (4) controls: POWER, AUDIO, RANGE SELECT and TEST VOLTAGE. The POWER switch turns the unit on, which is indicated by one of the RANGE LEDs illuminating. The AUDIO switch enables the user to disable the pulsating out-of-range audio indicator. The RANGE SELECT switch determines which resistance/resistivity decade will be indicated by the PASS indicator. The TEST VOLTAGE select switch determines which test voltage is being used for the measurements. The measurement capability of the instrument is disabled when the 10^2-10_3 ohm or the 10^3-10^4 ohm/sq. ranges are selected with the TEST VOLTAGE set at 100 volts.

3.1 Resistivity Measurements

The Model 870 can measure the surface resistivity of virtually any homogeneous, flat surface that is at least 4.25" x 2.5".

Turn the POWER switch to ON and select the desired TEST VOLTAGE. Set the RANGE SELECT to the desired PASS range. If a specific resistance/resistivity is not specified or known, then just place the Indicator firmly on the test surface and wait at least 10 seconds before taking a reading. A PASS indication will indicate that the measured resistivity is within the decade range selected. A yellow or red indication will indicate the measurement is below or above the selected decade. Rotate the RANGE SELECT until a green PASS indication is obtained. Check the range selected. The measured resistivity will be accurately indicated as being within that decade.

The pulsating audible tone will sound whenever the indicated resistivity is either over or under the selected decade range. The tone can be disabled by the user if desired by placing the AUDIO switch in the OFF position.

3.1.1 Surface Resistivity Measurement Considerations

For most film and foam materials the standard 5 pound weight of the Model 870 Indicator is sufficient for the electrodes to make total contact with the material surface. However, for rigid materials such as table tops, plastics, cardboard, etc., additional force, which will have to be determined by the user, may have to be applied to the Indicator to ensure total contact. Microscopically, these surfaces are generally not smooth and are uneven as illustrated in Figure 3.1.1-1.

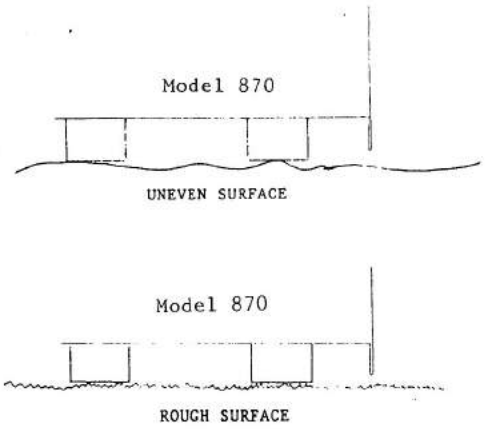


Figure 3.1.1-1

Microscopic Electrode/Rigid Surface Contact

In most cases the application of additionl pressure will cause the measured resistance reading to decrease. This is a result of both lower contact resistance and the total electrode/surface contact area (greater number of parallel resistance paths) Optimum contact pressure is obtained when the resistance/resistivity indication is stable.

Another area that must be considered when attempting to make a surface resistivity measurement is the composition of the material being evaluated. The materials defined in ANSI/ASTM D 257 are homogeneous, insulating types. However, in many specifications the materials are nonhomogeneous and relatively conductive. A surface resistivity, or in more accurate terms, a surface resistivity type measurement, can be made on these materials but modifications to the specified D 257 procedure must be made in order to obtain meaningful results.

The surface resistivities of materials having relatively low volume resistivities cannot be easily measured because the volume and surface resistivities interact. The current path between the electrodes is not only across the top surface but also through the material.

Similarly, the surface resistivities of materials that are coated with, or laminated to, a conductive surface cannot be measured. The surface resistance may actually be very high but the volume resistance may be relatively low. Therefore, the measured resistance may be that of the surface resistance path between the electrodes in parallel with the series combination of the two volume conductive paths and the conductive layer as shown in Figure 3.1.1-2.

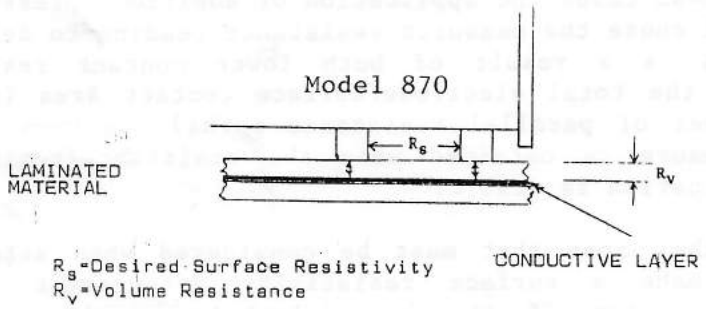


Figure 3.1.1-2

Volume Effects in ρ_S Measurements

Another material type is the composite. These materials generally consist of a high resistance resin loaded with conductive fibers. The surface resistivities of these materials is essentially nonmeasurable. What is actually being measured is the net resistance of the series/parallel combination of the conductive

fibers connecting the parallel bar electrodes.

Another very important consideration in measuring surface resistivity is the time of electrification. This is the time for the effective capacitance of the material to charge up. At this time, the current flow through the material reaches steady state and its flow is then a function of only the resistance of the material.

Effective material capacitance is generally quite low. For low resistance materials, the RC time constant, T , is very short. On the other hand, for high resistance materials the time constant can become quite long.

Resistances that are measured before the full time of electrification has occurred will appear to be lower than the actual resistance of the surface. This difference can be several orders of magnitude. ASTM D 257 recommends a time of electrification of 60 seconds, but in many measurements a shorter time may be used or a longer time may be required. Usually for small sample specimens with resistances less than 10^{12} ohms, an electrification time of 10 to 15 seconds is sufficient. On the other hand, with large surfaces such as table tops the capacitance is relatively large and 60 seconds may not be long enough. Here the user may either wait for the complete electrification to obtain a true resistance measurement or specify the measurement at the 60 second electrification time point for a relative resistance measurement. A rule of thumb, "When in doubt, allow more time than less time!"

3.2 Resistance to Ground Measurements

Select the resistance electrode by turning the 2.5 inch diameter electrode counterclockwise until it

is fully extended past the parallel bar electrodes. Connect the 3 foot red banana-to-banana cord to the red EXT PROBE banana jack located on the side of the unit. Connect the other end to the ground using either the banana plug or the alligator earth clip adaptor supplied. See Figure 3.2-1.

NOTE: When using the 2.5 inch diameter electrode, make certain that it is extended fully to ensure good electrical contact within unit.

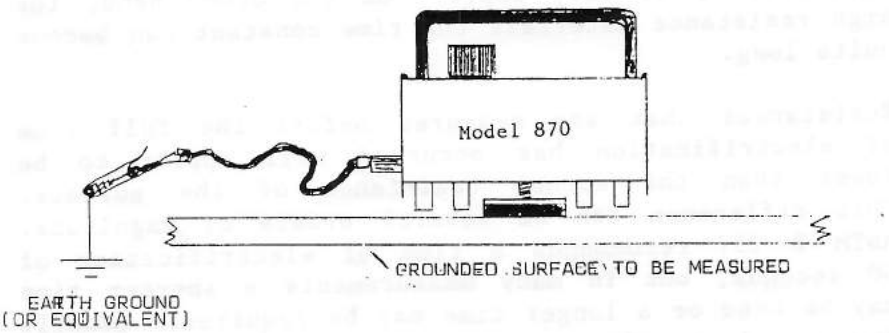


Figure 3.2-1

Resistance To Ground Test Set-up

Turn the POWER switch to ON and select the desired range.

Place the instrument firmly on the test surface and wait at least ten (10) seconds (or allow enough time for electrification) before reading the indicator. Rotate the selector switch until the green PASS LED lights.

Since the 5 pound weight of the indicator provides

the specified contact pressure, no additional pressure should be applied. The effects of electrification time discussed in Section 3.1.2 should also be observed when making the resistance to ground measurement particularly if the resistance range is above 10^{10} ohms.

3.3 Point To Point Resistance Measurements

Follow the procedure outlined in Section 3.2 for resistance to ground measurements except connect the EXT PROBE cable to a Model 850 Surface Resistance Probe as shown in Figure 3.3-1 below.

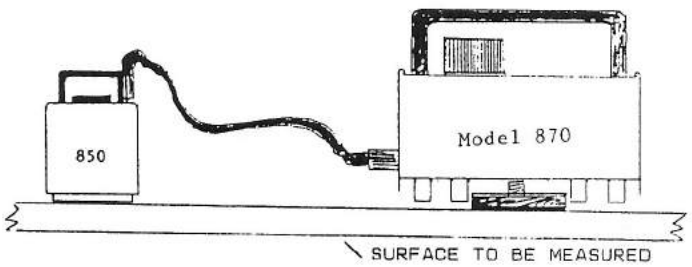


Figure 3.3-1

Point To Point Resistance Measurement

Place the Model 870 and the Model 850 at the required separation and take the measurement as desribed in Section 3.2.

3.4 Volume Resistivity

Extend the 2.5 inch resistance electrode as described

in Section 3.2. Connect the isolated ground plane (optional accessory) to the EXT PROBE output jack located on the side of the Model 860 as shown in Figure 3.4-1.

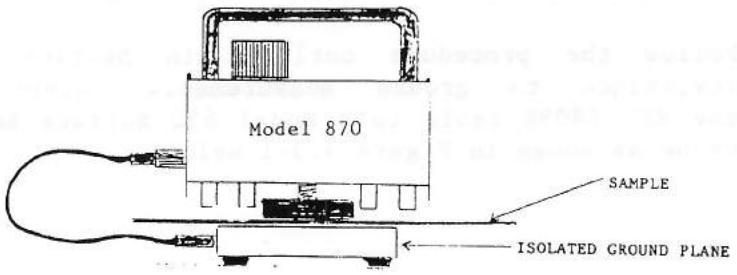


Figure 3.4-1

Measurement of Volume Resistivity

Turn the POWER switch to ON and select the desired range.

Place the test sample on the isolated ground plane and then place the Model 870 Indicator on top of the sample. The indicated resistance range will be the volume resistance of the sample. To obtain the volume resistivity, the thickness of the test sample must be measured. The volume resistivity may then be calculated as follows:

$$\rho_v = \frac{31.67}{t} \text{ Rm ohms-cm.}$$

If a non-metric measuring instrument is used, the measurement must be converted to cm. (NOTE: 1 mil = 2.54×10^{-3} cm.).

3.5 Battery Replacement

The Model 870 Indicator uses two (2) standard 9 volt alkaline batteries. Under normal use these batteries should last at least one (1) year. A Battery Low circuit is built-in to the instrument to warn the user when the batteries are approaching the end of their useful life.

1. When the battery voltage drops below 13 volts the BAT LO indicator will light. When the battery voltage drops below the minimum voltage for specified operation the instrument will shut down completely. No LED indicators will illuminate and no auto tone will sound.
2. UNDER or OVER range signals will flash more rapidly than normal.
3. Audible beep tone signal rate will increase.
4. Beep tone will become erratic or will produce a characteristic "squeal".
5. The unit will shut down completely.

To replace the batteries, remove the right side panel by loosening the 6-32 captive screw. The batteries are located between the printed circuit board and the solid brass chassis. When replacing the batteries be careful to dress the wires along the side panels so that they do not become pinched when the side panel is replaced. Replace with the following or equivalent: Duracell MN1604.

4.0 ANALOG METER READOUT (Optional)

The optional Analog Meter Readout converts the Model 870 Wide Range Resistance Indicator to a Wide Range Resistance Meter. The readout module plugs into the METER jacks provided on all Model 870 Indicators.

To install the meter module first screw in the black banana jack into the GND point located on the left side of the instrument. This jack now acts as both the case ground connection and the retainer for the

meter module. Slip the notched portion of the meter module bracket over the banana jack and then push the module downward so that the entire assembly fits over the raised side plate as shown in Figure 4.0-1 below.

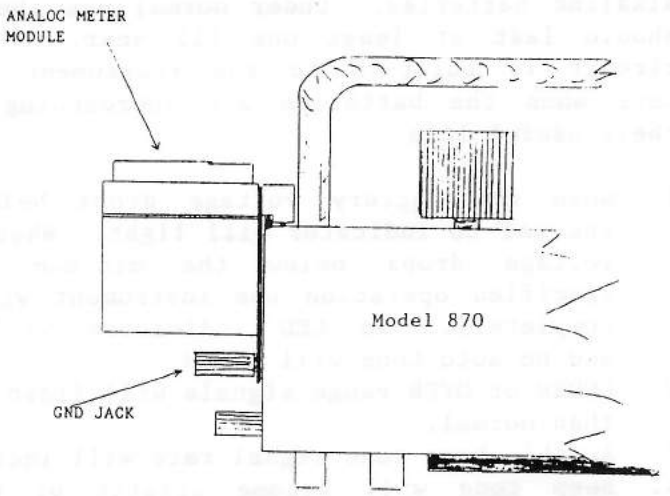


Figure 4.0-1

Analog Meter Module

Tighten the black banana jack to secure the meter module to the instrument.

The complete instrument is now a precision wide range resistance meter. The scales on the meter face are color coordinated with the range indicators on the 870. The green scale on the meter corresponds to the range selected using the RANGE SELECT knob on the 870. The yellow scale corresponds to the decade below the selected range and the red scale corresponds to the decade above the selected range. Since the red over range scale is highly compressed, only the yellow and green scales should be used to obtain actual resistance readings.

4.1 *Reading the Model 870M Meter*

The resistance or resistivity readings obtained from the 870M must be added to the range multiplier obtained from the setting of the 870 RANGE SELECT switch. For any measurement, the 870M provides the numerical part of the reading and the RANGE SELECT switch pointer on the 870 provides the decaded multiplier according to the following:

> Resistance or Resistivity = N x 10^X where N is the reading obtained from the 870M and 10^X is obtained from the RANGE SELECT switch setting of the 870.

EXAMPLES:

1. The resistance (point-to-point) of a surface is measured and the 870 Range Select switch is rotated until a green (PASS) indication is obtained. The 870M reading is 2.6 and the RANGE SELECT switch setting required to obtain a green (PASS) indication is the 10^4 to 10^5 ohm range (black). The point-to-point resistance measurement is then 2.6×10^4 ohms.
2. The resistivity of a "pink poly" material is measured and the 870 RANGE SELECT switch is rotated until a green (PASS) indication is obtained. The 870M reading is 4.5 and the RANGE SELECT switch setting required to obtain a green (PASS) indication is the 10^{10} to 10^{11} ohms per square range (inner [red] scale on the 870). The surface resistivity measurement is then 4.5×10^{10} ohms per square.
3. Same as number 2 above except the RANGE SELECT switch is set to the 10^{11} to 10^{12} ohms per square range, the yellow (UNDER) light is flashing and the 870M is indicating a .45 in the yellow region. The surface resistivity measurement is $.45 \times 10^{11}$ ohms per square. This is the same resistivity reading as was obtained in number 2 since $.45 \times 10^{11} = 4.5 \times 10^{10}$ (ohms per square).

In general, readings should only be taken using the yellow scale between .1 and 1.0 or the green scale between 1.0 and 10. Readings below .1 or above 10 (red region) should be avoided since the 870/870M system is not designed to provide accurate readings in these regions.

5.0 MAINTENANCE

The Model 870 Wide Range Resistance Indicator is a ruggedly constructed and reliable instrument but should be handled as you would any precision laboratory test equipment. The alignment of the electrodes is critical to ensure total surface contact. The silicone rubber contact material is impregnated with silver (resistivity electrodes) or carbon (resistance electrode). The user must ensure that the contact area is clean and free of contaminents prior to making a measurement. Also, the electrodes should not be exposed to atmospheres or surfaces that may corrode the silver particles. If exposure is necessary, the contacts should be cleaned with isopropyl alcohol immediately after use.

When not in use, the instrument should be kept in its carrying case (optional) or on a flat smooth surface. The electrodes should never be kept on a sharp or protruding object since this may damage or put a set in the silicone rubber.

If the rubber electrodes are damaged or the instrument fails to operate properly, the unit must be returned to Electro-Tech Systems for repair.

6.0 CALIBRATION CHECK

To verify the performance of the 870 and to check the calibration of each range, a test set-up utilizing a total of twenty (20) resistors of different values is required. Table 1 lists the resistor values required to check the calibration of each range.

An incorrect indication of a particular resistor value tested in the appropriate range indicates that the range is out of tolerance.

Figure 6.0-1 shows the recommended test set-up for performing the calibration check. Test leads should be short and preferably made with Teflon insulated wire. When measuring the higher ranges (above 10^7 ohms), lead dress and operator movement can affect the measurement. Utmost care should be exercised to minimize any erroneous indications.

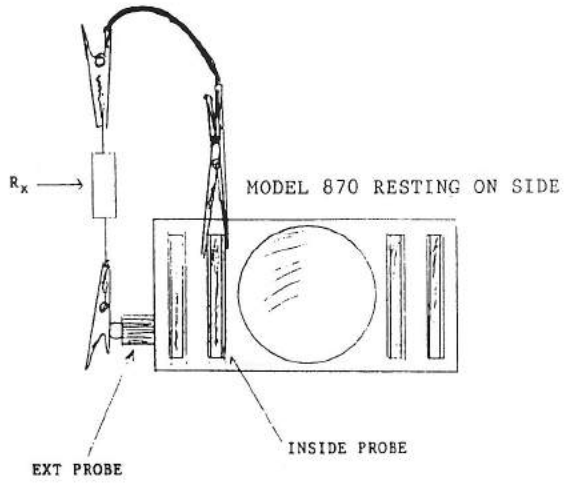


Figure 6.0-1

Calibration Test Set-up

ETS has available the Model 869 Wide Range Resistance Calibrator that contains all the necessary resistance values appropriately switched to test each range. Consult the factory for price and availability.

TABLE 1

Calibration Chart

RANGE	CALIBRATION RESISTOR VALUE	INDICATION UNDER	PASS	OVER	NOTES
1.0×10^2/ 1.0×10^3 Ω	98 Ω	X			Use ¼ watt or larger resistors for these tests.
	102 Ω		X		
	980 Ω		X		
	1.02K			X	
1.0×10^3/ 1.0×10^4 Ω	980 Ω	X			Allow at least 10 seconds for indicators to stabilize.
	1.02K		X		
	9.8K		X		
	10.2K			X	
1.0×10^4/ 1.0×10^5 Ω	9.8K	X			Allow at least 10 seconds for indicators to stabilize.
	10.2K		X		
	98K		X		
	102K			X	
1.0×10^5/ 1.0×10^6 Ω	98K	X			Allow at least 10 seconds for indicators to stabilize.
	102K		X		
	980K		X		
	1.02 Meg			X	
1.0×10^6/ 1.0×10^7 Ω	980K	X			Allow at least 10 seconds for indicators to stabilize.
	1.02 Meg		X		
	9.8 Meg		X		
	10.2 Meg			X	
1.0×10^7/ 1.0×10^8 Ω	9.8 Meg	X			Allow at least 10 seconds for indicators to stabilize.
	10.2 Meg		X		
	98 Meg		X		
	102 Meg			X	
1.0×10^8/ 1.0×10^9 Ω	95 Meg	X			Allow at least 1 minute for indications to stabilize
	105 Meg		X		
	950 Meg		X		
	1.05 Gigohm			X	
1.0×10^9/ 1.0×10^{10} Ω	950 Meg	X			Allow at least 1 minute for indications to stabilize
	1.05 Gigohm		X		
	9.5 Gigohm		X		
	10.5 Gigohm			X	
1.0×10^{10}/ 1.0×10^{11} Ω	9.5 Gigohm	X			Allow at least 2 minutes for readings to stabilize
	10.5 Gigohm		X		
	95 Gigohm		X		
	105 Gigohm			X	

7.0 WARRANTY

Electro-Tech Systems, Inc. warrants the Model 870 Wide Range Resistance Indicator for a period of one (1) year (from date of invoicing) to be free from malfunctions due to defects in material or workmanship. Should the system malfunction during the warranty period, ETS will, at its option, either repair or replace any part that, in its opinion, failed due to faulty material or workmanship. For service under this warranty, the equipment must be returned to ETS (shipping costs prepaid) with the following information:

1. Date of purchase
2. Model and serial number
3. RMA (Return Material Authorization) Number supplied by ETS
4. Description of malfunction or reason for return of equipment
5. Name and phone number of person who may be contacted for additional information

ETS must be contacted and authorization obtained prior to return of any equipment for servicing.

ETS liability under this warranty is specifically limited to the equipment sold by ETS. ETS shall not be liable for damage to any other equipment or material resulting or claimed to have resulted from a failure or malfunction of the said equipment covered by this warranty.

This warranty is void if the user repairs, modifies, alters or attempts to service this equipment without the specific prior knowledge and authorization of ETS.

Use of this equipment in any application or environment other than for which it was intended shall also void the warranty.

It is recommended that equipment returned for servicing be shipped in its original shipping carton with original packing material. If this is not possible, the equipment should be packaged adequately to insure arrival at ETS free from shipping damage. Bubble type packing material is recommended. Loose fill material should be avoided. ETS cannot be held responsible for damage to equipment that occurs during shipment.

This is the only warranty offered by the Seller. There are no other warranties expressed or implied with respect to the Model 870.

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