the GENERAL RADIO Experimenter

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

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IMPROVED SLOTTED LINE INCREASES ACCURACY AND CONVENIENCE OF COAXIAL LINE MEASUREMENTS

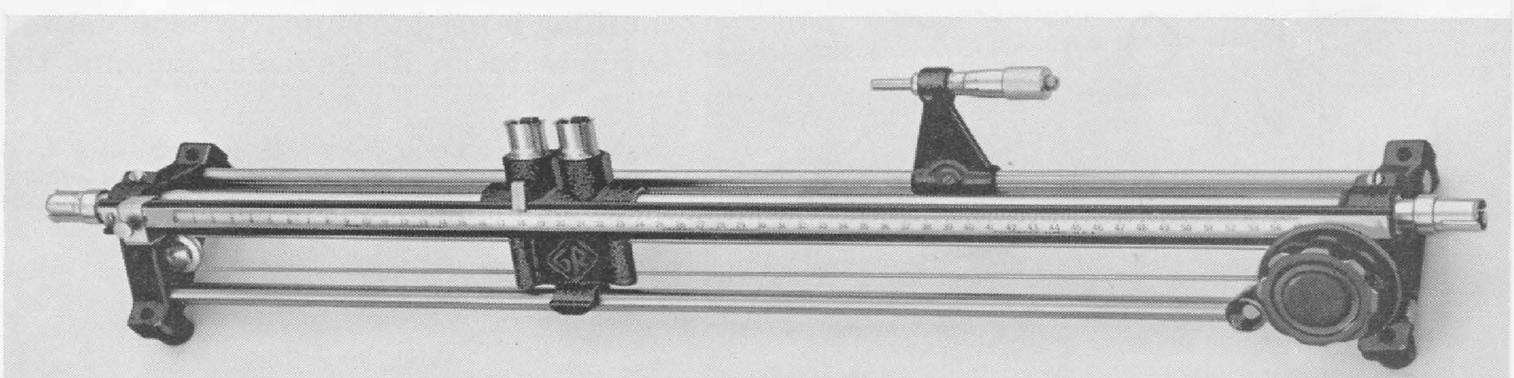
● **THE GENERAL RADIO** TYPE 874 Coaxial Connector has gained rapid acceptance as an outstandingly useful connector for measurement applications. Its universal nature, which permits any connector to plug into any other, simplifies setups, and fosters accuracy by eliminating the plug-to-plug and jack-to-jack adaptors that are so often necessary when plug-and-jack-type connectors are used. In addition, its quick-connect-and-disconnect feature has been found to be an important time saver in many applications.

Around this connector has been built an extensive line of coaxial components and instruments, which, because of their flexibility, accuracy, and economy, have been widely accepted in laboratories, on the production line, and in the field, for measurement work at frequencies from dc to 5000 megacycles.

One of the basic measuring devices used in measurements on coaxial-line circuits is the slotted line. With it the standing-wave pattern on a coaxial line can be measured, and standing-wave ratio, impedance, loss, and many other quantities can be determined. One of the most important General Radio coaxial devices is the TYPE 874-LB Slotted Line, which has been a popular commercial instrument for many years. A new version of this slotted line, the TYPE 874-LBA, has now been developed, which has higher accuracy and greater operating convenience than its predecessor.

The new instrument has an improved mechanism for driving the electrostatic pickup probe, a more constant probe coupling along the line, a sturdier supporting structure, negligible backlash, felt lubricating and cleaning washers, im-

Figure 1. View of the Type 874-LBA Slotted Line with Type 874-LV Micrometer Vernier.



proved center conductor and probe support, adaptability to motor drive, and many other mechanical and electrical improvements.

The new slotted line has a nominal frequency range from 300 to 5000 Mc, but measurements can be made at frequencies as low as 150 Mc and above 5000 Mc with some sacrifice in accuracy. The constancy of coupling of the pickup probe along its entire 50 cm of travel is within $\pm 1\frac{1}{2}\%$, and the residual voltage standing-wave ratio of the line and connectors is less than 1.025 at 1000 Mc and less than 1.07 at 4000 Mc.

Probe Carriage Drive

In order to minimize the distortion of the line and the changes in effective probe coupling resulting from forces applied to the knob that drives the probe carriage, the driving knob is mounted in a fixed position on the right-hand end casting as shown in Figure 1, and the carriage is driven by means of a nylon cord. The cord forms a complete loop, which is attached to the carriage at one point, and which passes over an idler pulley on one end of the line and around a drum attached to the knob shaft on the other, as shown in Figure 2. The connection between the cord and the driving drum is obtained by means of friction, and one and a half turns of the cord around the drum have been found sufficient for positive drive without slippage. Since there are no teeth or grooves involved in the drive mechanism, a very smooth adjustment is obtained. Ball bearings are used on the drum and pulley to reduce the driving force required and to minimize wear. A small ratchet-type take-up reel is mounted on the back of the carriage to permit adjustment of the tension in the nylon cord.

The fixed position of the driving knob, the use of ball bearings throughout, and the durability of the nylon cord make the line easily adapted to motor drive. A motor-drive attachment will be available in the near future.

Probe Carriage Construction

The probe carriage has several important features. It is made of cast bronze and hence slides on bronze bearings on the finely ground, chrome-plated surface of the outer conductor. Play in the carriage, which can cause rocking and consequent changes in probe coupling when the direction of travel is reversed, is eliminated by the use of two adjustable, spring-loaded nylon plugs, which bear against the bottom of the outer conductor of the line at each end of the carriage. A felt washer is mounted at each end of the carriage to prevent dirt and other foreign material, which may collect on the open surface of the outer conductor, from entering the bearing. Oil holes are provided to permit these washers to be filled with oil which provides long-lasting lubrication of the bearings in the sliding carriage. A long Teflon bushing is used to support the probe and reduces to an insignificant amount the

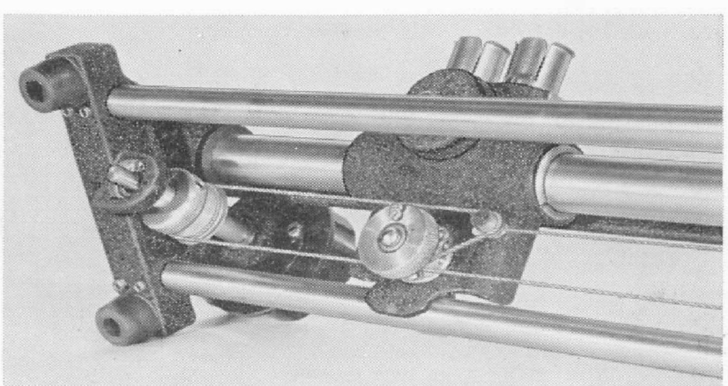


Figure 2. View of the drive mechanism showing the driving drum, ratchet take-up mechanism and nylon cord.

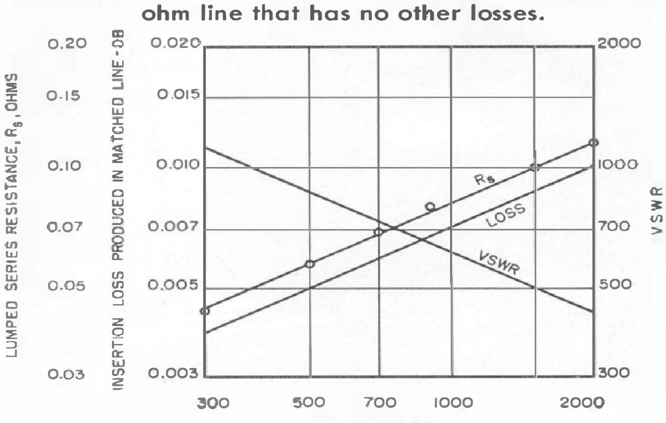
transmission of motion from the tuning stub to the probe.

Line Construction

The outer conductor of the line itself is rigidly clamped in heavy bronze castings at both ends and the structure is stiffened by means of two half-inch stainless rods, so that distortion of the conductor as a result of mechanical forces is very small. Two insulators at each end of the line support the center conductor in order to minimize the transmission of forces from the elements connected to the line, which might tend to deflect the center conductor. The supporting insulators are not located in the slotted section of the line and hence do not cause irregularities in the probe coupling. They are also electrically compensated to minimize reflections. The center conductor is made of steel tubing for rigidity, with heavy copper and silver platings applied for low electrical losses. The section in the slotted region is connected to the sections containing the supports by means of ball joints in order to reduce still further the transmission of deflecting forces.

The end castings are provided with holes which extend through the rubber feet to permit mounting the line permanently to a bench or board, if desired.

Figure 4. Plot of the effective lumped series resistance at the connector measured on a typical Type 874-LBA Slotted Line. The insertion-loss produced in a matched line by the measured value of lumped resistance is also indicated, as well as the VSWR which would be produced by the measured lumped resistance located at a current maximum in an open- or short-circuited 50-ohm line that has no other losses.



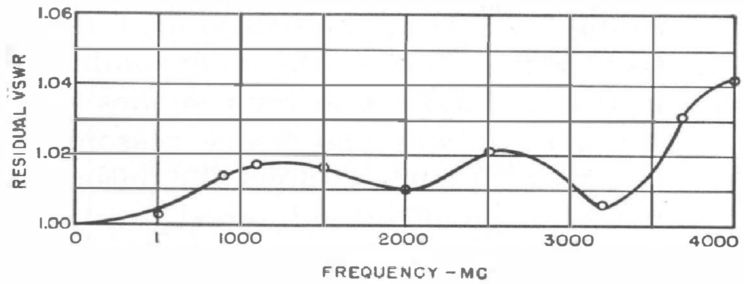


Figure 3. Residual VSWR of a typical slotted line and associated Type 874 Connectors, as measured by the sliding short-circuit method.

Performance

The high degree of constancy of probe coupling over the entire 50-cm length of probe travel is achieved by accurate straightening of the inner and outer conductors. Both conductors are straightened to within $\pm .001$ inch. A further reduction in the variation in probe coupling is obtained by rotation of the center conductor after assembly until the highest degree of constancy is obtained. The resultant variation in probe coupling is always less than $\pm 1\frac{1}{2}\%$.

The TYPE 874 Connector on the line provides a smooth transition between the line and the circuit under test. Figure 3 shows the results of measurements, made by the sliding-short-circuit method, of the residual VSWR of the line and the associated TYPE 874 Connector. Low-reflection adaptors are available to practically any commonly used 50-ohm connector series, including the large rigid lines which are used in television and radar transmission circuits. (See the list at end of article.)

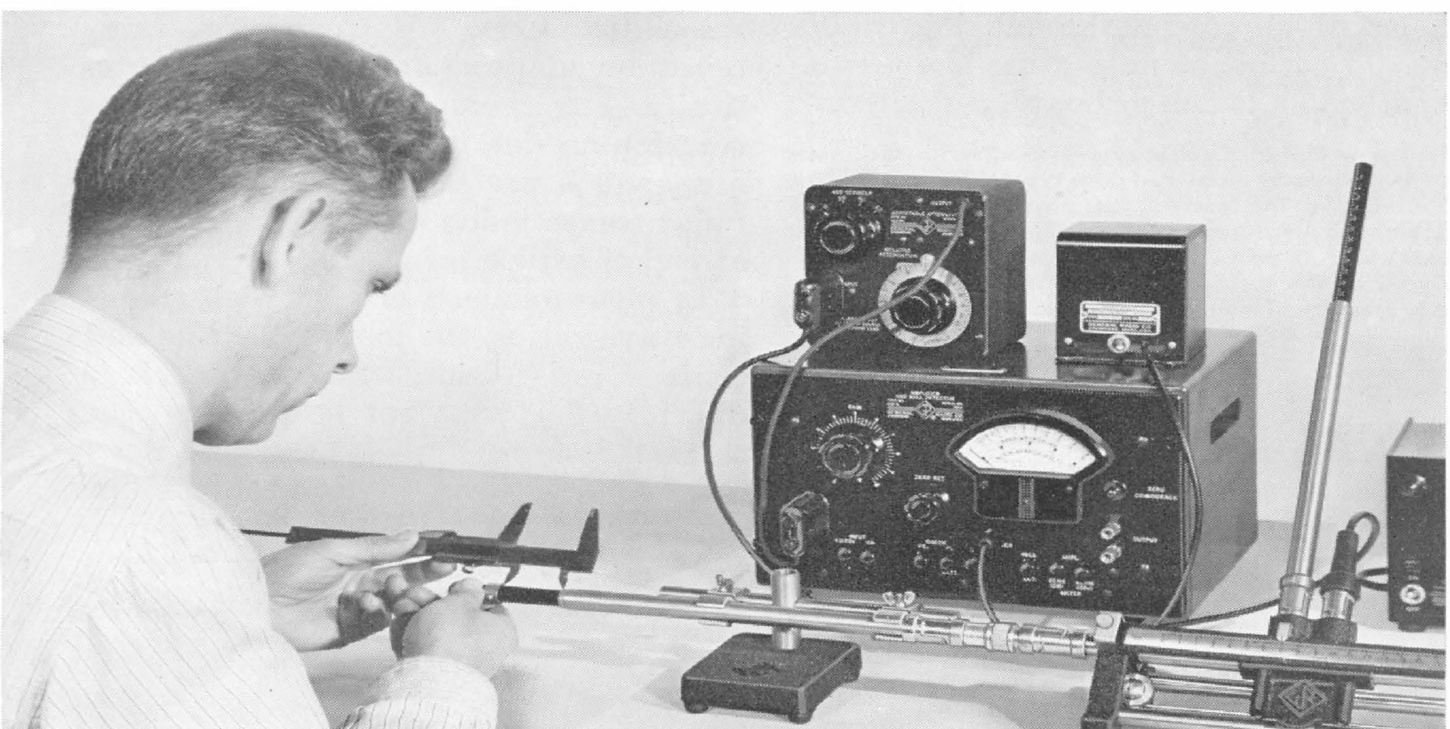
In measurements of very high standing-wave ratios, the loss in the line and connectors is of importance. Since it is difficult to correct for line losses that are not uniformly distributed, it is an advantage to have the losses both low and as uniformly distributed as possible. In the TYPE 874-LBA Slotted Line, some lumped loss is present at the connector and at the ball joint, but the large physical size of the inner conductor in the line and connector provides large contact surfaces and hence reasonably low losses. Figure 4 shows the measured value of the effective lumped resistance as a function of frequency in a typical Type 874-LBA Slotted Line.

Applications

The economy, size, and performance of the Type 874-LBA Slotted Line and the availability of numerous low-reflection adaptors and coaxial components make the line well suited to a wide variety of measurements in the laboratory, on the production line, and in the field. Measurements on dielectric materials, lumped components, coaxial elements and networks, and antennas in the u-h-f range can be made accurately and simply with this slotted line and its associated components.

One application is the measurement of the VSWR of adaptors such as the Type 874-QNP and -QNJ Adaptors to Type N Connectors. One method of making this measurement is to connect two adaptors back to back and to insert them between the end of the slotted line and a Type 874-D20 Adjustable Stub as shown in Figure 5. The VSWR of the pair of connectors is then measured by the sliding-short-circuit method. In this method, the stub is set to several accurately measured positions over a distance of at least a half wavelength, and the position of a voltage minimum on the slotted line is accurately determined for each stub setting. If a discontinuity is present, the linear distance between the stub and the voltage minimum on the slotted line will change with the position of the standing-wave pattern. For instance, if the discontinuity is a series inductance, the length of the line section will be decreased the maximum amount when a current maximum occurs at the series inductance. When a current minimum occurs at the series inductance, the line length is unaffected by the presence of the inductance. Hence, as the position of the short circuit in the stub is changed to move the standing-wave pattern

Figure 5. View of the slotted line and associated equipment set up for measuring VSWR of a pair of UG-type adaptors. The detector is a Type 1231-B Amplifier and Null Detector.



along the line under test, the apparent length of the line will change, and the distance between the position of the short circuit in the stub and the voltage minimum on the slotted line will vary. The maximum variation, Δ, is related to the VSWR introduced by the section of line under test by the approximation

$$VSWR \approx 1 + \frac{2 \pi \Delta}{\lambda}.$$

The approximation is valid when the VSWR is small.

The actual distance between the short circuit and the voltage minimum need not be measured because the variation in length can be determined from the relative motion of the stub and probe. The change in stub position must be accurately set, and a pair of calipers or gauge blocks can be used for this purpose. The probe position can be determined with sufficient accuracy by use of the scale on the slotted line. Figure 6 shows the results of typical measurements on UG-type adaptors.

The TYPE 874-LBA Slotted Line, in conjunction with the wide variety of oscillators, coaxial elements, and detectors produced by the General Radio

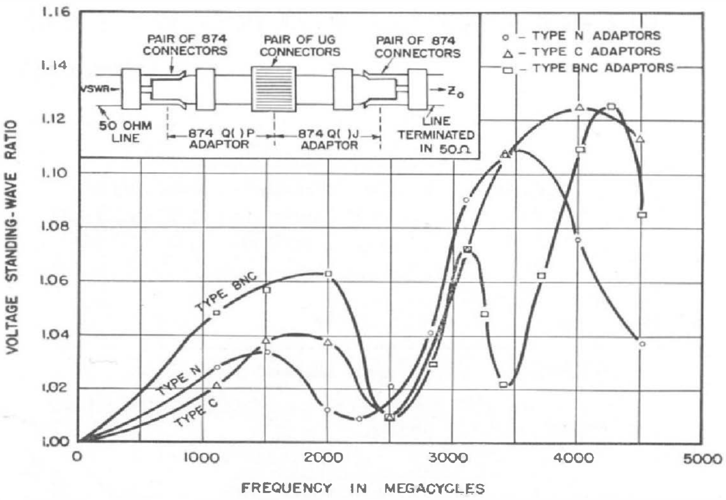


Figure 6. VSWR as a function of frequency for typical adaptors. Measurements were made on pairs of adaptor units, as shown in the sketch, and, hence, the standing-wave ratios shown are the totals produced by two pairs of Type 874 Connectors plus a pair of UG-type (i.e., N, C, or BNC) connectors.

Company, makes possible simple, accurate measurements of impedance, standing-wave ratio, attenuation, and many other quantities with relatively inexpensive equipment. The continual improvements of existing components and instruments and the development of new devices to expand the usefulness of the TYPE 874 Coaxial Elements will continue to broaden the applicability of this versatile line.

— R. A. SODERMAN

SPECIFICATIONS

Characteristic Impedance: 50 ohms $\pm 1\%$.

Probe Travel: 50 centimeters; scale is calibrated in millimeters.

Frequency Range: 300 to 5000 megacycles. Operation at frequencies below 300 Mc is possible, if lengths of TYPE 874-L30 Air Line are added.

Dielectric: Air.

Accuracy: Constancy of Probe Penetration — $\pm 1\frac{1}{2}\%$. VSWR of Terminal Connectors:
Less than 1.025 at 1000 Mc.
Less than 1.07 at 4000 Mc.

Crystal Rectifier: 1N21B-type silicon crystal.

Accessories Required: Suitable generator and detector (see next page).

Other Useful Accessories: TYPE 874-WM 50-ohm Termination; TYPE 874-WN3 Short-Circuit Termination; TYPE 874-W03 Open-Circuit Termination; TYPE 874-M Component Mount; TYPE 874-UB Balun; and other TYPE 874 Coaxial Elements. See current General Radio catalog for details and prices, or write our Sales Engineering Department. Coaxial adaptors as listed on page 6 are available for connecting to other types of coaxial connectors. Where standing-wave ratios greater than 10 are to be measured, a TYPE 874-LV Micrometer Vernier attachment and a harmonic filter should be used.

Dimensions: 26 x $4\frac{1}{2}$ x $3\frac{1}{2}$ inches, overall.

Net Weight: $8\frac{1}{2}$ pounds.

Type		*Code Word*	*Price*
874-LBA	Slotted Line	COAXRUNNER	$220.00
874-LV	Micrometer Vernier Attachment	COAXREADER	23.00
874-F1000	Low-Pass Filter	COAXMEGGER	10.00
874-F500	Low-Pass Filter	COAXDIPPER	16.00

GENERATORS AND DETECTORS FOR THE SLOTTED LINE

GENERATORS

The following generators are recommended:

Type		*Price*
1208-A	Unit Oscillator, 65-500 Mc	$190.00
1209-A	Unit Oscillator, 250-920 Mc	235.00
1215-B	Unit Oscillator, 50-250 Mc	190.00

The above Unit Oscillators do not include power supply; the TYPE 1203-A Unit Power Supply is recommended.

Type		*Price*
1203-A	Unit Power Supply	$ 40.00

If a modulated signal is desired, the TYPE 1214-A Unit Oscillator is recommended, to supply the modulating signal.

Type		*Price*
1214-A	Unit Oscillator	$ 66.00

DETECTORS

Two satisfactory detector combinations are listed below:

1. *Using audio-frequency output of crystal rectifier in slotted line.* Requires a modulated generator (see above). Necessary equipment consists of the following items:

Type		*Price*
1231-B	Amplifier and Null Detector	$250.00
1231-P2	Tuned-Circuit Filter	25.00
1231-P4	Adjustable Attenuator	70.00
874-D20	Adjustable Stub, 275-5000 Mc	11.00
874-R32A	Patch Cord	5.50
TOTAL		$361.50

2. *Heterodyne system.* The signal from the generator and a signal from an auxiliary oscillator are combined in a TYPE 874-MR Mixer Rectifier to produce a 30-megacycle difference frequency, which is fed to a TYPE 1216-A Unit I-F Amplifier.

This method of detection affords much better shielding than a receiver used directly at the operating frequency, and, in addition, provides the high degree of selectivity needed for measuring high standing-wave ratios.

The TYPE DNT Detectors are complete heterodyne detector assemblies and were described in the *General Radio Experimenter* for May, 1954.

Type		*Price*
DNT-1	Detector Assembly, 35 to 530 Mc	$628.00
DNT-2	Detector Assembly, 25 to 280 Mc	628.00
DNT-3	Detector Assembly, 220 to 950 Mc	667.00

ADAPTORS

When connections are to be made to systems using other types of coaxial connectors, adaptors as listed below will be needed.

Type	*Elements Used in Adaptor*	*Price*
874-QNP	Type 874 and Type N Plug	$4.50
874-QNJ	Type 874 and Type N Jack	3.75
874-QBP	Type 874 and Type BNC Plug	4.75
874-QBJ	Type 874 and Type BNC Jack	4.75
874-QCP	Type 874 and Type C Plug	6.25
874-QCJ	Type 874 and Type C Jack	4.75
874-QHP	Type 874 and Type HN Plug	6.50
874-QHJ	Type 874 and Type HN Jack	6.50
874-QUP	Type 874 and Type UHF Plug	4.25
874-QUJ	Type 874 and Type UHF Jack	4.00
874-QV3	Adaptor to V-H-F 3⅛″ rigid line (51.5 ohms)	87.00
874-QU3A	Adaptor to U-H-F 3⅛″ rigid line (50.0 ohms)	87.00
874-QV2A	Adaptor to V-H-F 1⅝″ rigid line (51.5 ohms)	46.00

TYPE 874 Coaxial Connectors are manufactured and sold under U. S. Patents 2,125,816 and 2,548,457.

NEW MODEL OF THE MEGOHMMETER HAS TWO TEST VOLTAGES

The Type 1862-A Megohmmeter,[1] has found wide acceptance in the electrical and electronic industries for the rapid measurement of insulation resistance, the measurement of high-valued resistors, and for general resistance testing. In this instrument, the voltage across the resistance being measured is 500 volts, a value accepted as standard by most industrial and professional groups.

There have developed, however, a number of tests that should be made at a voltage considerably lower than 500, in order to avoid any damage to the specimen under test, and, to meet this requirement, a new model, the Type 1862-B, has been developed, in which two test voltages are provided, 500 volts and 50 volts, either of which can be selected by means of a panel switch.

The 50-volt test level will be found useful in resistance measurements on printed circuits and on components used in transistor circuits and in miniaturized equipment. The 500-volt level is used for measuring the insulation of rotating electrical machinery, transformers, capacitors, cables, appliances, and other power-line operated equipment.

From measurements made with both voltages, it is possible to determine the voltage coefficient of insulation resistance.

The selection of 50 volts as the low-voltage test potential permits a single meter scale to be used, thus preserving the simplicity and ease of interpretation inherent in the original design. The answer in megohms is still the product of a meter reading and a decimal multiplier. A neon lamp operated by the voltage-selection switch warns when the operating voltage is 500 volts.

Figure 1. View of the Type 1862-B Megohmmeter.

The low end of the resistance range is one half megohm for both operating-voltage conditions. For the 500-volt condition, the limiting factor is short-circuit current. When the unknown resistance is a short-circuit, the current that flows is about ten milliamperes at the lowest multiplier setting and is proportionately less at the higher settings. For the 50-volt condition, the limiting factor is the source resistance of the 50-volt supply (about 27 kilohms), which accounts for the larger error at the low range of the low-voltage condition (see specifications).

The high end of the resistance range is ten times as great (2,000,000 megohms) for the 500-volt condition as for the 50-volt condition. This is inherent in the circuitry, which consists essentially of a d-c supply (50 or 500 volts), an unknown, and a standard resistance, all in a series loop; a vacuum-tube voltmeter of two volts full scale is connected

[1] "A 500-Volt Megohmmeter for Insulation Testing," *General Radio Experimenter*, Vol. XXVI, No. 6, November, 1951.

across the standard and is calibrated to indicate megohms directly.

While the new megohmmeter is useful for measuring resistors and the leakage of both high-voltage and low-voltage capacitors and insulators, the facility with which voltage coefficient can now be determined opens up new fields of application.

—A. G. Bousquet

SPECIFICATIONS

Voltage Across Unknown: 500 volts or 50 volts, as selected by means of a panel toggle switch. A neon lamp warns when the 500-volt supply has been selected.

Over a 105-125-volt range in line voltage and over the resistance range of the instrument, the variation in voltage across the unknown resistor will be less than ±10 volts at 500 volts and less than ±4.0 volts at 50 volts.

Range: 0.5 megohm to 2,000,000 megohms at 500 volts and to 200,000 megohms at 50 volts. There are six decade steps as selected by a multiplier switch.

Scale: Each resistance decade up to 500,000 megohms (50,000 megohms for 50 volts) utilizes 90% of the meter scale. Center scale values are 1, 10, 100, 1000, and 10,000 megohms, with an additional center scale value of 100,000 megohms for 500-volt operation.

Accuracy: For 500-volt operation, the accuracy in per cent of indicated value at all but the highest multiplier setting is ±3% at the low-resistance end of each decade, ±8% at mid-scale, and ±12% at the high-resistance end. There can be an additional ±2% error at the highest multiplier setting.

For 50-volt operation, there can be an additional ±2% error on all but the 0.5-5 megohms decade where the additional error can be ±5%.

Terminals: In addition to terminals for connecting the unknown, ground and guard terminals are provided. At two positions of the panel switch, all voltage is removed from all terminals to permit connection to be made in safety. In one of the positions, the UNKNOWN terminals are shunted to discharge the capacitive component of the unknown. All but the ground terminal are insulated.

Calibration Check: A switch position is provided for standardizing the calibration at 500 volts.

Design: Since field applications are more severe than laboratory use, the instrument was designed to be unusually rugged. The carrying case can be completely closed; accessory power cable and test leads are carried in the case. Controls are simplified for use by untrained personnel.

Tubes: Supplied with the instrument:

1 — 12AU7	1 — 2X2-A
1 — OA2	1 — 6AB4
1 — 6X4	1 — 6AU6
1 — 5651	1 — NE-51

Controls: A switch for selecting the operating voltage, a switch for selecting the multiplying factor, a control for standardizing the calibration, a control for setting the meter to the infinity reading, and a power switch.

Mounting: The instrument is assembled on an aluminum panel finished in black-crackle lacquer and is mounted in an aluminum cabinet with black-wrinkle finish and with black-phenolic protective sides. The aluminum-cover finish is black wrinkle. The case is provided with a carrying handle.

Power Supply: 115 (or 230) volts at 40 to 60 cycles. The power input is approximately 25 watts.

Accessories Supplied: Two color-coded test leads with phone tips, two insulated probes, two alligator clips, and a Type 274-MB plug.

Dimensions: (Height) 10⅛" x (width) 9⅛" x (depth) 11¾", overall.

Net Weight: 15½ pounds.

Type		*Code Word*	*Price*
1862-B	**Megohmmeter**	JUROR	**$225.00**

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