2423

INSTRUCTIONS AND APPLICATIONS

Megohmmeter Type 2423

Up to 10 million megohms can be measured. Measurements of voltages to 2000 V and currents down to 10 micromicroamps dc make Type 2423 an instrument for wide industrial and laboratory use.

:celerometers
oustic Standing Wave Apparatus
:ificial Ears
:ificial Voices
dio Frequency Response Tracers
dio Frequency Spectrometers
idio Frequency Vacuum-Tube Voltmeters
Automatic A. F. Response and Spectrum Recorders
Automatic Vibration-Exciter Control Generators
Band-Pass Filter Sets
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Deviation Bridges
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Frequency Analyzers
Frequency Measuring Bridges
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Strain Gage Apparatus and Accessories
Surface Roughness Meters
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VHF-Converters
Vibration Pick-ups
Vibration Pick-up Preamplifiers
Wide Range Vacuum Tube Voltmeters

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Megohmmeter.

Type 2423.

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Contents

Description.

General.

The Megohmmeter Type 2423 (fig. 1) is a mains operated d. c. tube voltmeter with high input resistance. The tube voltmeter can be used either for measuring d. c. voltages or in connection with a built-in stabilized voltage supply for measuring high resistances, e. g., insulation resistance in capacitors, cables and insulation materials. One particular application of the equipment is the measurement of insulation in strain-gage set-ups.

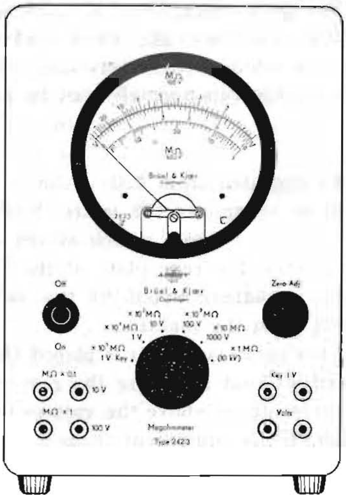


Fig. 1. Drawing of the Megohmmeter Type 2324.

As the circuit diagram at the back shows, the d. c. voltage to be measured is fed to a voltage divider with a total resistance of 100 megohms. Use of such high resistance values is made possible by a cathode-coupled pre-amplifier stage, operating with a specially low anode voltage, in fact so low that no ionization takes place in the tube, so that the grid current is very low.

From this stage, which is balanced and which uses a double-triode, the voltage is led from the cathodes to the grids of another double-triode, between whose anodes is placed the moving-coil meter. This latter balanced amplifier stage operates in consequence with a low and constant impedance on the grids, so that the grid current is insignificant. The sensitivity of this last amplifier stage can be controlled by means of a variable resistance placed between the two cathodes. The instrument is completely safeguarded against overload and has an easily read illuminated logarithmic scale. Zero point adjustment is carried out by means of a potentiometer in the anode circuit of the last amplifier stage.

The d. c. voltmeter has ranges 1 — 10 — 100 — 1000 and 10000 volts for full deflection, to which it must be pointed out that the last measuring range of 10000 volts should only be used for voltages of up to approx. 2000 volts. This voltage range is only included because there was use for that range in measuring insulation resistance.

When measuring insulation resistance the tube voltmeter is used in connection with two built-in voltage sources for stabilized voltages of respectively 10 volts and 100 volts. To make possible the measurement of insulation resistance in large capacitors, these voltages are stabilized very carefully by means of two glow-tubes. The 100 volts supply is normally used for measuring insulation resistance in cables and capacitors, while the 10 volts supply is specially intended for measuring insulation in strain gage set-ups, where a higher voltage can normally not be used.

Power Supply.

The equipment can be operated from 220 — 150 — 127 — 115 volts a. c. mains. Power consumption is approx. 12 watts. Setting to different mains voltages is carried out with a voltage switch which can be operated by a screwdriver through a hole in the rear plate of the equipment. The voltage selected is indicated on a plate coupled to the switch. When adjusting, disconnect the equipment from the mains.

A fuse in the transformer-primary circuit is placed above the voltage switch. The fuse can be replaced without removing the rear plate of the equipment, simply by removing a cover placed above the voltage switch.

If it is desired to operate the equipment from d. c. mains or accumulator, a vibrator unit or rotary converter should be used.

Operation.

General.

The apparatus is connected to the mains and switched on, the scale lamp lighting immediately. The tube cathodes warm up in about 20 seconds, and in about 2 minutes the apparatus is ready for use.

Zero point adjustment is carried out by means of the knob on the right. The adjustment is practically constant for all ranges, except for the 100000 MΩ range, where the zero point may shift a little.

When measuring d. c. voltages, the voltage to be measured is connected to the two sockets on the right marked "Volt". The right hand socket of the two is connected to the equipment's frame, while the left hand socket goes to the voltage divider, with a total resistance of 100 megohms. The apparatus normally only measures voltages which are positive in relation to the frame. If one wishes to be able to measure voltages which are both positive and negative in relation to the equipment's frame, a zero point adjustment can be made corresponding to the instrument's internal scale, i. e., in the zero position the instrument's pointer is set at the electrical mid-point of the scale; in this way one obtains a scale range of — 0.5 — 0 — + 0.5 volt, instead of the normal 1 volt range, and similar ranges can be set up in the case of the others.

When measuring insulation resistance with the 100 volts supply, the unknown resistance is connected to the two sockets marked $M\Omega \times 1$, and the resistance can then be read off on the scale, being a product of the reading and the factor given on the range switch. If one wishes to use the 10 volts supply, the resistance is connected to the two sockets marked $M\Omega \times 0.1$, and this factor of 0.1 must be introduced into the value read. The meter has a further scale effective for a measuring voltage of 500 volts. This voltage must be supplied from an external source.

For precision measurements with the 10 volts supply, corrections for the scale calibrations must be used. The reason is that the value of the full deflection on the meter's 1 volt scale is not negligible in comparison with the measuring voltage, as is the case with the 100 volts supply. The corrections are made according to the following table:

Correction Table for the 10 V Range.

Real Value	Meter Value	Real Value	Meter Value
1	1.05	8	7.72
1.5	1.53	9	8.66
2	2.00	10	9.61
3	2.95	15	14.40
4	3.90	20	19.20
5	4.85	50	48.00
6	5.80	100	95.00
7	6.76		

If the measuring object is a capacitor or cable of large capacity, much of the charging time can be saved by connecting a switch across the two sockets on the right marked "Key", this switch only being opened when the reading is taken on the instrument. The insulation resistance of this switch should be great in comparison with the 1000 megohms input resistance in the equipment.

If during measurements of insulation resistance of materials it is wished to avoid leakage currents over the surface of the material, a guard-ring can be used, which can be connected to the equipment's frame, for example by connecting it to the right-hand of the two sockets marked "Volt".

A 10 % variation in the mains voltage changes the tube voltmeter's sensitivity approx. 1½ % and the measuring voltages approx. 0.03 %. Changes in resistance measurements are consequently less than 2 %.

When measuring the insulation resistance of large capacitors, even a variation in the measuring voltage of only 0.03 %, e. g. 30 mV in 100 V, can be troublesome, if the variation takes place *quickly*. In such a case the variation will of course go through the capacitor into the d. c. tube voltmeter, whose sensitvity for full scale deflection is 1 V, so that the 30 mV will produce a 3 % change in the full deflection on the scale. If this cannot be accepted, a battery voltage source will have to be used.

Changing of Tubes and Readjustment.

The tubes are accessible when the equipment's rear plate is removed. After changing the tubes the equipment should be readjusted as described below. The scale-lamp socket is fastened to a bracket on the moving-coil instrument by means of a screw, and can be removed by loosening the screw by a screwdriver.

The tube voltmeter's sensitivity is adjusted by means of a potentiometer placed between the cathodes in the last amplifier stage. This potentiometer can be adjusted by means of a screwdriver through an aperture in the rear plate of the equipment. By comparing with a standard voltmeter the meter reading can be checked. This will be necessary after the replacement of tubes etc.

A readjustment of the measuring voltage after the glow tube stabilizers have been changed, is carried out by changing the resistance R5, placed on the terminal strip which is accessible when the equipment's rear plate is removed. If the measuring voltages are too small, this resistance must be decreased, and vice versa. However, this resistance should be altered only after the glow tubes have been well run-in.

The measuring voltages are between the equipment's frame and the two right-hand sockets of the pairs marked 100 V and 10 V, and their nominal values are 100½ volts and 10½ volts. They can be measured with a compensation or tube voltmeter. The voltages can however also be adjusted with the aid of known resistances, for example of 10 and 1 megohm, after the instrument's sensitivity as tube voltmeter has been adjusted.

Applications.

A series of examples will now be given to show how the Megohmmeter can be used for typical measurements.

Resistance and Insulation Measurements.
Fig. 2 shows the measuring set-up in which the resistance of a non-grounded object is measured, for example, between two transformer windings, the insulation resistance of a capacitor, or measurement of high resistance values. It is an advantage in this connection to ground the equipment, so that static voltages on the measuring object do not make measurements difficult by causing the pointer to fluctuate too much up and down. When measuring capacitors with very high insulation resistance the pointer can sometimes be very disturbed; see the special section on this for further details.

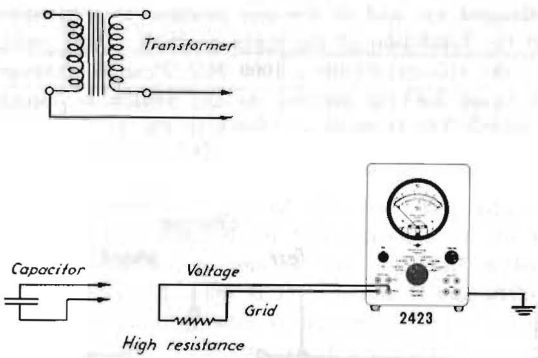


Fig. 2. Set-up for resistance-measurement of non-grounded objects.

Measuring Large Capacitors.
When measuring large capacitors or cables during production and so on, it can be an advantage to use a key to allow quick charging of the capacitor or cable. The key can be a simple telegraph key whose insulation resistance should be great in relation to 1000 MΩ and connected across the points marked "Key". The key should be arranged as shown in fig. 3, so that when the key button is depressed the contact is broken. When the key is not

depressed, the Megohmmeter's voltage divider of 1000 MΩ is short-circuited, so that the capacity which is being examined is charged up almost immediately. On depressing the key the voltage divider is put into circuit again, and the capacitor's insulation resistance is measured.

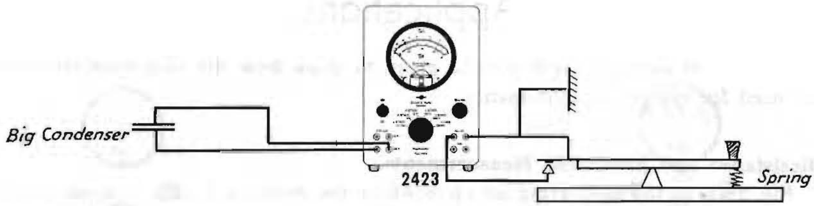


Fig. 3. Measuring arrangement for the measurement of large capacitors.

This quick charging key can be used for measurements with both 100 V and 10 V. In general, it is not necessary to have any special arrangement for discharging the capacitor again, as a voltage of 100 V is not dangerous.

If, however, it is desired to discharge the capacitor, the arrangement shown in fig. 4 must be used. Here a 2-pole 3 position switch is used. In the one position the measuring object is short-circuited, in the next position the capacitor is charged up, and in the last position it is measured. It is only necessary that the insulation of the main contacts in the switch be great in comparison to the voltage divider's 1000 MΩ. Possible leakage currents are eliminated by being lead to ground, as the switch is constructed in two sections. The connection is made as shown in fig. 4.

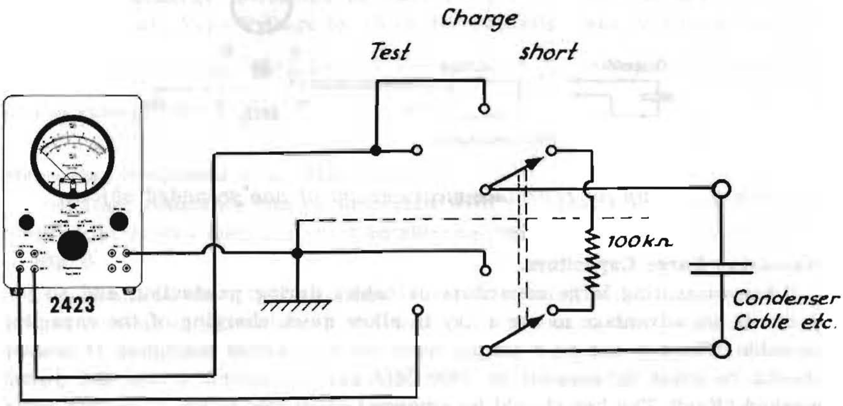


Fig. 4. Set-up for discharging large capacitors after measurement.

Measurement of Strain Gage Insulation and Insulation Measurements on Grounded Objects.

When the insulation is to be measured with respect to ground, for example on strain gages which are stuck to a grounded metal surface, or the insulation of cables with respect to ground, or the insulation between the windings of a transformer, whose iron core is grounded, the Megohmmeter must not be grounded. The ground lead must be connected to the right one of the plug pairs marked 10 V and 1000 V respectively, depending on the measuring voltage desired. The strain gage wire or the transformer winding is connected to MΩ × 1 or MΩ × o.1, as shown in fig. 5.

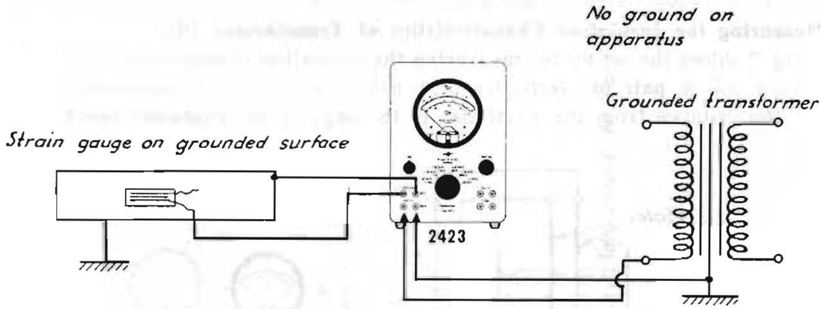


Fig. 5. Measurement of the insulation resistance of a strain gage installation.

Care should be taken by these measurements that the Megohmmeter is *not* connected to earthed objects. When measuring strain gages only the 10 V measuring voltage should be used, as most strain gages will break down if subjected to 100 V measuring voltage. The distance between the gage wire and the matel surface is often only a few hundredths of a millimeter.

Resistance Measurements with External Voltage Source.

If for one reason or another it is desired to measure with other voltages than the built-in 10 and 100 V, resistances and insulation resistance can be

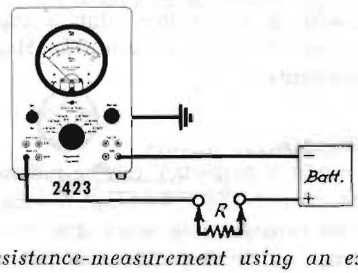


Fig. 6. Set-up for resistance-measurement using an external voltage source.

measured as shown in fig. 6. The voltage source, normally a battery, must be greater than 10 V and has its negative pole connected to the chassis of the apparatus, and the resistance to be measured is inserted between the positive pole of the battery and the left one of the apparatus "$M\Omega \times 1$" bushings. The resistance can be calculated from the following formula, when the deflection is read on the apparatus megohm scale:

$$R = \frac{\text{(Scale deflection} \times \text{multiplication factor} \times \text{battery voltage)}}{100}$$

Generally, it is adviseable to ground the Megohmmeter.

Measuring the Insulation Characteristics of Transformer Oil.

Fig. 7 shows the set-up for measuring the insulation characteristics of transformer oil. A pair of electrodes of considerable size are immersed in the oil, the distance from the electrodes to the edge of the container being great

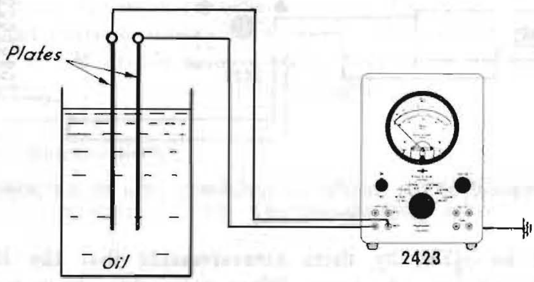


Fig. 7. Set-up for the measurement of insulation characteristics of transformer oil.

in relation to the distance between the electrodes. The insulation resistance is measured and the specific resistance determined according to the following formula:

$$\text{Specific resistance} = \frac{\text{Measured resistance} \times \text{electrode area}}{\text{electrode distance}} \text{ ohm cm.}$$

If the oil being measured is highly insulating, a small electrode distance and large electrode area are naturally chosen. The Megohmmeter should be grounded during measurements.

Measuments of D. C. Voltages.

All d. c. voltages from 0.01 V to 2000 V can be measured at the two lower right bushings marked "Volt". The bushing to the right is grounded, which must be taken into consideration when d. c. voltages are being measured. The input impedance on the 5 positions of the attenuator is 100 $M\Omega$.

In the position marked "1 V Key", the impedance is 1000 MΩ. It is thus possible to have a measuring range with 1 V full deflection, and an input impedance of 100 MΩ or 1000 MΩ. In the latter case the voltage should be fed to the bushings marked "Key".

A large range of laboratory measurements can thus be carried out with this apparatus: for example, it is actually possible to measure potentials with glass electrodes and similar apparatus with high internal resistance. If the positive pole is earthed, negative d. c. voltages can still be measured by shifting the zero-point, so that it lies for example at 5 V on the scale. When the negative voltage is applied, the pointer will deflect backwards, and the deflection from 5 to the deflection point gives the negative voltage. See fig. 8.

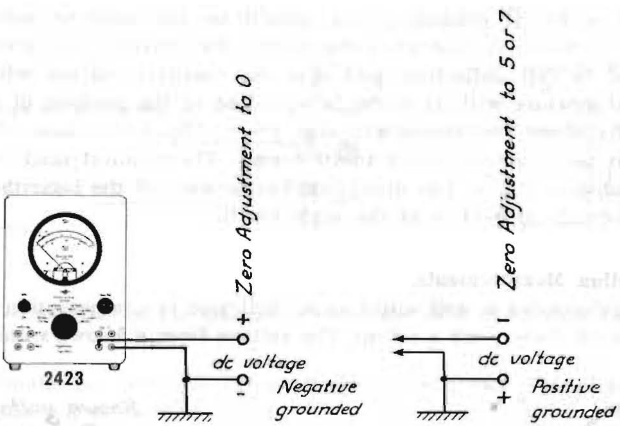


Fig. 8. Measurement of d. c. voltages.

The range marked 10 kV corresponds to a full deflection of 10 kV, but the input sockets are only made to stand a voltage or 2—3 kV at most, which is therefore the highest voltage permissible.

Measurement of Small Currents.

Megohmmeter Type 2423 is also an excellent, highly sensitive micromicro-ammeter. The current to be measured is fed to the sockets marked "Key".

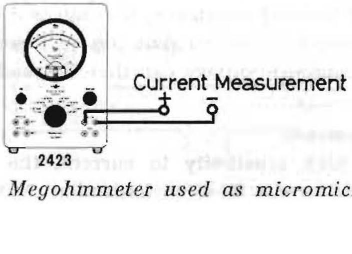


Fig. 9. The Megohmmeter used as micromicroammeter.

Switch Position	Resistance	Current	
		Full Deflection	Smallest Readable
$\times 1$ MΩ (10 kV)	10 kΩ	0.1 mA or 10^{-4} Amp.	1 μA or 10^{-6} Amp.
$\times 10$ MΩ 1000 V	100 kΩ	10 μA or 10^{-5} Amp.	0.1 μA or 10^{-7} Amp.
$\times 10^2$ MΩ 100 V	1 MΩ	1 μA or 10^{-6} Amp.	10 nA or 10^{-8} Amp.
$\times 10^3$ MΩ 10 V	10 MΩ	0.1 μA or 10^{-7} Amp.	1 nA or 10^{-9} Amp.
$\times 10^4$ MΩ 1 V	100 MΩ	10 nA or 10^{-8} Amp.	0.1 nA or 10^{-10} Amp.
$\times 10^5$ MΩ 1 V key	1000 MΩ	1 nA or 10^{-9} Amp.	10 pA or 10^{-11} Amp.

The right socket is grounded, and should be the negative pole. Fig. 9 shows the connection, and after the figure the currents are given which correspond to full deflection, and also the smallest current which it is possible to measure with accuracy independent of the position of the main switch. The shunt resistances are also given. The table shows that it is possible to read currents down to 10^{-11} amp. The smallest readable values are calculated as 1 % of full deflection, but because of the logarithmic scale this corresponds to 3—4 % of the scale length.

Compensation Measurements.

The Megohmmeter is well suited as an indicator in compensation measurements. Fig. 10 shows such a set-up. The voltage from a known voltage source

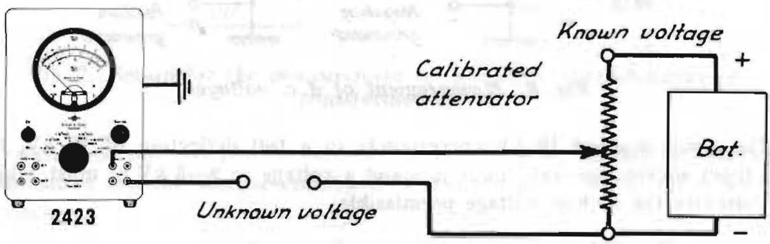


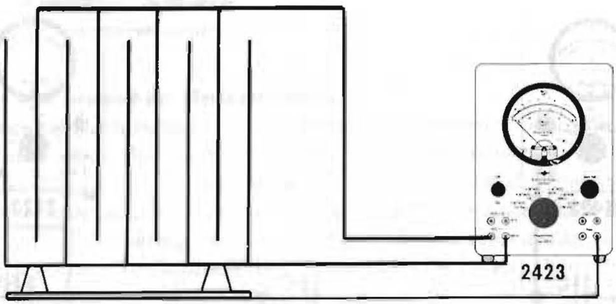
Fig. 10. Set-up showing the Megohmmeter used for compensation measurements.

is applied across a calibrated attenuator, and the unknown voltage, which may have a very great internal resistance, is connected as shown in the figure. The attenuator is adjusted till no current passes through the Megohmmeter, and the value of the unknown voltage can then be read off on the attenuator.

Radioactivity Measurements.

On account of its high sensitivity to current, the Megohmmeter is also suitable for measuring currents from an ionization chamber using the internal voltage of 100 V. An arrangement is shown in fig. 11. It is assumed that the ionization chamber is constructed of a series of parallel coupled plates, so that with the 100 V available a field-strength of at least 100 V per cm between the plates can be obtained, making it possible to measure up to 1000 Röntgen per hour.

Ionization chamber



Full deflection reading

Switch Position	×10⁵ MΩ	×10⁴ MΩ	×10³ MΩ	×10² MΩ	×10 MΩ	×1 MΩ
1000 cm^3 chamber volume	10.8 r/h	108 r/h	1080 r/h			
926 cm^3 chamber volume	10 r/h	100 r/h	1000 r/h			

Fig. 11. Measurement of the current from a ionization chamber.

With an effective chamber volume of 1000 cm^3, the radiation intensities given in the table can be measured for full deflection on the meter. By reducing the effective chamber volume to 926 cm^3, full deflection will be obtained for the intensity in powers of 10 as given. If one wishes to measure heavier radiation intensities, a greater voltage must be put across the ionization chamber, to obtain saturation current. The higher the voltage available, the greater can be the distance between the electrodes.

Measurements on Capacitors with very High Insulation.

With capacitors whose insulation resistance lies exceedingly high, the set-up of fig. 12 can be used. This method is based on the use of the well-known R-C discharge curve for a capacitor discharging through a resistor, and the value of R is here the capacitor leakage resistance. The capacitor is first charged up as shown on the left with exactly 10 V or 100 V. It is then left charged for a period, if necessary weeks or even months. It is then connected to the voltage sockets and its voltage measured.

If the capacitor is small, it will naturally quickly discharge across the 100 MΩ resistance (or 1000 MΩ when its voltage is less than 1 V), and the instrument will be unable to show the proper voltage. By the cut-and-try method the correct voltage is now found as the voltage to which the capacitor must be charged, to give the same deflection as previously when connected to the voltage sockets.

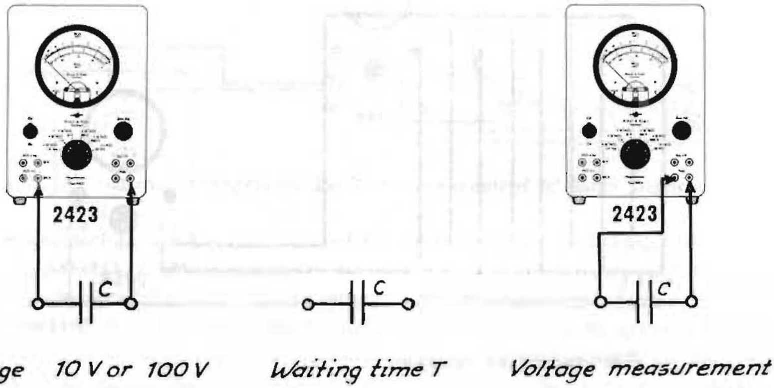


Fig. 12. Set-up showing how measurements on capacitors with very high insulation resistance can be carried out by means of the Megohmmeter.

The leakage resistance R can then be calculated according to the formula

$$R = \frac{t}{C \times \ln\left(\frac{V_o}{V}\right)}$$

where R = Leakage resistance in MΩ, t = Waiting time in seconds, C = Capacity in μF, V_o = Voltage to which the capacitor was originally charged and V = Voltage measured after t seconds, $\ln\left(\frac{V_o}{V}\right)$ = Napierian logarithm of the voltage ratio $\left(\frac{V_o}{V}\right)$.

Measuring Resistance with High Voltage.

Insulation resistance can be measured with voltages up to 1000 V by the Megohmmeter in connection with an external voltage source, set-up similarly to Fig. 6.

Care should be taken that a voltage source is selected which has a maximum output current of only about 1 mA making this source completely harmless in use. Hearing aid type batteries, 30 Volts, for example Hellesens Atomax 10123, Burgess U 20 E or National Carbon Co. "Eveready" 413 are suitable batteries for building up this external voltage source. All the previously mentioned applications can also be carried out with this combination.

Finally, Fig. 13 shows how measurements are made on insulating materials. A disc is turned from the insulation material which is to be measured, and a centre depression and an outer ring are then turned in the disc, as shown. The disc is then floated on mercury in a container, and mercury is placed in the central depression and the ring, which then becomes a guard-ring.

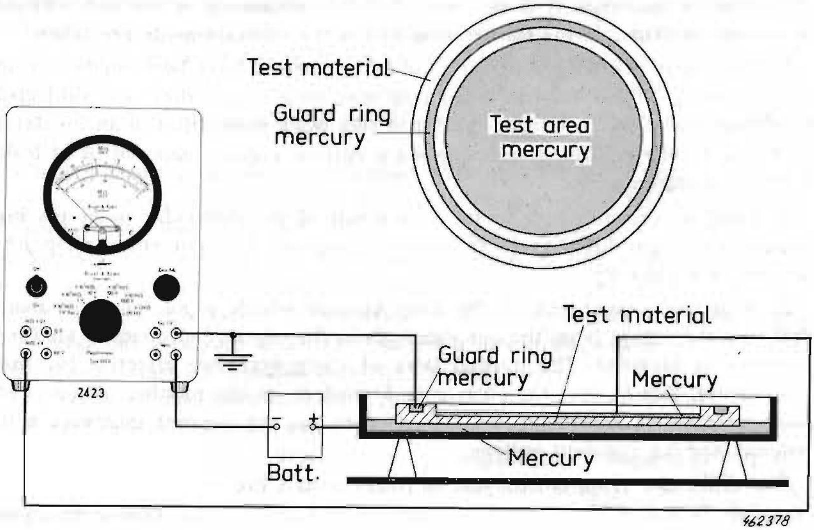


Fig. 13. Measurement on insulation materials.

It will be seen that the guard-ring completely eliminates leakage currents, for the mercury ring is grounded, so that any currents which attempt to travel over the surface of the insulation material will then be discharged to earth. The current measured will then be only that which goes through the body of the material itself. The specific resistance is then defined, as in the case of the measurement with transformer oil, as

$$\text{Specific resistance} = \frac{\text{Measured resistance} \times \text{test area}}{\text{disc thickness}} \text{ ohm cm.}$$

With poor insulating materials, and when one wishes to measure with 100 V measuring voltage, the Megohmmeter can of course be used without the external voltage source. Advantage would of course still be taken of the guard-ring.

Some Remarks on Insulation Resistance.

Resistance in metallic conductors is measured in Ω, and is defined as the ratio between voltage and current. The resistance in these conductors depends entirely on temperature, the dimensions of the conductor and the specific resistance, which is a constant, absolute value independent of the voltage or current.

It is, however, much more difficult to define resistance when it is a question of current in insulators, where current flow from one point to another under the influence of a voltage. However, the resistance in Ω is still defined as the ratio between voltage and current, but for the majority of insulation materials it is the case that this resistance is not independent of current, voltage, or the time during which the measurements are taken.

In the course of time a long series of investigations have been made to find what actually takes place in insulation materials, when they are subjected to voltage variation. Briefly, the result of this work shows that in an insulator to which a voltage difference is applied a current arises composed of at least 3 different components.

1) First, a current which arises as a result of the molecular poles placing themselves in the direction of the voltage gradient. This current corresponds nearest to a capacity current.

2) A second component of the total current which is an ion movement, that is, a movement from the one electrode to the other of electrically charged particles of material. The normal laws of electrolysis are effective for this ion current, that is, that the current is dependent on the number of ions and their freedom of movement. On this account the ion current increases with temperature for constant voltage.

One difference from electrolysis in fluids is that the movement of the ions in solids is not uniform at all points, so that not all the ions have equal opportunities to reach the electrodes. There is therefore often found in a seemingly homogeneous insulation material quite definite paths along which the ions move. An ion current is not of constant value, considerable variations and stepwise jumps are often found. The number of ions as a rule decreases after the insulation material has been subjected to a voltage difference for some time, that is, the insulation resistance will be greater a short while after measurements have been begun.

The aggregating of ions in definite zones, which can not discharge as a current, results in these zones acting as a sort of capacitor, which, when alternately charging and discharging, can cause changes in the ion stream normally flowing.

3) Apart from conditions inside the insulator, the boundary surface must also be considered. Every insulator in practical use has a continuous surface between the electrodes, which is in contact with the air, and over which a surface current can move.

The size of this current is dependent on the characteristic of the surface. With hygroscopic materials these surface currents can be many times greater than the remaining currents. Particularly strong surface currents arise with various types of glass which have the property of binding water to their surfaces. It is possible to decrease these surface currents considerably by treatment with various compounds.

Many insulation materials have their surfaces covered with microscopic scratches and cracks, which have a powerful capillary attraction for water molecules, and these surfaces are therefore often liable to hold moisture. The surface currents are, as a result, very dependent on the humidity of the atmosphere.

The normal electron current which is found with metallic conductors is quite infinitesimal in insulation materials, compared to the other components. This means that with insulation materials one cannot take into account these considerations to which one is accustomed with metallic conductors. Because the current which flows in insulation materials has no linear relationship to the voltage, one cannot discuss insulation resistance defined as a relationship between voltage and current, without at the same time defining a long list of other factors, such as the voltage one is measuring with, the time during which the material has been exposed to the voltage, the humidity of the air, the temperature, and so on.

Even when all these factors are well defined, easily reproduceable measuring results can not be expected. The measuring instrument should therefore not be considered inacurate because different values of the insulation resistance of a capacitor are obtained during measurements. Likewise, it is often noticed when measuring good capacitors that the pointer on the meter swings a little back and forward. This is as a rule not due to any fault in the Megohmmeter, but to the irregular character of the current through the insulation material.

Specification.

As Megohmmeter.

Resistance Range: 0.1 to 10,000,000 megohms in 7 ranges.

Measuring Voltages: 100 and 10 volts. Stabilized to 0.03 % for 10 % variation in supply voltage.

Megohm Scales: Two scales for 100 and 500 volts. The scales are approx. logarithmic for inverse megohms from 1 to 10 (5 to 50) and approx. hyperbolic from 10 to ∞ (50 to ∞). The scale is illuminated for convenience.

Accuracy in Resistance Measurement:
100 Volts-scale: (2 + 0.2 A) %
500 Volts-scale: (2 + 0.04 A) %
where A is the actual scale-figure.

Zero Point: The same zero adjustment applies to all ranges.

Leakage Resistaucc of Capacitors: Special terminals are provided for the connection of a key, whereby the capacitor's charging time can be reduced to a minimum.

As d. c. Voltmeter.

Voltage Range: 1 — 10 — 100 and 1,000 volts full scale deflection. Up to 2 kV on the (10 kV) range, 0.01 volt can be read.

Input Impedance: 100 megohms at terminals marked "Volts". In posilion "1 V Key" the input impedance is 1,000 megohms at the terminals marked "Key 1 V".

Scale: Linear from 0 to 1, logarithmic between 1 and 10.

Accuracy: 2 % of actual scale value + 0.15 % of full scale deflection.

As d. c. Micromicroammeter.

Current Ranges: 10^{-9} — 10^{-8} — 10^{-7} — 10^{-6} — 10^{-5} — 10^{-4} amp. full scale deflection. 10^{-11} amp. can be read.

Shunt Resistance: 1,000 — 100 — 10 — 1 megohm and 100 and 10 kiloohm.

Scale: Same as voltage scale.

Accuracy: 2 % of actual scale value + 0.2 % of full scale deflection.

Power Supply: 115 — 127 — 150 — 220 — 240 volt. 50—400 c/s.

Power Consumption: Approx. 12 watts.

Tubes: 12AU7 (ECC82), 12AT7 (ECC81), OA2 (150C2), and OB2 (108C2).

Dimensions:

DIMENSIONS excl. dials and knobs	HEIGHT	WIDTH	DEPTH
Centimetres	26	18	16
Inches	10	7	6
WEIGHT	4 kg	9 lbs.	

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