INSTRUCTION MANUAL

for the use of

"MEGGER"

TRADE MARK REGISTERED U.S. PAT. OFF.

INSULATION TESTERS

SIXTH EDITION
1966

JAMES G. BIDDLE CO.
ELECTRICAL AND SCIENTIFIC INSTRUMENTS
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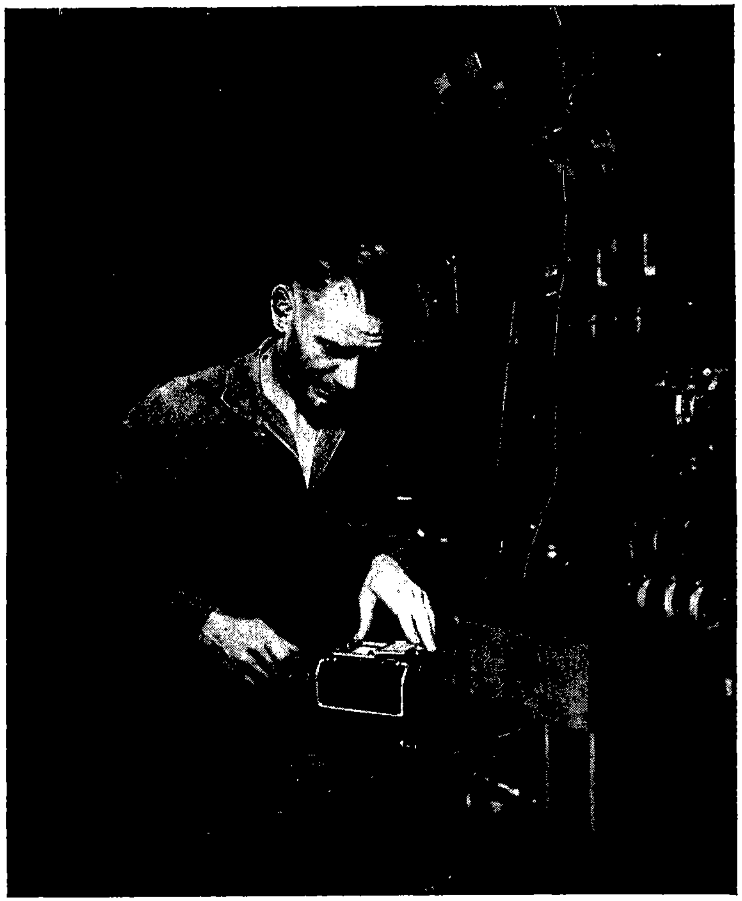

Photo by courtesy of the Hartford Steam Boiler Inspection and Insurance Co.

Testing Insulation Resistance

The testing instruments referred to in this Instruction Manual are members of our famous family of "Megger" Insulation Testers, Ground Testers and Ohmmeters.

The name "Megger" is an identifying trade mark, registered in the United States Patent Office.

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HOW TO CONNECT AND OPERATE "MEGGER" INSULATION TESTING INSTRUMENTS

GENERAL DIRECTIONS FOR HAND-DRIVEN TYPES

[For Special Directions for the Various Types, see page 4.
For Motor-Driven Type, see page 5.
For Rectifier- and Dual-Operated Types, see page 8.]

CAUTION

See Safety Precautions, page 11.

Do not use a "Megger" Tester whose terminal or operating voltage is in excess of that which is safe to apply to the equipment to be tested.

1. **Place the instrument** on a firm and fairly level base. Avoid large masses of iron and strong magnetic fields. The pointer may appear to stand anywhere over the scale until the instrument is operated, because the "Megger" Ohmmeter has no control springs.

2. **Selector Switch.** If the instrument has a selector switch, set it to MEGOHMS ÷ 1.

For further use of selector switch, see page 24.

3. **Check Infinity** by turning crank at normal speed in clockwise direction. (Normal speed is indicated on the instrument.)

The pointer should move promptly to Infinity.

Important: This check is made with no connections to the test terminals.

4. **Check Zero** by short-circuiting the testing terminals. Turn the crank slowly. The pointer should move promptly to Zero —or off the lower end of the scale in some instruments.

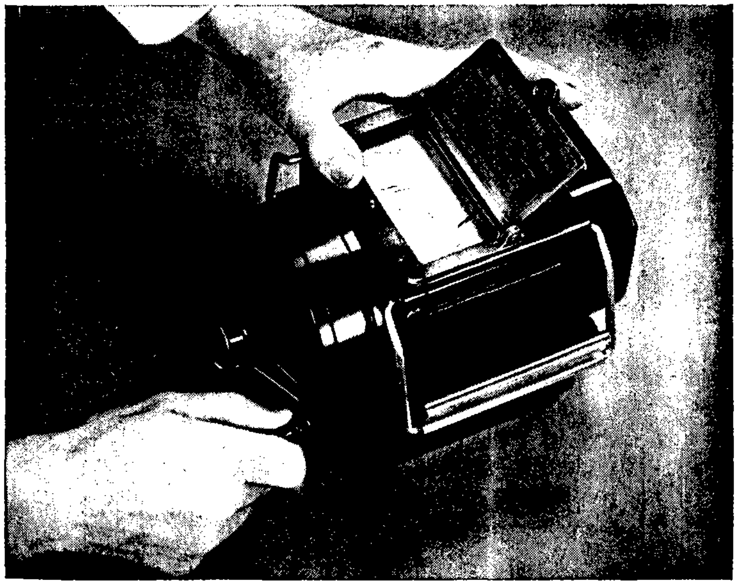

FIGURE 1. When using a hand-cranked "Megger" Instrument, hold the forearm of the cranking hand approximately parallel with the crankshaft. Turn the crank with a combined arm and wrist motion.

5. Use well-insulated testing leads having single-conductor stranded wire. See page 29.

6. Check testing leads. With leads connected to the instrument terminals and with opposite ends separated, turn the crank at normal speed. If the pointer indicates less than Infinity, there is a leak between the leads which must be removed before proceeding with tests. Touch together the test ends of the leads while turning the crank, to make certain—by a Zero reading—that the leads are not open-circuited.

7. Apparatus to be tested must not be live. It must be taken out of service and disconnected electrically from all other equipment. See *Safety Precautions,* page 11.

8. Connect leads to apparatus to be tested. See connection diagrams, pages 13 to 23.

For testing to Ground—connect from the Line terminal to a conductor of the apparatus, and from the Earth terminal to frame of machine, sheath of cable or to a good ground.

For testing between two conductors—connect test leads to the two conductors.

See page 32 for use of Guard terminal.

9. Operate and read. Turn crank in clockwise direction at normal speed which is indicated on the instrument, and observe position of pointer over the scale—it shows the value of the insulation resistance under test. Take the reading while operating and at a fixed time, preferably 30 or 60 seconds. See *Operating Time,* page 31.

10. See Supplementary Instructions, page 29.

11. See Special Directions for the Various Types, page 4.

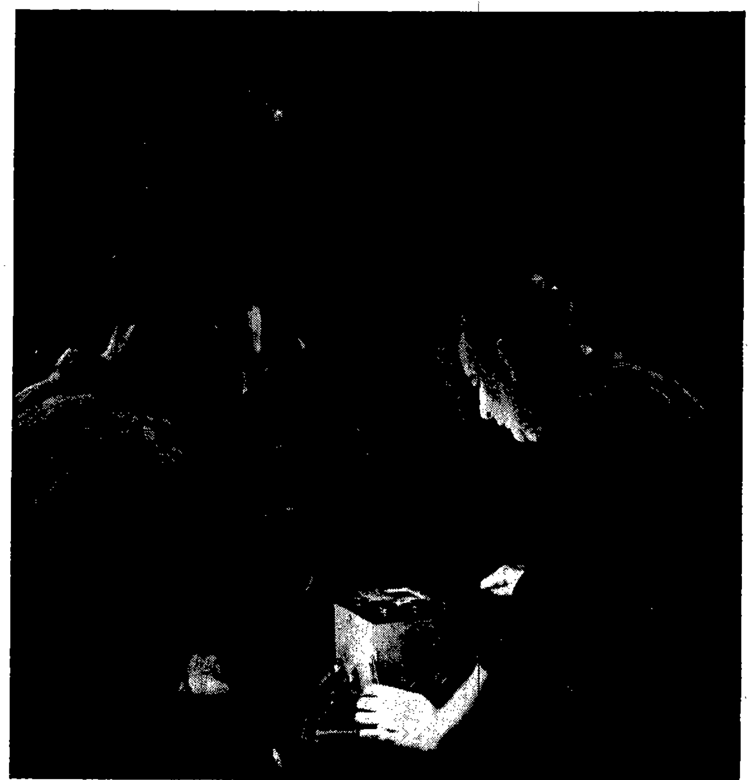

FIGURE 2. Using the "Bridge-Meg" type of "Megger" Insulation and Resistance Tester.

II

HOW TO CONNECT AND OPERATE "MEGGER" INSULATION TESTING INSTRUMENTS

SPECIAL DIRECTIONS FOR THE VARIOUS TYPES

1. Constant-Voltage Heavy-Duty Type—Hand-Driven

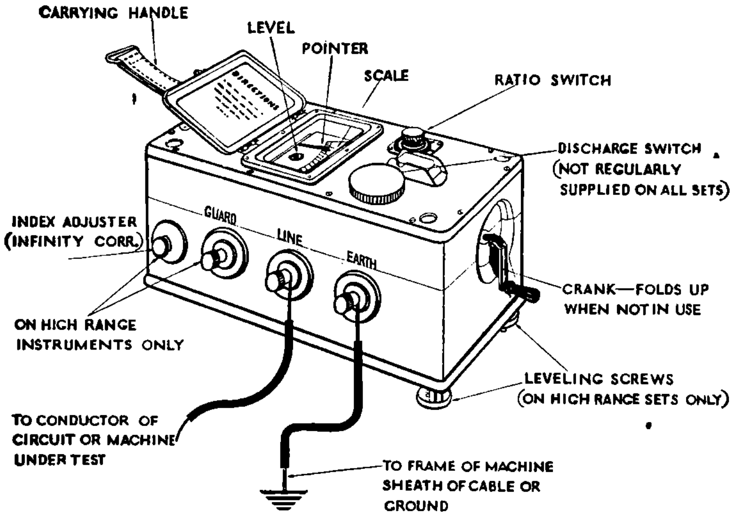

FIGURE 3

See General Directions for Hand-Driven Types, page 1.

For High Range Instruments: Level the instrument, centering the bubble in the spirit level which is set in the scale plate. When checking Infinity, turn the Index Adjuster one way

or the other, while cranking at full (slip) speed, until the pointer stands over the Infinity line.

Low Range Instruments do not have leveling facilities and Index Adjuster. Some older low range instruments of this type have variable-voltage hand generators, i.e., there is no slip clutch. Normal cranking speed is about 120 rpm.

When using multi-voltage sets, make proper setting of voltage selector switch. See *Safety Precautions,* page 11.

For use of Guard terminal, see page 32.

2. Heavy-Duty Type—Motor Driven

Motor-driven "Megger" sets are used where a large number of tests are to be made at one location, and also where the time duration of the test must be continued for many minutes.

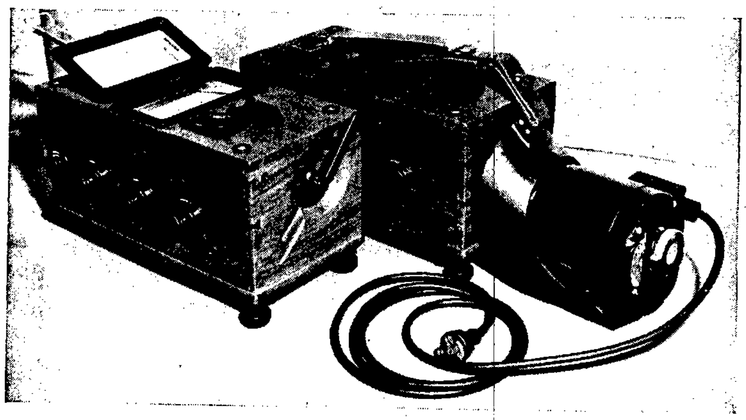

FIGURE 4. Hand-operated and motor-drive Megger Insulation Testers.

To Operate:

Make proper setting of voltage and selector switches.

Follow directions for hand-driven type, page 4, except that instead of turning the crank, connect to suitable supply voltage and run the driving motor.

NOTE: Present motor-driven models may be operated continuously—24 hours per day if necessary. Older models, with detachable motors, were for intermittent duty up to 30 minutes at one time.

To Remove the Motor and Drive by Hand

First, remove the four screws which hold the motor bracket to the instrument case, thus detaching the bracket and motor as a unit. The flexible coupling will remain attached to the motor shaft. (In older models the coupling must be detached.)

CAUTION: Rotate this shaft only in a counterclockwise direction when facing the crank end of the instrument. If forced in the opposite direction, a pin will be sheared in the hand-cranked gear train.

Second, unfold the crank handle and the instrument is ready for hand operation.

Lubrication: Instruments supplied prior to April, 1947, require occasional oiling or greasing. Insert a *few* drops of best grade *light* oil in the hole or holes provided for the purpose on the top of the instrument. Some older instruments also have grease cups. Present models have permanently lubricated ball bearings and require no oiling.

Motors with wool-packed sleeve bearings are oiled at the factory for one year's normal service. Reoil once a year, or every 2,000 operating hours, whichever occurs first. The amount of oil added should vary from 30 drops for three-inch diameter motors to 100 drops for nine-inch diameter motors. Use preferably Electric Motor Oil or, in emergency, SAE-10 automotive oil. Do not use oils recommended for cleaning or rust prevention.

Motors having ball bearings are packed with sufficient grease for approximately 10,000 operating hours. Once a year remove the oil screws and add five to ten drops of a good grade Electric Motor Oil or SAE-10 automotive oil to each bearing. After five years or 10,000 operating hours (whichever occurs first), the bearings and housings should be cleaned thoroughly and regreased with best grade ball bearing grease. Care must be taken to keep dirt out of the bearings and the grease.

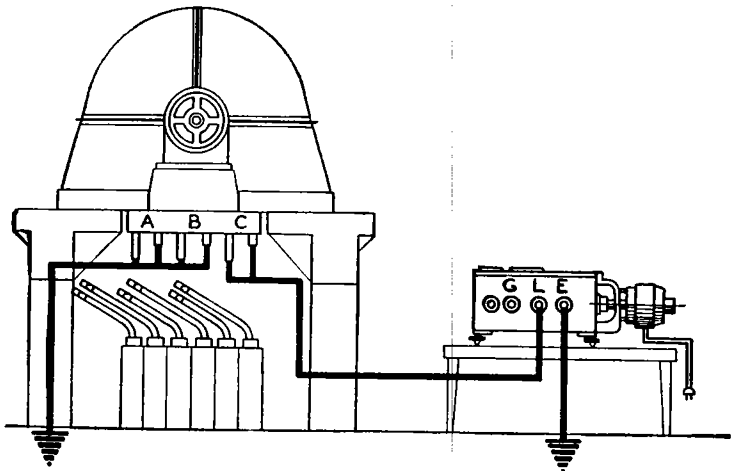

FIGURE 5. Connections for making a time-resistance measurement on one phase of a generator winding with the other phases grounded.

3. Hand-Driven Meg®, Midget and Mark III Types

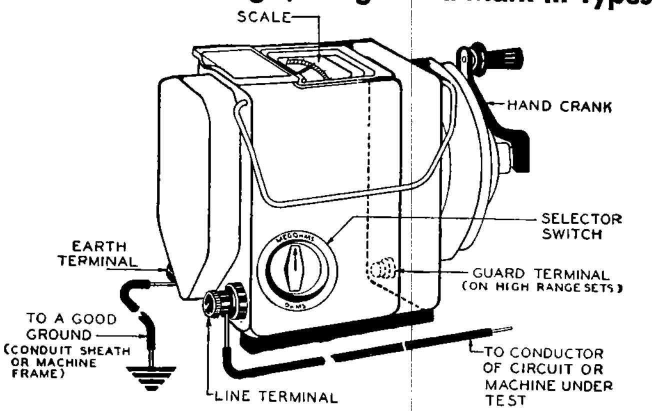

FIGURE 6

See General Directions for Hand-Driven Types, page 1.

Turn the crank at just above the speed at which the constant-voltage clutch is felt to slip, which is about 160 rpm.*

* Some instruments have a constant voltage generator in place of a slip clutch. These instruments should also be cranked at approximately 160 rpm. Many older superseded instruments had variable voltage generators. In these instruments the output voltage varied with cranking speed.

4. Rectifier-Operated "Meg" Type

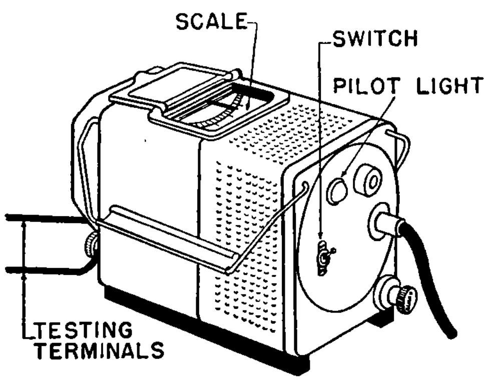

FIGURE 7

This instrument is operated by connecting to suitable a-c supply. It has no generator.

Follow *General Directions for Hand-Driven Types,* page 1, except that instead of operating generator, connect supply cord to voltage and frequency shown on instruction label. The accuracy of the reading is unaffected by the exact value of the supply voltage—within ±20%. The reading *may* be affected momentarily by large and sudden changes in supply voltage, particularly at the upper end of the scale.

5. Dual-Operated "Meg" Type

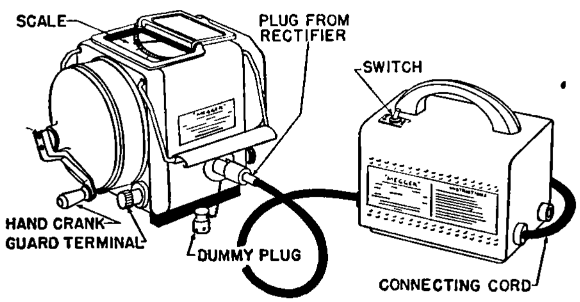

FIGURE 8

This set consists of a constant-voltage "Meg" type instrument (page 7), modified for use with a separate, special rectifier power supply. It may be operated either by its own hand-cranked generator or by means of the power supply.

When using the hand-cranked generator, follow directions for "Constant-Voltage Meg Type" (page 7). The power supply must be disconnected from the instrument.

When using the special rectifier power supply, make sure that it corresponds by Cat. No. and voltage rating to the instrument with which it is to be used. Connect power supply to instrument by means of plug connection attached to power supply unit. Follow directions for "Rectifier-Operated Meg Type" (page 8).

If the special rectifier power supply is used for purposes other than operating its companion "Megger" Insulation Tester, its rated current output must not be exceeded. *CAUTION:* There is no series resistance in the power supply to limit its current output.

III

PREPARATION OF APPARATUS FOR TEST

1. Take Out of Service

Shut down the apparatus. Open switches. De-energize. Disconnect from other equipment and circuits, including neutral and protective (workmen's temporary) ground connections. See *Safety Precautions,* page 11.

2. Make Sure Just What Is Included in the Test

Inspect the installation very carefully to determine just what equipment is connected and will be included in the test, especially if it is difficult or expensive to disconnect associated apparatus and circuits. Pay particular attention to conductors that lead away from the installation. This is very important, because the more equipment that is included in a test, the lower the reading will be, and the true insulation resistance of the apparatus in question may be masked by that of the associated equipment.

It is always possible, of course, that the insulation resistance of the complete installation (without disconnecting everything) will be satisfactorily high, especially for a spot check. Or, it may be higher than the range of the "Megger" instrument in use, in which case nothing would be gained by separating the components, because the insulation resistance of each part would be still higher.

For an initial test, it may be necessary to separate the component parts, even though labor and expense are involved, and test each one separately. Also make a test of all the components connected together. With this information on record, it may not be necessary to separate the components on future tests unless unaccountably low readings are observed.

3. Discharge of Capacitance

It is very important—especially in large equipment—that capacitance be discharged, both before and after an insulation resistance test.

Discharging capacitance after a test is a wise safety precaution.

"Megger" instruments are frequently equipped with Discharge Switches (see page 25) for this purpose.

4. Current Leakage at Switches, etc.

When apparatus is shut down for the insulation resistance test, make sure that the readings are not affected by leakage over or through switches or fuse blocks, etc. Such leakage may mask the true insulation resistance of the apparatus under test. See *Use of Guard Terminal,* page 32.

Or, what may be more serious, current from an energized line may leak into the apparatus and cause inconsistent readings, particularly if the live line is d-c. However, such leakage usually can be detected by watching the pointer of the "Megger" instrument at the moment the test leads are connected to the apparatus and before the instrument is operated. (Before making these observations, be sure that all capacitance is discharged by short-circuiting or grounding the apparatus.)

SAFETY PRECAUTIONS

Observe all rules for safety when taking equipment out of service. Block out disconnect switches. Test for foreign or induced voltages. Apply workmen's grounds.

Remember that when working around high voltage equipment there is always a possibility of voltages being induced in apparatus under test or lines to which it is connected, because of proximity to energized high voltage equipment. Therefore, rather than removing a workmen's ground in order to make a test, it is more advisable to disconnect the apparatus, such as a transformer or circuit breaker, from the exposed bus or line, leaving the latter grounded. Use rubber gloves when connecting the test leads to the apparatus, and when operating the "Megger" instrument.

Apparatus Under Test Must Not Be Live

See page 10, on *Preparation of Apparatus for Test.*

If neutral or other ground connections have to be discon nected, make sure they are not carrying current at the time, and that when disconnected no other equipment will lack necessary protection.

Pay particular attention to conductors that lead away from the circuit being tested and make sure they have been properly disconnected from any source of voltage.

Shock Hazard from Test Voltage

Observe the voltage rating of the "Megger" instrument and regard it with appropriate caution. Large electrical equipment and cables usually have sufficient capacitance to store up a dangerous amount of energy from the test current. Make sure this capacitance is discharged after the test and before handling the test leads.

Explosion and Fire Hazard

So far as is known, there is no fire hazard in the normal use of a "Megger" Insulation Tester. There is, however, a hazard when testing equipment located in inflammable or explosive atmospheres.

Slight sparking may be encountered: (1) When attaching the test leads to equipment in which the capacitance has not been completely discharged. (2) Arcing through or over faulty insulation during a test. (3) Discharge of capacitance following a test.

Suggestions

DO NOT USE THE INSTRUMENT IN AN EXPLOSIVE ATMOSPHERE.

For (1) and (3): Arrange permanently installed grounding facilities and test leads to a point where instrument connections can be made in a safe atmosphere.

For (2): Use low voltage testing instruments, or a series resistance.

For (3): Do not disconnect the test leads for at least 30 to 60 seconds following a test, so as to allow time for capacitance discharge.

IV

CONNECTIONS FOR TESTING INSULATION RESISTANCE OF ELECTRICAL EQUIPMENT

The following diagrams show how to connect a "Megger" Insulation Tester to various types of electrical equipment. The diagrams also show in principle how equipment must be disconnected from other circuits before the instrument is connected.

These illustrations are typical and will serve as guides for testing insulation resistance of practically all types of apparatus and conductors.

Before proceeding with tests, read the article on "Preparation of Apparatus for Test," page 10.

REMEMBER! ***The "Megger" Insulation Resistance Tester measures whatever resistance is connected between its terminals. This may include series or parallel leakage paths through insulation or over its surface.***

1. A-C Motors and Starting Equipment

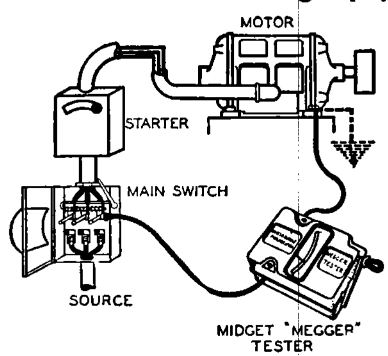

FIGURE 8

Connections for testing the insulation resistance of a motor, starting equipment and connecting lines, *in parallel.* Note that the starter switch is in the "on" position for the test. It is preferable always to disconnect the component parts and test them separately in order to determine where weaknesses exist.

2. D-C Generators and Motors

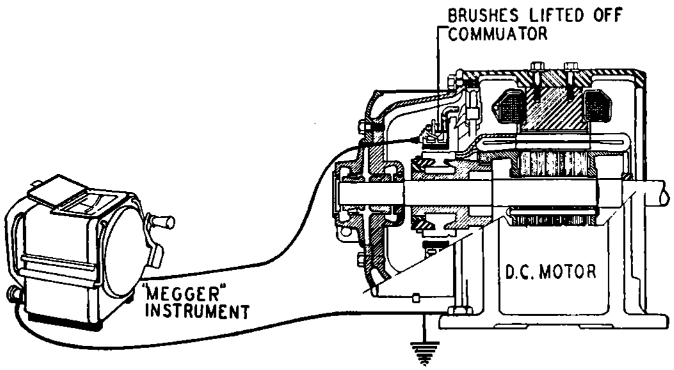

FIGURE 9

With the brushes raised—as indicated—the brush rigging and field coils can be tested separately from the armature. Likewise the armature can be tested by itself. With the brushes lowered, the test will be that of brush rigging, field coils and armature combined.

3. Wiring Installation

Connections for testing to ground each circuit separately, working from the distribution panel.

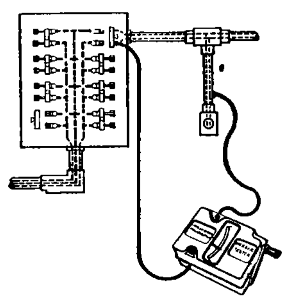

FIGURE 10

Connections at the main power board, from which point the entire system can be tested to ground at one time, providing all switches in the distribution panel are closed.

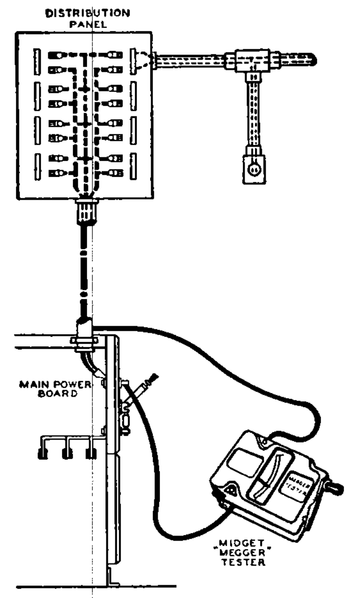

FIGURE 11

4. Appliances, Meters, Instruments and Miscellaneous Electrical Apparatus

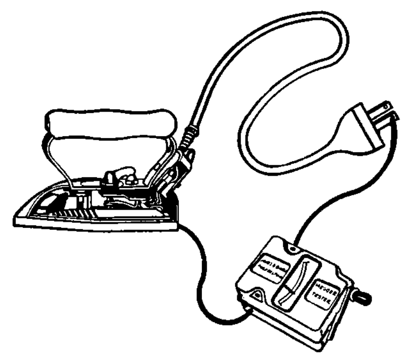

FIGURE 12

Connections for testing an appliance. The test is made between the conductor, such as heating unit, motor, etc., and exposed metal parts. The apparatus must be disconnected from any source of power and placed preferably on some insulating material.

5. Control, Signaling and Communication Cables

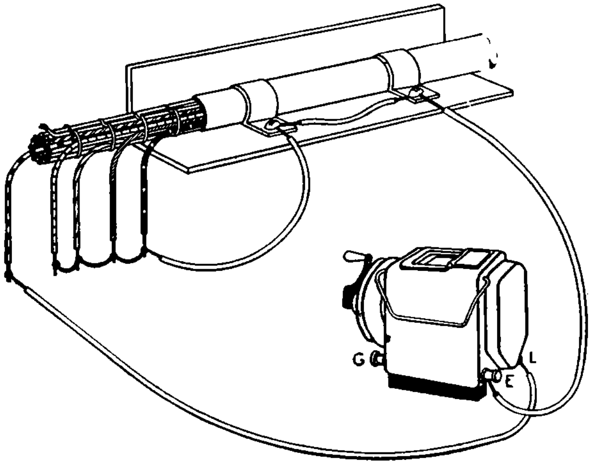

FIGURE 13

Connections for testing insulation resistance of one wire in a multi-conductor cable against all other wires and sheath connected together.

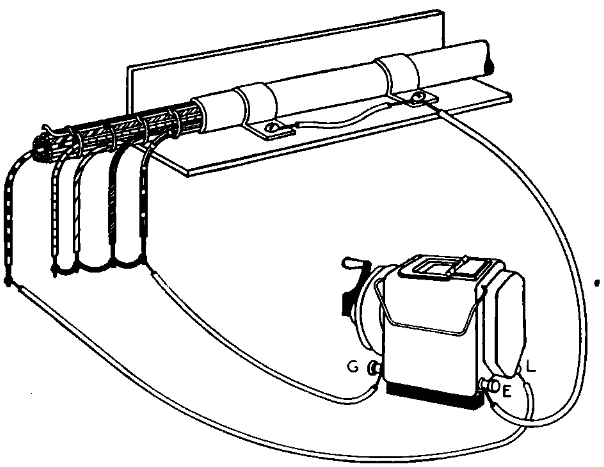

FIGURE 14

Connections for testing insulation resistance between one

wire and ground, without being affected by leakage to other wires. Note use of Guard connection.

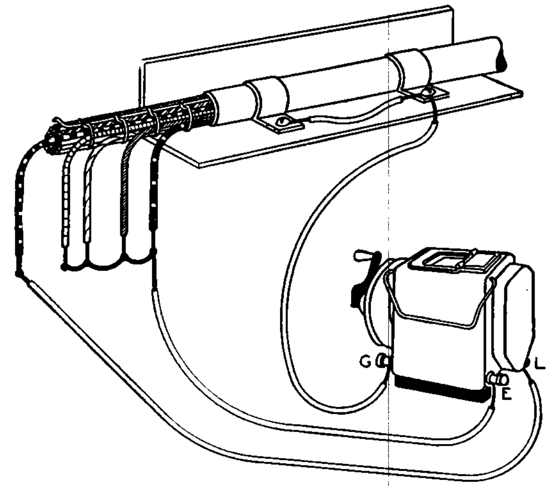

FIGURE 15

Connections for testing insulation resistance between one wire and all other wires connected, without being affected by leakage to ground. See *"Use of the Guard Terminal"*, Chapter VII.

6. Power Cables

Connections for testing the insulation resistance of a power cable. When testing cable, it is usually best to disconnect at

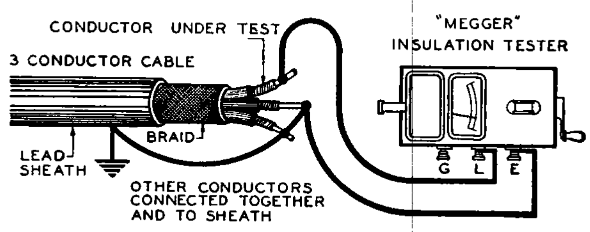

FIGURE 16

both ends in order to test the cable by itself, and to avoid error due to leakage across or through switchboards or panelboards.

See also *Use of Guard Terminal,* page 32.

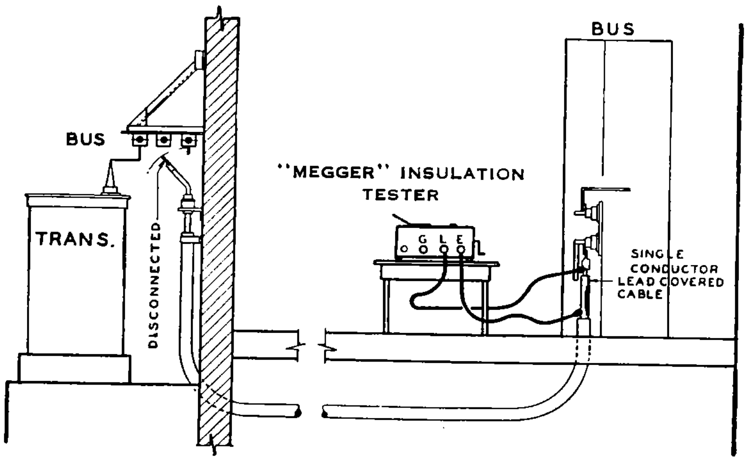

FIGURE 17. Testing a Single-Conductor Cable.

7. Bushings, Potheads and Insulators

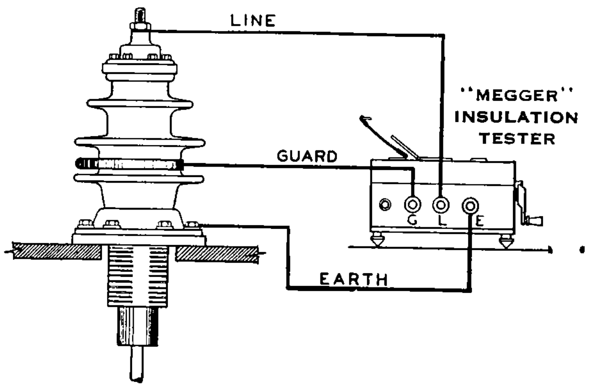

FIGURE 18

The illustration shows use of spring collar as a Guard connection to eliminate the effects of surface leakage. The device under test *must* be disconnected from *all* other equipment.

8. Power Transformers

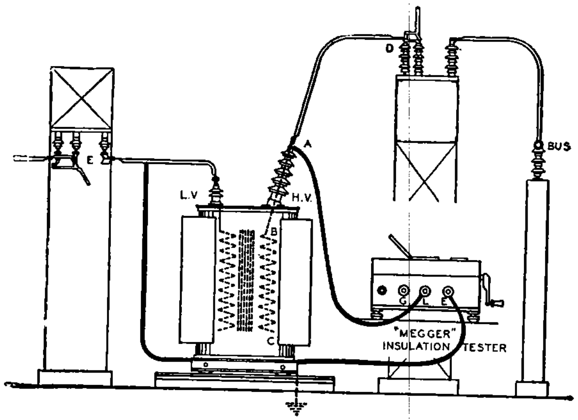

FIGURE 19

Connections for testing insulation resistance of a transformer high voltage winding and bushings, and the high tension disconnect switch—*in parallel,* with reference to the low voltage winding and ground. Note that the low voltage winding is grounded for this test.

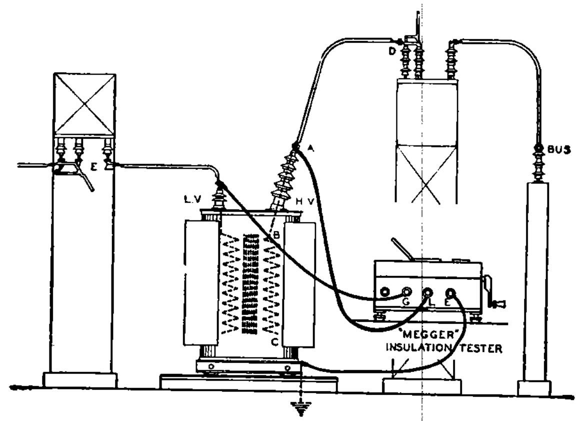

FIGURE 20

Same as Figure 19 but without being affected by leakage between the high and low voltage windings. Note use of Guard connection.

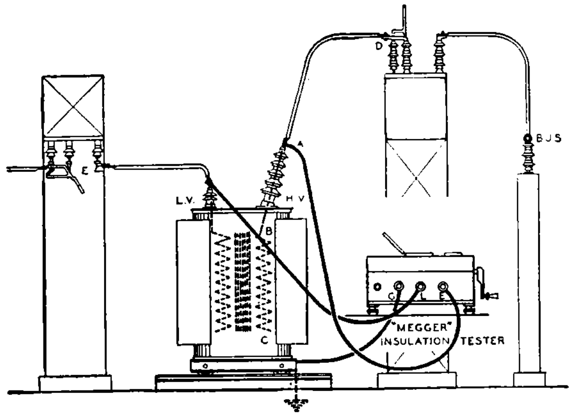

FIGURE 21

Connections for testing insulation resistance between high and low voltage windings without being affected by leakage to ground. See *"Use of the Guard Terminal"*, Chapter VII.

9. A-C Generators

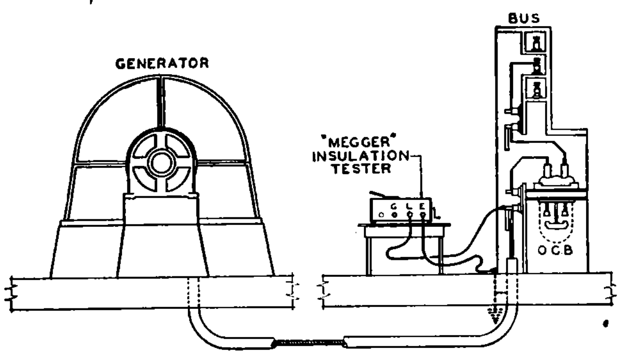

FIGURE 22

With this connection, the insulation resistance will be that of the generator stator winding and connecting cable combined. To test either the stator winding or the cable itself, the cable must be disconnected at the machine.

10. Outdoor Oil Circuit Breakers

The four illustrations (Figs. 23, 24, 25 and 26) show the usual methods of testing bushings and associated parts of an outdoor oil circuit breaker, and the accompanying table indicates the test procedure by steps.

If the test values are below 10,000 megohms in any of the 4 steps, the tank should be lowered or drained so that the excessive losses can be isolated by further tests and investigations. If the test values are below 50,000 megohms in test #1, the trend of the condition of the particular bushing involved should be watched by making more frequent tests. See page 44.

Test	Breaker Position	Bushing Energized	Bushing Guarded	Bushing Grounded	Part Measured
1	open	1 (2 to guard)	1	......	Bushing 1
2	open	1	1	2	Bushing 1 in parallel with cross member
3	open	1 & 2	1 & 2	......	Bushing 1 & 2 in parallel
4	closed	1 & 2	1 & 2	......	Bushing 1 & 2 in parallel with lift rod

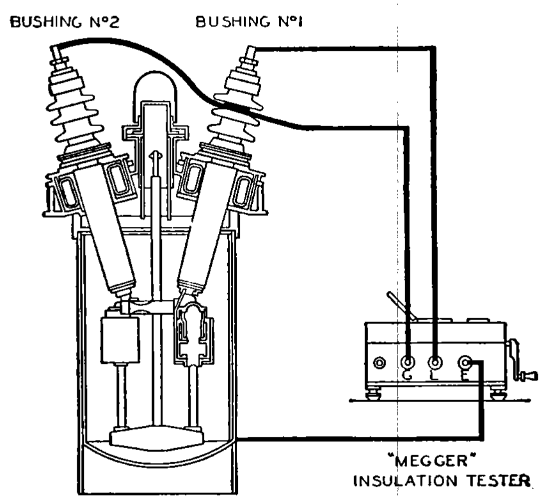

FIGURE 23. Step 1.

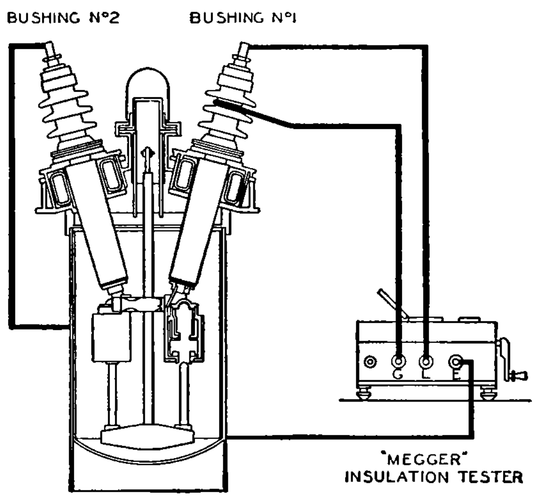

FIGURE 24. Step 2.

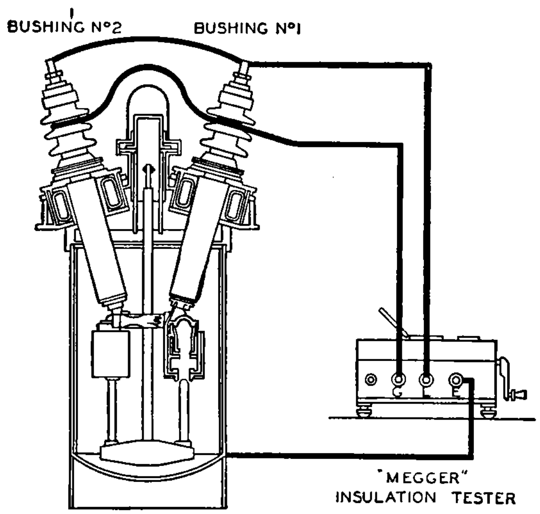

FIGURE 25. Step 3.

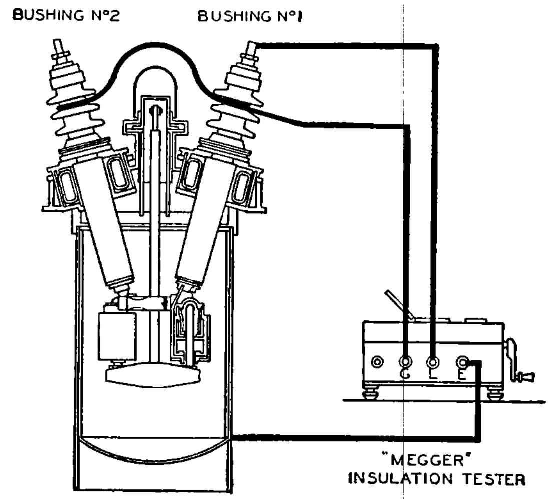

FIGURE 26. Step 4.

V
SUPPLEMENTARY INSTRUCTIONS

Selector Switches

Voltage Selector—On heavy duty type only: Set switch to desired voltage (and corresponding range). Figure 28.

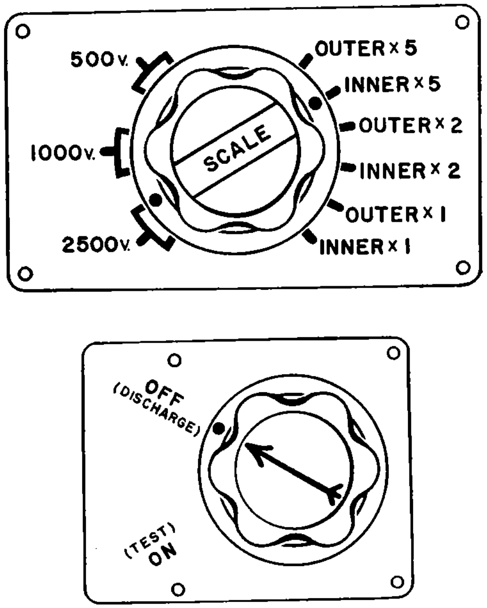

FIGURE 28. Range and voltage switch and associated control switch commonly used on high range instruments.

Megohm Scale, Divide by 1 and Divide by 10: Set switch to the ratio (÷ 1 or ÷ 10) that brings the reading as near as possible to the middle of the scale. Record the numerical scale reading and the position of the ratio switch. Figures 28 and 29.

Megohm and Ohm Scale: Set switch to MEGOHMS for insulation resistance tests. Connect testing leads to the Earth and Line terminals, and read the Megohm Scale. Figure 30.

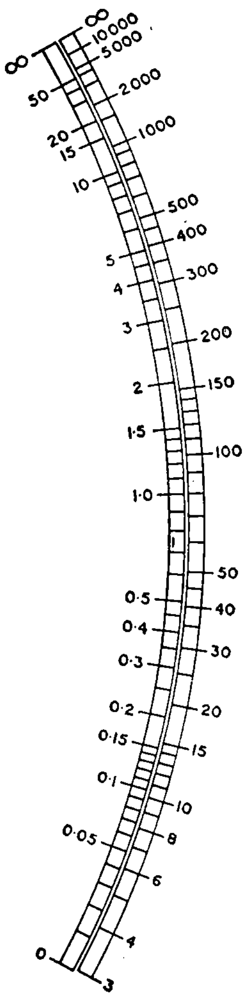

FIGURE 27. Facsimile scale of a multi-voltage, high-range instrument, Cat. 638. 500 v X 1, 1000 v X 2, 2500 v X 5.

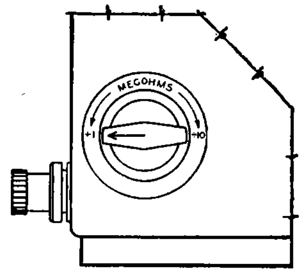

FIGURE 29. Megohm Scale with Divide-by-10 (The A Switch).

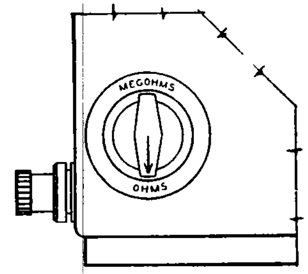

FIGURE 30. Megohm and Ohm Scale (The R Switch).

Instructions for lead connections to terminals of "Meg" type instruments having ohm scales:

Hand-driven 2 and 3-terminal types—use Line and Earth terminals.

Hand-driven 4-terminal types (including dual-operated)—use Guard and Ohms terminals.

Rectifier-operated 3-terminal type—use Earth and Guard, or Line and Guard terminals.

Megohms and Capacitance Discharge for constant-voltage "Meg" type: First set switch to TEST. (See Figure 31.) As soon as the test is completed, turn switch to DISCHARGE. Leave switch on DISCHARGE for at least 30 seconds.

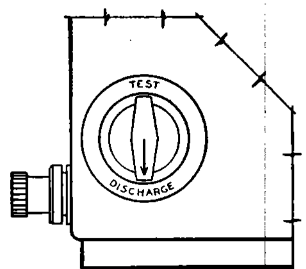

FIGURE 31. Megohm and Capacitance Discharge Switch (The K Switch).

Capacitance Discharge for heavy duty type: The spring type switch, Figure 3, is normally in the DISCHARGE position. When making a test, depress the switch head. When test is completed, release switch to DISCHARGE position. With the rotary type switch, simply turn to TEST or DISCHARGE.

Combination Switches for "Meg" type. Follow instructions as in Figures 32, 33 and 34.

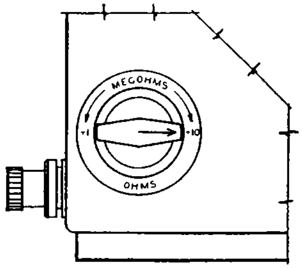

FIGURE 32. Megohm Scale with Divide-by-10 and Ohm Scale (The AR Switch).

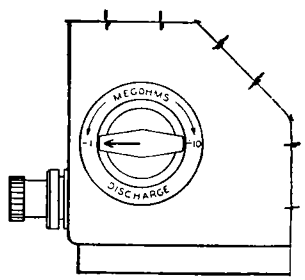

FIGURE 33. Megohm Scale with Divide-by-10 and Discharge Switch (The AK Switch).

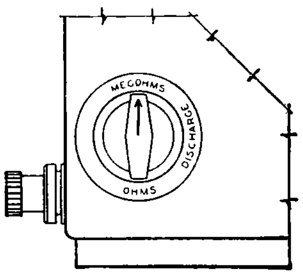

FIGURE 34. Megohm Scale, Ohm Scale and Discharge Switch (The RK Switch).

Checking the Ohmmeter

Checking the Infinity and Zero positions, as per items 3 and 4 in *General Directions,* page 1, will suffice for daily use of a "Megger" instrument. When instruments are correct at these values, they are usually correct throughout the range.

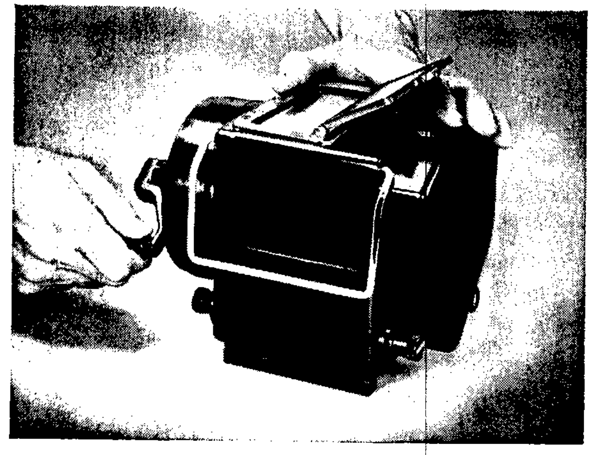

FIGURE 35. Checking Infinity—with no leads connected.

Further check can be made by using precision wire-wound resistors.

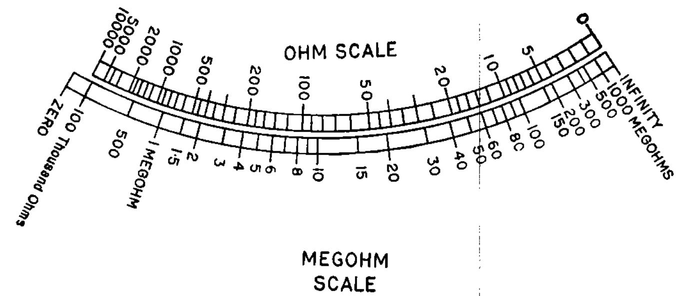

FIGURE 36. Facsimile scale of a 500-volt "Meg" type instrument, 0 to 1000 megohms (with or without Divide-by-10) and Ohm Scale.

Checking Voltage

It is seldom necessary to check the voltage of a "Megger" instrument because of the allowable variations in voltage referred to on page 52.

To measure the terminal (Earth to Line) voltage, use an electrostatic voltmeter. Do not try to use a low resistance voltmeter because the ballast resistance *R′* in Figure 45 will cause the voltmeter to read in error.

An approximation of the generator voltage can be made by using a voltmeter of known high resistance connected to the Earth and Guard terminals on those instruments equipped with Guard terminals.

Lubrication and Repairs

In hand-driven "Megger" Insulation Testers, all bearings are packed with lubricant and ordinarily do not need attention for a long time. Directions for lubricating motor-driven "Megger" instruments are given on page 6. After several years of normal use, instruments should be returned to us for inspection and such servicing as may be necessary.

We repair, rebuild and service all types of our "Megger" instruments, and strongly advise that they be sent to us for the purpose. A report of condition, together with estimate of cost, will be submitted upon request. Reconditioned instruments are returned to the user in condition practically equal to new.

Instruments for repair or servicing should be packed carefully—surrounded by at least three to four inches of excelsior—and forwarded, properly insured and with shipping charges prepaid, to James G. Biddle Co., Township Line & Jolly Roads, Plymouth Meeting, Pa. 19462, together with full information as to the owner and what is desired.

Note: When writing in regard to instruments for servicing or repair, please give serial number.

VI

SUPPLEMENTARY INSTRUCTIONS FOR USING "MEGGER" INSULATION TESTERS

Testing Leads

Inferior or defective testing leads will cause erroneous and misleading results of insulation resistance tests. Take care in this respect.

Uninsulated Leads

To avoid error due to the insulation of leads, place the "Megger" instrument close to the ungrounded terminal or conductor of the apparatus under test and connect a short piece of light bare wire directly from the Line terminal of the instrument to the apparatus. If the Guard terminal is used, it may be treated similarly. No. 18 or 20 gauge solid wire will suffice. Support the lead only by its connections to the instrument and the apparatus.

With this method of connecting from the Line terminal, the quality of the insulation, if any, of the Earth or Ground lead becomes unimportant.

Insulated Leads

Where dependence is placed on the insulation of leads they must be durable and of the best quality insulating material. Oil resistant, synthetic, rubber-insulated, single-conductor No. 14 stranded wire is recommended. The outer jacket should be smooth, with no outer braid. Lugs should be fitted for attaching to the instrument terminals, and stout spring clips are recommended for connecting to the apparatus or circuit under test. Any convenient length of lead may be used. Joints are to be avoided.

After connecting the leads to the instrument, and just before connecting them to the apparatus, *make sure there is no leak from lead to lead.* Do this by operating the instrument, which should read Infinity. Do not correct slight lead leakage by attempting to reset the Infinity Adjuster on a high range instrument. Then touch the test ends of the leads together to make sure they are not disconnected or broken.

Current testing with the high range (50,000 megohms) Megger insulation testers requires that the LINE test lead be maintained at a high value so that it will not enter into the measurement. The shielded test lead, with the shield connected to GUARD prevents any leakages, over its terminations or through the lead insulating material, from being measured.

Instructions For Use

The untagged end of the shielded lead is to be connected to the Line and Guard terminals of the "Megger" instrument —the end terminal to Line and the side (shield) terminal to Guard. The clip on the Line lead is connected to the apparatus under test in the regular way. The outboard Guard terminal may be connected to that part of the apparatus under test which the user wishes to guard. The conductor employed in making this connection must be insulated for the voltage rating of the "Megger" instrument used.

Effect of Capacitance

Capacitance in apparatus under test must be charged up to the rated d-c voltage of the "Megger" Insulation Tester, and maintained for 30 to 60 seconds before a final reading is taken. Make sure that capacitance is discharged–by short-circuiting and grounding the apparatus before connecting the test leads. See *Discharge of Capacitance,* page 11.

NOTE: Capacitance causes the pointer to swing towards Zero while the "Megger" instrument is being brought up to speed; and to swing off scale beyond Infinity when the generator is slowing down. This is simply the charge current flowing into and out of the capacitance and through the deflecting coil of the ohmmeter.

Capacitance effects are most noticeable in large generators, in power and communication cable more than a few hundred feet in length, and in capacitors.

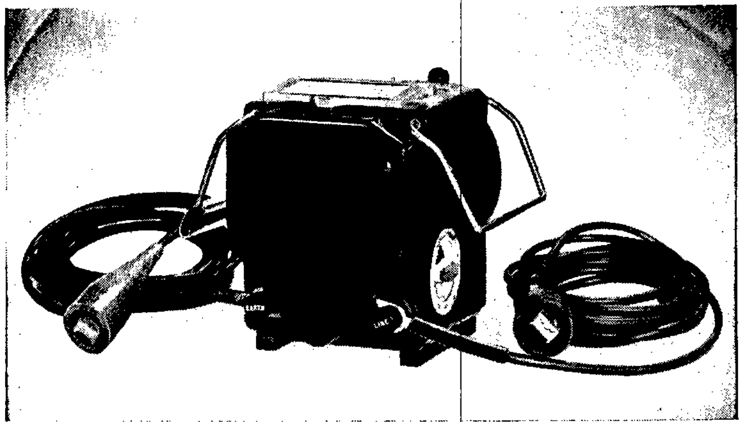

FIGURE 37. "Megger" Insulation Tester with one pair 12-foot heavy duty insulated testing leads.

Operating Time

A very important consideration in making insulation resistance tests is the time required for the reading of insulation resistance to reach a maximum. The time required to charge the geometric capacitance is very short—usually no more than a few seconds—and that which causes further delay in reaching full "charge" is a dielectric absorption effect. It may be a matter of minutes or even hours, for this electrification time to be completed, and for the pointer to reach an absolute maximum.

Short-Time Readings

For short-time readings of insulation resistance, operate the instrument for a definite length of time—either 30 seconds or 1 minute, and read at the end of that time. Continue cranking steadily at slip speed until the reading has been taken. Make future tests with the same length of operating time.

Time-Resistance Method

When using a hand-cranked instrument, operate continuously for 1 minute. Take a reading at the end of the first 30 seconds and another reading at the end of the minute.

When using a motor-driven or rectifier-operated instrument, the time intervals are usually 1 minute and 10 minutes from the time the testing voltage is applied. Or, time-resistance curves may be taken over a period of 10 to 30 minutes, or longer.

VII

USE OF THE GUARD TERMINAL

All Megger insulation testers having ranges of 1,000 megohms and higher are equipped with Guard terminals. The purpose of this terminal is to provide facilities for making a so-called three-terminal network measurement, so that the resistance of one of two possible paths can be determined directly. It has the further or secondary purpose of providing a source of d-c voltage of good regulation and of limited current capacity.

The insulation of all electrical apparatus has two conducting or leakage paths—one through the insulating material and the other over its surfaces. By providing a third test terminal in the path of the surface leakage it is separated into two parts, forming a three-terminal network as shown in Figure 42a. In practice, this third terminal may be provided as shown in Figures 18 and 38 to 41.

There are also cases, such as found in two winding transformers or multi-conductor cables, where a three-terminal network is formed as shown in Figure 42b. Figures 14, 20 and others show practical applications of this form of three-terminal network.

In making a three-terminal test involving only one measurement, the Line terminal of the Megger instrument is connected to Terminal 1, Figure 42a, the Guard terminal to Terminal 3, and the Earth terminal to Terminal 2. This will give the true value of r_{12}, provided r_{23} and r_{13} are not too low in value. The leg r_{23}, which is connected across the Megger instrument generator (see Figure 48), should be about 1 megohm or higher to prevent excessive load on the generator, and maintain satisfactory generator voltage. In using the Guard terminal, particularly in the case of motor-driven or rectifier-operated Megger instruments, also make certain that there

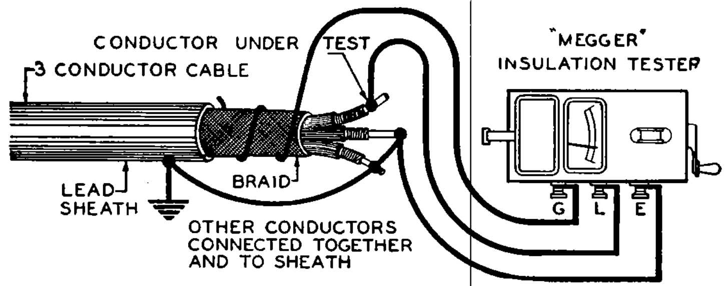

FIGURE 38. Showing how to use the Guard terminal to eliminate the effects of surface leakage across exposed insulation at one end of a cable. See also Figs. 14, 15 and 40.

is no chance of an arc-over between the guarded terminal of the specimen and ground. Such an arc-over may cause undesirable arcing at the commutator of the instrument generator.

The leg r_{13}, which shunts the Megger deflecting coil (coil a, Figure 45), should be at least 100 megohms for a measuring accuracy of approximately 1%. The 1% accuracy figure is based on the R′ ballast resistor (see Figure 45) being 1 megohm, which is typical. For more precise determinations of accuracy, obtain the exact value of R′ by writing to the James G. Biddle Co. giving the serial number of the instrument in use.

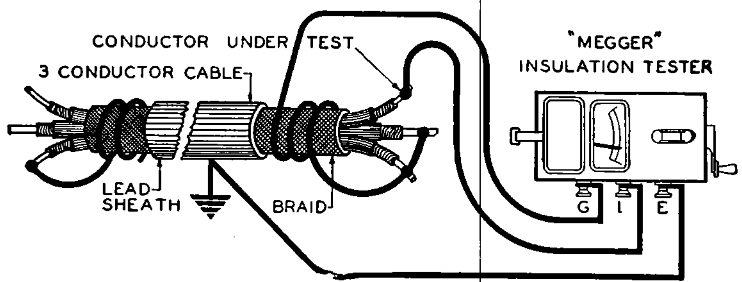

FIGURE 39. Showing how to use the Guard terminal to eliminate the effects of surface leakage across exposed insulation at *both ends* of a cable when a spare conductor in the cable is available for completing the Guard connection.

Where the highest accuracy is desired in cases as shown in Figure 42a, or where the true resistance of each leg is wanted as in the case of Figure 42b, three measurements are re-

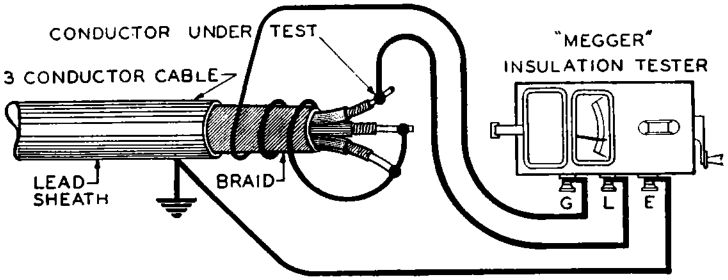

FIGURE 40. Showing use of the Guard connection to eliminate the effect of leakage to ground, as in Figure 38, and also the effect of leakage to adjacent conductors. Note that the Guard wire is wrapped around the exposed insulation and also is connected to the adjacent conductors.

Do not confuse this diagram with Figure 38, where the Guard wire goes only to the exposed insulation, and the adjacent conductors are grounded.

quired and the following equations used:

$$r_{12} = \frac{R_{12}\,R_{13} - (R')^2}{R_{13} + R'}$$

$$r_{23} = \frac{R_{12}\,R_{23} - (R')^2}{R_{12} + R'}$$

$$r_{13} = \frac{R_{12}\,R_{13} - (R')^2}{R_{12} + R'}$$

where R_{12}, R_{23} and R_{13} are the actual readings in megohms measured across the terminals of the network which are connected to the Line and Earth terminals of the Megger instrument with Terminals 3, 1 and 2 respectively connected to the instrument Guard terminal. R′ is the value of the ballast resistance in megohms of the instrument in use. In making these three measurements do not connect the Line terminal of the instrument to the grounded terminal of the network, as any leakage over the instrument case between the Earth terminal and ground will shunt the resistance being measured.

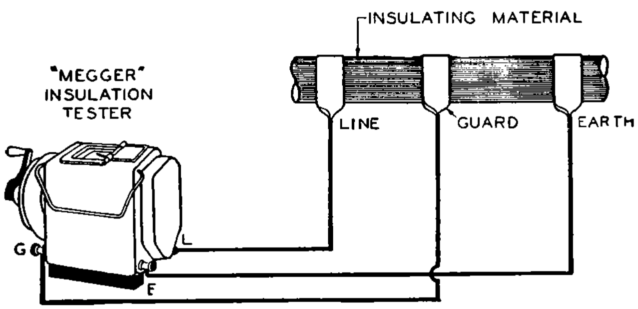

FIGURE 41. To eliminate the effect of surface leakage in measuring the true resistance of an insulating member, such as a lift rod in a circuit breaker.

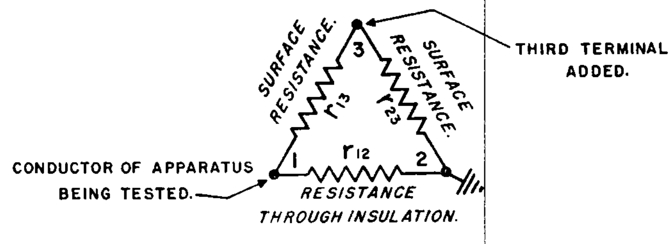

FIGURE 42a

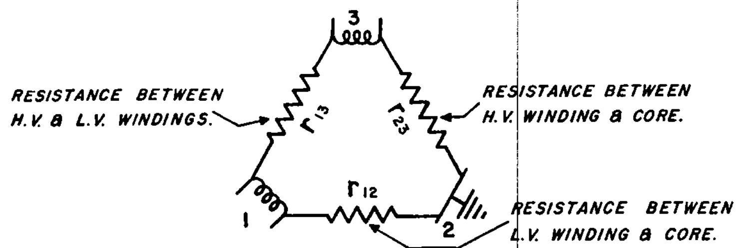

FIGURE 42b

As a Source of Direct Current

With connections from the Earth and Guard terminals, the "Megger" Insulation Tester serves as a convenient source of d-c voltage. This is used:

For Dielectric Strength Tests and for breaking down high resistance faults.

For Operating Wheatstone Bridges at high potential. This is frequently done in telephone work for locating high resistance faults. The instrument is substituted for the Wheatstone Bridge battery, with a corresponding increase in sensitivity of the Bridge.

In a hand-cranked instrument, an overload or a breakdown in a dielectric test is immediately noticed by the load on the hand crank. Cranking must not be forced under load.

When using the Earth-Guard connection, the ohmmeter will read Infinity irrespective of the current which the generator may be delivering. The reason for this should be clear from the diagram, Figure 45. With the Earth-Guard connection, no current flows through the ohmmeter deflecting coil *A*.

Use of Guard Terminal on Motor-Driven Sets For Dielectric Strength or Break Down Tests

Motor-driven "Megger" sets as now supplied have a protective resistance in the guard circuit sufficient to limit the Earth-Guard current in event of a short circuit across the Earth and Guard terminals. In order to detect a short circuit during a dielectric strength or break down test, a milliammeter should be connected externally in series with the Guard terminal. The following currents must not be exceeded:

2500-volt instruments	12 milliamperes
1000-volt instruments	20 milliamperes
500-volt instruments	30 milliamperes

These limitations are necessary to prevent overheating of internal components and driving motor and to preserve proper commutation. The milliammeter referred to in the previous paragraph must be watched carefully and the motor de-energized at the first sign of current values in excess of those given. Otherwise generator commutation may be adversely affected to the extent that pointer excursions may be caused in making insulation resistance measurements on specimens having appreciable capacitance.

Older motor-driven sets, other than the 2500v, 10,000 megohm types supplied prior to Sept., 1947, do not have guard circuit protective resistances. To avoid damaging these instruments from an Earth to Guard short circuit, a resistance of 40,000 ohms should be connected in series with the Earth-Guard connection.

Where the resistance of the circuit under test is high, i.e., above the middle of the scale of instrument being used, approximately full rated voltage will be obtained when using the Earth and Line connections. In this case no dangerous overload will occur under any conditions because of the protective ballast resistance within the instrument. See Figure 45.

VIII

TESTS USING MULTI-VOLTAGE MEGGER INSULATION TESTERS

Maintenance practice trends indicate the value of testing insulation with d-c voltages at levels somewhat higher than the peak value of the rated a-c voltage of the equipment being tested. Such d-c tests have in some cases been shown to reveal nondestructively incipient weaknesses in insulation which could not otherwise be found except possibly by corona detection at nondestructive a-c test voltage levels.

The technique involves the application of two or more d-c voltages, and critically observing any reduction of insulation resistance at the higher voltage. Any marked or unusual reduction in insulation resistance for a prescribed increase in applied voltage is an indication of an incipient weakness.

It is important to mention that the merits of this technique arise from more recent investigations which indicate that rather high d-c voltage can be used to detect weaknesses without damaging the insulation. The maximum value of voltage which should be used will depend largely on the cleanliness and dryness of the insulation to be tested.

In making tests on insulation at such d-c voltages the ohmmeter method has at least two advantages. First, prescribed fixed voltages are switched into use, and one instrument measurement made with the direct reading ohmmeter. This is a more simple and reproducible method than one in which many choices of voltage are available. Another important advantage of the ohmmeter can best be explained by referring to Figure 43. In this figure the change which may occur in leakage current after the absorption current has disappeared is shown plotted in terms of insulation resistance against three different voltages. It is noted that there is no change in resistance shown in the figure between 500 and 1000 volts, indicating no change in the insulation as a result of applying these two voltages. This is an assumption, but is a condition which is not uncommon in practice. If the insulation continues to be stable at 2500 volts there will be no change in the insulation resistance value obtained, which is shown by the dotted extension of the horizontal line in the figure. When nonlinear conditions appear at a higher voltage the voltage-resistance curve reveals this very clearly by a lower resistance value, indicated by the downward curve in the figure. The figure, therefore, reveals the simplicity of determining the change in insulation stability by using three fixed voltages which are easily reproducible when making 3-voltage tests on a routine basis.

We wish to emphasize that the curve in Figure 43 indicates the resistance change due to leakage current only, and not the absorption current which may appear for a period of time with each change in voltage. It may be necessary to wait an appreciable time after each voltage change for the absorption current to disappear before taking a reading.

To understand better the technique of making insulation resistance tests at two or more voltages the following steps are suggested, using an industrial or traction motor classed in the 300 to 1000 volt range as an example:

1) Make a one minute Megger instrument test at 500 volts to serve as a basis of comparison for subsequent steps.
2) After a careful cleaning operation make a second 500 volt Megger instrument test to determine the effectiveness of this cleaning.
3) If the one minute insulation resistance value is subnormal, or if the 60 second/30 second insulation resistance ratio is no greater than one at this point then a drying operation may be desirable before using a higher test voltage. However, making another test at 1000 volts and comparing these readings with those from the 500 volt test will help in determining the need for drying. If the 1000 volt test value is appreciably less than that at 500 volts then a drying operation should be performed. On the other hand, if the 1000 volt and 500 volt test values are approximately the same it is reasonable to assume that the decision to perform a drying operation can be deferred until after the next step.
4) Make a Megger instrument test at 2500 volts. If there is no appreciable difference in the 500 and 2500 volt test

values good evidence has been obtained that the motor in question is in reliable condition as far as its insulation is concerned. If there is an appreciable difference in the two, there is, on the other hand, good evidence that more thorough reconditioning is called for. If the insulation fails under the 2500 volt test, after following steps 1, 2 and 3, we believe there is a likelihood that the motor in question, which in this example is a unit considered to be classed in the 300 to 1000 volt range, would fail in service even though an attempt were made to recondition it on the basis of low voltage tests only.

The multi-voltage method can also be helpful in determining the presence of excessive moisture in the insulation of equipment rated at voltages equivalent to or greater than the highest voltage available in the multi-voltage Megger instrument in use. In other words, even though the highest Megger instrument voltage available does not stress the insulation beyond its rating, a 2-voltage test can, nevertheless, often reveal the presence of moisture. If the insulation resistance is first tested on the short time reading basis—at one voltage, e.g., 500 volts, and then at a higher potential, e.g., 2500 volts (nominal in relation to the voltage rating of the equipment being tested), a lower value of insulation resistance at the higher d-c test voltage usually indicates the presence of moisture. The applied voltages should preferably be in the ratio of 1 to 5. Experience has indicated that a change of 25% in the insulation resistance value, with a 1 to 5 ratio in test voltages, is usually due to the presence of an excessive amount of moisture.

This method is not based on a dielectric absorption phenomena, but it does relate to the "Evershed Effect".

As with time-resistance measurements, the multi-voltage method of testing insulation resistance has increased value when made on a periodic or scheduled basis.

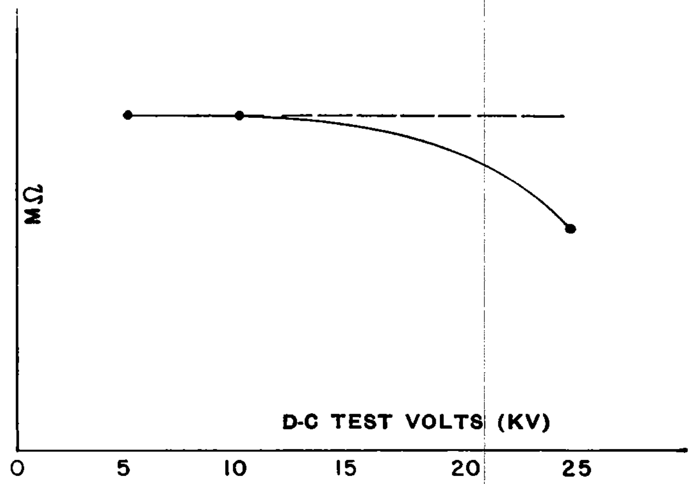

FIGURE 43

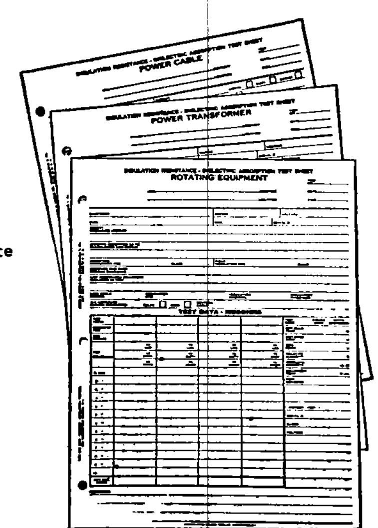

FIGURE 44. Time-resistance test forms.

IX

INTERPRETATION—MINIMUM VALUES

Insulation resistance of electrical equipment is affected by many variables such as the equipment design, the type of insulating material used, including binders and impregnating compounds, the thickness of the insulation and its area, cleanliness (or uncleanliness), moisture, and temperature. For insulation resistance measurements to be conclusive in analyzing the condition of equipment being tested, these variables must be taken into consideration.

Such factors as the design of the equipment, the kind of insulating material used, and its thickness and area cease to be variables after the equipment has been put into service, and minimum insulation resistance values can be established within reasonable tolerances. The variables that must be considered after the equipment has been put into service, and at the time that the insulation resistance measurements are being made, are uncleanliness, moisture, temperature, and damage such as fractures.

Good Housekeeping

The most important requirements in the reliable operation of electrical equipment are cleanliness, and the elimination of moisture penetration into the insulation. This may be considered as good housekeeping and is essential in the maintenance of all types of electrical equipment. The very fact that insulation resistance is affected by moisture and dirt, with due allowances for temperature, makes the "Megger" Insulation Tester the valuable tool which it is in electrical maintenance. It is at once a gauge of cleanliness and good housekeeping as well as a detector of deterioration and impending trouble.

What Readings to Expect—Periodic Tests

Several criteria for *minimum values* of insulation resistance have been developed and are here summarized. They should

serve as a guide for equipment in service. However, periodic tests on equipment in service will usually reveal readings considerably higher than the suggested minimum safe values.

It is therefore strongly recommended that records of periodic tests be kept, because persistent downward trends in insulation resistance usually give fair warning of impending trouble, even though the actual values may be *higher* than the suggested minimum safe values.

Conversely, allowances must be made for equipment in service showing periodic test values *lower* than the suggested minimum safe values, so long as the values remain stable or consistent. In such cases, after due consideration has been given to temperature and humidity conditions at the time of the test, there may be no need for concern. *This condition may be caused by uniformly distributed leakages of a harmless nature, and may not be the result of a dangerous localized weakness.* Here again, records of insulation resistance tests over a period of time reveal changes which may justify investigation. The "trend of the curve" may be more significant than the numerical values themselves.

The "One-Megohm" Rule

For many years *One Megohm* has been widely used as a fair allowable lower limit for insulation resistance of ordinary industrial electrical equipment rated up to 1000 volts, and is still recommended for those who may not be too familiar with insulation resistance testing practices, or who may not wish to approach the problem from a more technical point of view.

For equipment rated above 1000 volts the "one megohm" rule is usually stated: "A minimum of one megohm per thousand volts." Although this rule is somewhat arbitrary, and may be criticized as lacking an engineering foundation, it has stood the test of a good many years of practical experience. It gives some assurance that equipment is not too wet or not too dirty and has saved many an unnecessary breakdown.

More recent studies of the problem, however, have resulted in formulas for minimum values of insulation resistance that are based on the kind of insulating material used, and the electrical and physical dimensions of the types of equipment under consideration.

Minimum Values for Insulation Resistance

Rotating Machinery

Report #43, entitled *"Recommended Practices for Testing Insulation Resistance of Rotating Machinery"* published by the American Institute of Electrical Engineers, deals with the problem of making and interpreting insulation resistance measurements for rotating machinery. It reviews the factors which affect or change insulation resistance characteristics, outlines and recommends uniform methods for making tests, and presents formulas for the calculation of approximate minimum insulation resistance values for various types of a-c and d-c rotating machinery.

It is strongly recommended that those who operate and maintain rotating machinery with ratings of 1000 kva and above in the a-c class and 100 kw and above in the d-c class, obtain copies of this publication for guidance. They may be obtained direct from American Institute of Electrical Engineers, 33 West 39th Street, New York City or through the James G. Biddle Co.

In the case of small a-c machinery rated 999 kva and less, this report states that since these small units are not likely to be designed for use on high voltages, and since it is seldom that users of these machines wish more than a simple test to determine the insulation condition, the following simplified formula is recommended. It is in effect, the old rule "One megohm per 1000 volts" with a minimum of one megohm:

$$R_1 = Kv + 1$$

where

R_1 = Standard insulation resistance of class A or B stator armature windings in megohms at winding temperatures up to 75° C, obtained by applying 500 volts d-c to the entire winding for one minute.

Kv = Rated machine voltage in kilovolts

In the case of small d-c machines rated 99 kv and less the report states that since these small units are not likely to be designed for use on high voltages, and since the users of these machines seldom wish more than a simple test to determine the condition of the insulation, the standard insulation resistance for these armature windings should be of the order of one megohm at winding temperatures up to 75° C, obtained by applying 500 volts d-c to the winding for one minute.

Bushings

In the case of outdoor oil circuit breaker bushings, experience has shown that any bushing, with its assembled associated

insulating members, should for reliable operation, have an insulation resistance value above 10,000 megohms at 20°C. This assumes that the oil within the tank is in good condition, that the breaker is separated from its external connections to other equipment, and that the porcelain weather shield is guarded. This means that each component such as the stripped bushing itself, cross-member, lift rod, lower arcing shield etc., should have an insulation resistance in excess of that value.

Any components which are superficially clean and dry and having values less than 10,000 megohms are usually deteriorated internally, by the presence of moisture or carbonized paths, to such an extent that they are not reliable for good service unless reconditioned. This is particularly so when operating under surge conditions such as during lightning disturbances. In the case of the stripped bushing itself, the lower stem and upper weather shield must be either perfectly clean or guarded before it is condemned as unreliable because of an insulation resistance value less than 10,000 megohms.

What has been said for stripped oil circuit breaker bushings also applies to bushings for other equipment such as transformers. Since bushings and other associated members have very high insulation resistance values normally, a "Megger" Insulation Testing Set having a range of at least 10,000 megohms is necessary in testing such equipment. "Megger" instruments having ranges up to 50,000 megohms will permit the observation of deteriorating trends in bushings before they reach the questionable value of 10,000 megohms.

Cable and Conductors

Cable and conductor installations present a wide variation of conditions from the point of view of the resistance of the insulation. These conditions result from the many kinds of insulating materials used, the voltage rating or insulation thickness, and the length of the circuit involved in the measurement. Furthermore, such circuits usually extend over great distances, and may be subjected to wide variations in temperature, which will have an effect on the insulation resistance values obtained. The terminals of cables and conductors will also have an effect on the test values unless they are clean and dry, or guarded. See Section VII.

The Insulated Power Cable Engineers Association gives minimum values of insulation resistance in its Specifications for various types of cables and conductors. These minimum values are for new, single-conductor wire and cable after being subjected to an a-c high voltage test and based on a d-c test potential of 500 volts applied for one minute at a temperature of 60°F.

These standard minimum values (for single-conductor cable) are based on the following formula:

$$R = K \log_{10} \frac{D}{d}$$

where

R = megohms per 1000 feet of cable
K = constant for insulating material
D = outside diameter of conductor insulation
d = diameter of conductor

Minimum values of K at 60°F.

Insulation Type		
Impregnated Paper		2640
Varnished Cambric		2640
Thermoplastic—Polyethylene		above 50,000
Thermoplastic—Polyvinyl		
	Natural Rubber	*Synthetic Rubber*
Code		950
Performance	10,560	2000
Heat Resistant	10,560	2000
Ozone Resistant	10,000 (Butyl)	2000
Kerite		4,000

See pages 48 and 49 for tables of $\log_{10} \frac{D}{d}$

The insulation resistance of one conductor of a multiconductor cable to all others and sheath is:

$$R = K \log_{10} \frac{D}{d}$$

where

D = diameter over insulation of equivalent single conductor cable
$= d + 2c + 2b$
d = diameter of cond. (for sector cables d equals diameter of round cond. of same cross-section)
c = thickness of conductor insulation
b = thickness of jacket insulation

(all dimensions must be expressed in same units).

Transformers

Acceptable insulation resistance values for dry and compound-filled transformers should be comparable to those for class A rotating machinery, although no standard minimum values are available.

Oil-filled transformers or voltage regulators present a special problem in that the condition of the oil has a marked influence on the insulation resistance of the windings.

In the absence of more reliable data the following formula is suggested:

$$R = \frac{CE}{\sqrt{kva}}$$

R = minimum 1-minute 500-volt d-c insulation resistance in megohms from winding to ground, with other winding or windings guarded, or from winding to winding with core guarded.

C = a constant for 20°C measurements.

E = voltage rating of winding under test.

kva = rated capacity of winding under test.

For tests of winding to ground with the other winding or windings grounded, the values will be much less than that given by the formula. R in this formula is based on dry, acid-free, sludge-free oil, and bushings and terminal boards that are in good condition.

Values of C at 20°C.

	60-cycle	*25-cycle*
Tanked oil-filled type	1.5	1.0
Untanked oil-filled type	30.0	20.0
Dry or compound-filled type	30.0	20.0

The foregoing formula is intended for single-phase transformers. If the transformer under test is of the three-phase type, and the three individual windings are being tested as one, then:

E = voltage rating of one of the single-phase windings (phase to phase for delta connected units and phase to neutral for star connected units.)

kva = rated capacity of the complete three-phase winding under test.

Values of $\log_{10} \frac{D}{d}$

A.W.G. or C.M.	Insulation Thickness - Inches												
	.047	.063	.078	.094	.109	.125	.141	.156	.172	.188	.203	.219	.234
14 sol.	.392	.470	.537	.594	.645	.691	.732	.770	.804	.836	.866	.894	.921
12	.334	.405	.467	.520	.568	.611	.651	.686	.720	.751	.779	.806	.832
10	.283	.348	.404	.453	.498	.538	.575	.609	.641	.670	.698	.723	.748
8	.239	.296	.347	.392	.432	.470	.505	.537	.566	.594	.621	.645	.669
6 str.		.225	.267	.305	.340	.373	.403	.431	.453	.483	.506	.529	.550
5		.206	.245	.281	.314	.346	.373	.401	.426	.450	.463	.495	.515
4		.187	.224	.257	.289	.318	.345	.371	.395	.418	.440	.460	.480
3		.171	.204	.236	.265	.293	.318	.343	.366	.388	.409	.429	.448
2		.155	.186	.215	.243	.269	.293	.316	.338	.359	.379	.398	.416
1		.139	.168	.195	.220	.244	.267	.288	.309	.328	.347	.365	.382
1/0		.126	.152	.177	.201	.223	.244	.264	.284	.302	.320	.337	.354
2/0		.114	.138	.161	.183	.204	.223	.242	.261	.278	.295	.311	.327
3/0		.102	.125	.146	.166	.185	.204	.221	.238	.255	.271	.286	.301
4/0		.0923	.113	.132	.151	.168	.187	.202	.218	.233	.248	.262	.276
250,000		.0854	.104	.123	.140	.157	.173	.189	.204	.218	.232	.246	.259
300,000		.0787	.0963	.113	.130	.145	.160	.175	.189	.203	.216	.229	.250
350,000		.0731	.0897	.106	.121	.136	.150	.164	.177	.190	.203	.215	.227
400,000		.0688	.0845	.0995	.114	.128	.142	.155	.168	.181	.193	.204	.216
500,000		.0620	.0763	.0901	.103	.116	.129	.141	.153	.165	.176	.187	.198
600,000			.0700	.0853	.0952	.107	.119	.130	.141	.152	.163	.173	.183
700,000			.0686	.0769	.0888	.100	.111	.122	.133	.143	.153	.163	.172
750,000			.0665	.0749	.0861	.0971	.108	.118	.129	.139	.148	.157	.167
800,000			.0644	.0727	.0836	.0943	.105	.115	.125	.135	.144	.154	.163
900,000			.0580	.0687	.0793	.0895	.0994	.108	.120	.128	.137	.146	.155
1,000,000			.0551	.0656	.0755	.0851	.0948	.104	.113	.122	.131	.140	.148
1,250,000			.0500	.0590	.0681	.0770	.0856	.0943	.103	.111	.119	.127	.134
1,500,000			.0456	.0541	.0625	.0708	.0789	.0870	.0946	.102	.110	.116	.125
1,750,000			.0423	.0502	.0581	.0658	.0734	.0810	.0899	.0954	.103	.110	.117
2,000,000			.0397	.0472	.0546	.0619	.0691	.0761	.0830	.0898	.0965	.103	.108
2,500,000			.0357	.0425	.0492	.0558	.0623	.0687	.0750	.0812	.0874	.0934	.0993

Continued on next page.

Values of $\log_{10} \frac{D}{d}$

A.W.G. or C.M.	Insulation Thickness - Inches												
	.250	.266	.281	.297	.313	.328	.344	.359	.375	.391	.407	.422	.438
14 sol.	.945												
12	.856												
10	.771	.793	.814	.834	.853	.871	.889	.906	.922				
8	.691	.712	.731	.751	.770	.787	.804	.821	.836	.851	.866	.880	.894
6 str.	.570	.590	.608	.626	.643	.660	.676	.699	.706	.720	.734	.746	.760
5	.535	.554	.572	.589	.606	.622	.637	.652	.667	.680	.694	.707	.720
4	.500	.517	.535	.551	.568	.583	.598	.613	.625	.640	.653	.666	.678
3	.466	.483	.500	.516	.532	.547	.562	.576	.589	.603	.615	.628	.640
2	.433	.450	.466	.482	.497	.512	.526	.540	.553	.565	.578	.590	.602
1	.399	.415	.431	.445	.461	.474	.487	.501	.513	.525	.538	.549	.561
1/0	.369	.385	.399	.414	.428	.441	.454	.466	.479	.491	.502	.514	.525
2/0	.342	.356	.370	.384	.397	.410	.422	.435	.446	.458	.469	.480	.490
3/0	.315	.329	.342	.355	.367	.380	.392	.403	.414	.425	.436	.447	.457
4/0	.289	.302	.315	.327	.339	.351	.362	.373	.384	.395	.405	.415	.425
250,000	.272	.284	.296	.309	.320	.331	.342	.352	.363	.373	.383	.392	.402
300,000	.254	.266	.278	.289	.300	.310	.321	.331	.341	.351	.360	.369	.379
350,000	.239	.250	.262	.272	.283	.293	.303	.313	.323	.332	.341	.350	.359
400,000	.227	.236	.249	.259	.269	.279	.289	.298	.308	.317	.326	.334	.343
500,000	.208	.218	.228	.238	.248	.257	.266	.275	.284	.292	.301	.309	.317
600,000	.193	.203	.212	.221	.230	.239	.248	.256	.265	.273	.281	.289	.297
700,000	.181	.191	.199	.209	.217	.225	.234	.242	.250	.258	.266	.273	.281
750,000	.176	.185	.194	.203	.211	.220	.228	.236	.243	.251	.259	.266	.273
800,000	.172	.180	.189	.198	.206	.214	.222	.230	.237	.245	.252	.260	.267
900,000	.164	.172	.180	.189	.196	.204	.212	.219	.227	.234	.242	.249	.255
1,000,000	.157	.165	.173	.181	.189	.196	.203	.211	.218	.225	.232	.239	.245
1,250,000	.142	.150	.157	.165	.172	.179	.186	.192	.199	.206	.212	.219	.225
1,500,000	.132	.139	.146	.153	.159	.166	.172	.179	.185	.190	.197	.204	.210
1,750,000	.123	.130	.136	.143	.149	.155	.162	.168	.174	.180	.185	.191	.197
2,000,000	.116	.122	.128	.135	.141	.145	.153	.159	.164	.170	.176	.181	.187
2,500,000	.105	.111	.117	.122	.128	.134	.139	.144	.150	.156	.160	.165	.170

X

PRINCIPLE OF OPERATION OF "MEGGER" INSULATION TESTING INSTRUMENTS

The "Megger" ohmmeter is a permanent magnet, cross-coil indicating instrument whose accuracy is independent of the exact voltage supplied for the test. No compensation or adjustment is necessary.

The ohmmeter consists essentially of two coils—*A* and *B* in Figure 45, mounted on the same moving system with pointer attached and free to rotate in a permanent magnet field. The system is pivoted in spring-supported jewel bearings.

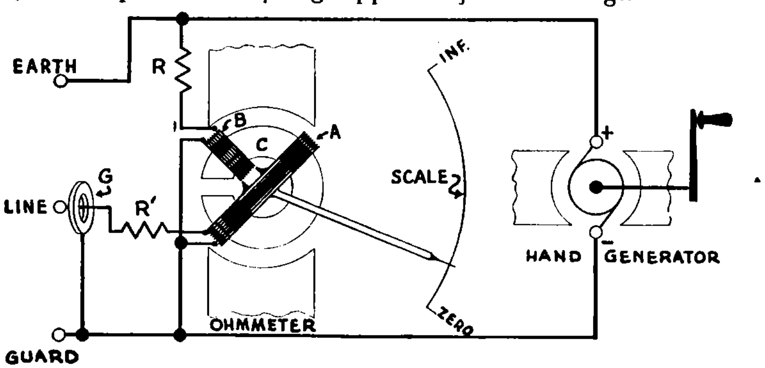

FIGURE 45. Basic diagram of electrical connections for the "Megger" Insulation Tester.

There are no control springs such as are used in ammeters and voltmeters. Current is led to the coils by flexible conducting ligaments which offer the least possible restraint, so that when the instrument is level and no current is supplied, the pointer should float towards Infinity.

Deflecting and Control Coils

The deflecting coil *A* is connected in series with a fixed ballast resistance *R'* and the resistance under test, the latter being connected to the Earth and Line terminals.

The control coil *B* is connected in series with a fixed resistance *R*.

Coils *A* and *B* are mounted on the moving system at a fixed angle to each other, and are so connected that when current is supplied they develop opposing torques and tend to turn the moving system in opposite directions. The pointer, therefore, comes to rest where the two torques are balanced.

With either perfect insulation or nothing at all connected to the testing terminals, no current will flow in coil *A*. Coil *B*, however, receives current and will take a position opposite the gap in the C-shaped iron core. The corresponding position of the pointer over the scale is marked Infinity.

When a resistance is connected to the Earth and Line terminals, a current will flow in the deflecting coil *A* and the corresponding torque will draw coil *B* away from the Infinity position into a field of gradually increasing magnetic strength until a balance is obtained between the forces exerted by the two coils. In this manner coil *B* acts like a restraining spring.

As shown in Figure 46, the control coil is actually in two parts forming an astatic system, B being the main part that develops control torque as a result of the permanent magnet field. B' is a coil mounted outside of the permanent magnet field, and in series with the control coil, but connected in opposition so that stray fields are neutralized. In other words, any external fields which may ordinarily tend to displace the pointer from its infinity calibration, will produce equal and opposing torques in the two parts of the control coil, thereby making the moving system free of any errors from that cause.

Scales—Calibration

By connecting resistances of different known values to the Earth and Line terminals and marking the corresponding position of the pointer in each case, a scale calibrated in resistance is obtained. In this manner the scales of all "Megger" Insulation Testers are *individually* calibrated and drawn.

See Appendix (page 56) for "Instructions for Checking the Calibration of Megger Insulation Testers—All Types."

If the Earth and Line terminals are short circuited, the pointer simply moves to Zero. The ballast resistance *R'* offers ample protection against excessive current in coil *A*. With no current supplied to the ohmmeter, the pointer will relax and float towards Infinity as already explained.

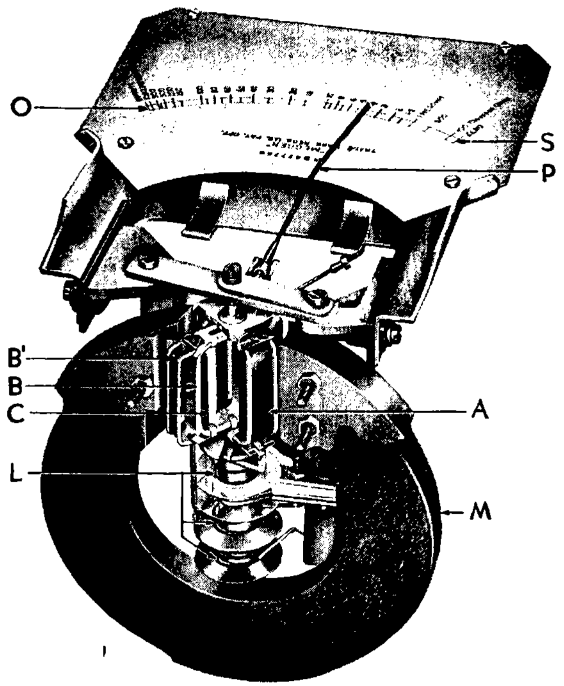

FIGURE 46. Ohmmeter system of the "Meg" type of "Megger" Insulation Tester.

OS = ohmmeter scale	A = deflecting coil
P = pointer	C = fixed C-shaped iron core
B = control coil	L = ligaments
B' = astatic part of control coil	M = permanent magnet

Variations in Generator Voltage

The calibration of the "Megger" ohmmeter is unaffected by the applied voltage, within plus or minus 20% of normal—or between 400 and 600 volts in a 500-volt instrument. This is because the two ohmmeter coils *A* and *B* (Figure 45) receive current from the same source. Any change in the applied voltage will affect both coils in the same proportion, and therefore the pointer will take the same position for a given resistance under test. Consequently the calibration is unaffected by the exact speed at which a hand crank may be turned or by the exact strength of the permanent magnets.

Guard System

Figure 45 shows how the Line terminal is guarded by a metallic guard washer which prevents errors due to leakage

across the outer surface of the instrument between the Earth and Line terminals. The leakage current is simply shunted away from the Line terminal and returns to the current supply without passing through the deflecting coil of the ohmmeter.

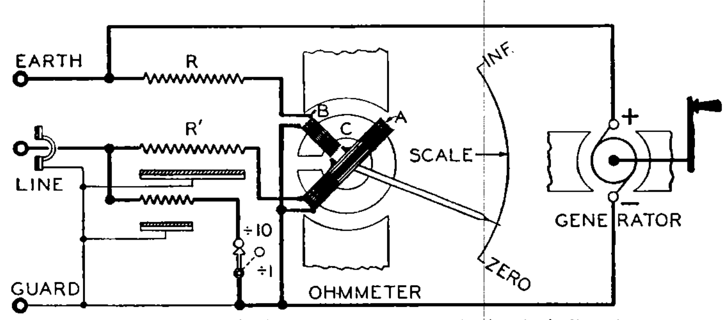

FIGURE 47. Basic diagram, as in Figure 45, but including the Guard System and ratio switch.

Figure 47 shows, in principle, how the Guard System is used inside the instrument. The same Figure also shows the method of shunting the ballast resistance *R'* for the purpose of dividing the scale range by 10 and by 100.

All types of the "Megger" Insulation Testing Instruments have the Guard System, except the Midget type, which is of low range and has a molded plastic case of good insulating quality.

Voltage Characteristics

When using a "Megger" Insulation Tester the voltage actually applied to the apparatus under test is a function of the resistance under test in series with the instrument ballast resistance *R'* in Figs. 45 and 47. Voltage regulation of the generator or other source of supply may be considered negligible. The voltage characteristic is therefore expressed by the formula—

$$V_t = \frac{R}{R+R'}\,Vi$$

Where V_t = the terminal or applied voltage
R = Insulation Resistance of the apparatus under test
R' = Instrument ballast resistance
Vi = instrument voltage, i.e. the voltage generated or applied to the instrument

Figure 48 shows the Earth-to-Line terminal voltage characteristic for a 500-volt, 200-megohm "Meg" type instrument, having a ballast resistance of approximately 100,000 ohms in the divide-by-one range, and a ballast resistance of approximately 11,000 ohms in the divide-by-ten range. If the resistance under test happens to be 100,000 ohms, and the divide-by-one range is being used, the rated instrument voltage of 500 volts will obviously be divided equally between these two resistances, and the voltage at the Earth and Line terminals will be 250. If the divide-by-ten range is used for the same test, the rated instrument voltage of 500 will be divided in the ratio of 100,000 to 111,000, o.e., 10/11 of the total, or approximately 455 volts. When testing an external resistance of one megohm, the terminal voltage will be about 455 volts when the divide-by-one range is used, and practically full voltage (i.e., 500 volts) when the divide-by-ten range is used.

This example shows: (a) that over the upper two-thirds of the scale (the principal working range of the instrument) 90%

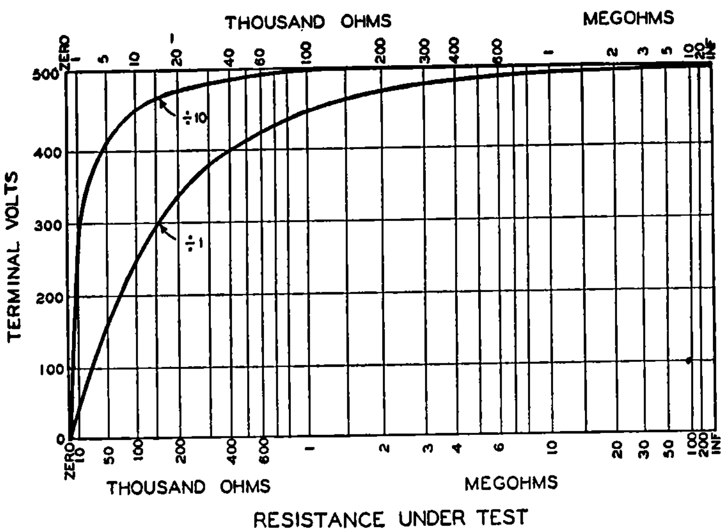

FIGURE 48. Earth-to-Line terminal voltage characteristic of a 500-volt "Meg" type instrument having a ballast resistance of 100,000 ohms.

or more of the rated voltage is applied to the equipment under test, and (b) that low insulation resistance is automatically protected from what otherwise might be too high a voltage, particularly when the divide-by-one range of the instrument is used.

Figure 49 shows the Earth-to-Line terminal voltage characteristic of a high-range, heavy-duty type instrument having a ballast resistance of 1 megohm. Note that the voltage is constant between 100 and 10,000 megohms and reduces to about 20% of full voltage at the four-megohm end of the scale.

More detailed voltage characteristic data for all types and ratings of "Megger" Insulation Testers will be furnished upon request.

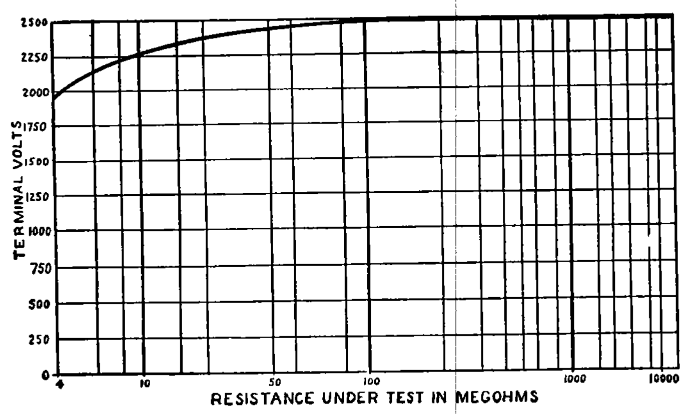

FIGURE 49. Terminal Voltage characteristic of a 2500-volt, 10,000-megohm "Megger" Insulation Tester, having a ballast resistance of 1 megohm.

The abscissae scales in Figures 48 and 49 are laid out to correspond with the actual scales of the instruments. This practical form of presentation is suggested for judging the voltage characteristic of any type of insulation resistance testing device.

APPENDIX

Instructions for Checking the Calibration of Megger Insulation Testers—All Types

In checking the calibration of Megger Insulation Testers two methods are suggested. One method involves the use of direct measured resistance standards for the full range. These are usually difficult to obtain except at great expense. The second method makes use of low resistance standards, adapted to the full range by means of shunting. This permits use of commercially available standards.

As an aid to understanding the application of the two methods, refer to Figure 47, in which a Guard terminal and the guard system are shown. As explained, all types of Megger Insulation Testing Instruments have guard systems, except the Midget type. However, the Guard terminal is not used on low range types (below 1,000 megohms, 500 V), even though internally the elements of the guard system are present. On Megger Instruments not having Guard terminals, and manufactured prior to approximately 1948, the external guard connection may be made to the brass disk in back of the hard-rubber disk on which the Line terminal is mounted. This brass disk is connected directly to the internal guard system. The guard disk of the Meg Instrument is set in a deep groove in the insulating washer supporting the Line terminal. The connection to the internal guard system can, therefore, be made by winding a fine wire tightly in the groove. If the Guard connection is not externally accessible the direct substitution method must be used.

Direct Substitution Method:

When using the direct substitution method, it is only necessary to connect a standard resistance unit of suitable multiple values between the Earth and Line terminals of the Instrument. The calibration is checked by operating the generator at rated speed and reading the scale. The reading corresponds to the value of standard resistance inserted between Line and Earth. There are several precautions to be observed in using this method. For higher range measurements, 1000 megohms and up, the resistance should be adequately guarded against leakage, as explained in Chapter VII. Also, the wattage rating of the resistance used should not be exceeded. The wattage rating may be taken as $\left(\frac{V_t}{R_s}\right)^2 \times R_n$, where V_t is the rated voltage of the instrument and R_s is the standard resistance under test. When R_s is made up of units in series, $R_s = R_1 + R_2 + R_3$, etc., the watts in any one unit is: $\left(\frac{V_t}{R_s}\right)^2 \times R_n$, where R_n is the resistance of that particular unit. As shown on pages 53 and 54, V_t will vary with the load and wattage capacity of the resistance standard may be lessened as V_t is reduced. This method MUST be used on rectifier operated and dual operated Meg Instruments and certain Megger Instruments, as will be explained later.

Shunting Method:

The second method involves the use of only a limited number of resistance standards, supplemented by the shunt principle. The choice of this method is based on commercially available standards rated from 1 to 10 megohms in 10 steps, 1 watt per step. A rheostat, covering a range up to approximately 50,000 ohms is also required.

The shunting method can be best understood by noting the function of the ratio switch in Fig. 47, which is connected between the Guard and Line terminals. In Fig. 47, the resistance in the divide-by-10 shunt must be exactly 1/9 of the total A or deflecting coil circuit resistance, (consisting of R′ and the resistance of the A coil in series). This makes the total resistance between Line and Guard exactly 1/10 the value it was in the divide-by-1 position of the switch. Therefore, in the divide-by-10 position only 1/10 of the load current flows through the A coil circuit, causing the pointer to indicate 10 times the actual resistance connected to the Earth and Line terminals. In the divide-by-100 position as found on some early models, the resistance of the shunt is similarly 1/99 of the unshunted value of the A coil circuit resistance, and the total current through the A coil is 1/100 of the current in the divided-by-1 position for the same resistance connected to Line and Earth.

This same shunt principle may be used to check the entire resistance range above 1 megohm of Megger Insulation Testers with only a limited number of resistance standards available. A single range Meg type of Insulation Tester, Cat.

#7680, rated at 1,000 V and 2,000 megohms, will be given as an example and checked by using a 1 to 10 megohm standard cited above. The standard resistance, having 10 steps of 1 to 10 megohms, is first used to check the corresponding scale graduations on the Instrument directly by connecting to the Earth and Line terminals, and then switching through the range of the standard. After the 10 megohm graduation is found to be correct, the standard is switched back to the 1 megohm position and a shunting resistance is connected between the Guard and Line terminals. The value of shunting resistance is determined from the A coil circuit resistance of approximately 400,000 ohms, thus the necessary shunt must have at least 1/9 of this value to give a multiplying factor of 10. It is not necessary to measure this value by auxiliary means, since after connecting it between Line and Guard, it is only necessary to adjust it until the pointer on the Instrument again indicates exactly 10 megohms. At this point the scale factor is 10, so the shunting resistance must be exactly 1/9 (approximately 45,000 ohms) of the A coil circuit resistance. Now the scale graduations from 10 to 100 megohms can be checked by switching the standard resistance through its steps, 1 to 10 megohms.

When the 100 megohm graduation has been checked, the standard resistance is again returned to the 1 megohm position and the shunt resistance reduced until the pointer again indicates 100 megohms. At this point the shunt is 1/99 (approximately 4,000 ohms) of the resistance in the A coil circuit, giving a scale factor of 100. With the shunt adjusted, the scale graduations from 100 to 1,000 megohms may be checked by again switching the standard resistance through its steps.

When the 1,000 megohm graduation has been checked, the standard and shunt resistances are again adjusted. Now the shunt resistance is adjusted to 1/999 of the A coil circuit resistance, giving a scale factor of 1,000. The 2,000 megohm graduation is checked by switching the standard resistance to its 2 megohm step. Thus, all the scale graduation above 1 megohm, except 15 and 150 megohms, are checked. These two values are not checked by this method since there is no 1.5 megohm step on this particular standard.

An alternate procedure, that may only be applied to the hand operated Meg type Instruments and certain other Meg-

ger Instruments, involves using only one standard resistance, preferably 1 megohm and a shunt resistance. However, the shunt resistance must be re-adjusted for each scale graduation to be checked. First, the A coil circuit resistance must be accurately measured from Line to Guard with a Wheatstone bridge and recorded. Then each shunt resistance value S must be calculated from the formula $S = \frac{A + R'}{f - 1}$ where $A + R'$ is the measured A coil circuit resistance and f is the scale factor (the scale graduation to be checked divided by the value of the standard resistance). As an example, the 15 megohm graduation, one of the two missed by the previous example, could be checked by this method. First, the resistance is measured accurately from Line to Guard and recorded. Then, substituting into the formula

$$S = \frac{A + R'}{f - 1} \text{ we have } S = \frac{A + R'}{\frac{15}{1} - 1} = \frac{1}{14}(A + R'),$$

using a megohm standard. The shunt is then set for 1/14 of the A coil circuit resistance. When the shunt is connected between Line and Guard, with a 1 megohm standard between Earth and Line, the Instrument should indicate 15 megohms.

On the Meg type Instrument having a divide-by-10 switch, this switch may be used instead of an external shunt to extend the range of the available standard resistances. However, the resistance values between Line and Guard must first be checked to insure that the resistance in the divide-by-1 range is exactly 10 times the resistance in the divide-by-10 range. If the available standards do not cover the entire range of the Instrument by using the divide-by-10 range, the switch may be set to divide-by-1 and external shunts used instead.

Earlier it was mentioned that the shunt method was applicable only to certain models. The shunt method may be used on all hand operated models of the Meg type. However, it cannot be used on rectifier operated types because the ballast resistance is inserted in the earth circuit instead of the line circuit to protect the rectifier against external short circuits between the Earth and Guard terminals. On hand operated models any such short circuit would immediately become apparent because of difficulty in cranking. Furthermore, it is impractical to shunt the A coil alone since the shunt setting would never be correct due to the change in resistance of the A coil caused by the heating effect of the current. This same resistance change is present in the hand operated types, but the percentage change is made negligible by masking this small change by the relatively large ballast resistor in series with it. All current models of Megger Insulation Testers are equipped with Guard terminals. However, on motor-driven models and on 2500 volt models, and higher, there is a resistor in series with the Guard terminal to protect the generator in case of short circuit. On some models this resistance is as high as 100,000 ohms. Therefore, even with the Guard and Line terminals shorted the maximum shunting ratio would be approximately 40, limited by the guard resistance in series with the short. As was found in the example, this ratio must be 1,000 or more to check the upper end of the scale. Therefore, shunting is impractical on Instruments having a protective resistance in the guard circuit. Where the Line terminal guard ring is not accessible, the shunting method can only be used by opening the Instrument to reach the guard system ahead of the guard resistance. In this case it is recommended that the Instrument be returned to factory for the calibration check.

Practical limits must be observed in selecting the values of the standard resistance and the shunting resistance. If the standard resistance selected requires a correspondingly low value shunt resistance, the load on the generator may be excessive, which will cause overheating and poor commutation and at the same time reduce the voltage across the control coil. This in turn will reduce the current through this coil, causing loss of control. Likewise, if the shunting is carried to extremes, errors may result because the adjustment of the shunt becomes very critical. The resistance values of the standards used in the previous examples are found to be most practical.

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