Battery MEGGER® Tester BM11

Operating Instructions

MEGGER®

SAFETY WARNING

- ★ *The circuit must be de-energised and isolated BEFORE connections are made for an insulation test.*
- ★ *Do not touch the circuit during an insulation test.*
- ★ *After insulation tests, capacitive circuits MUST be allowed to discharge BEFORE disconnecting the test leads.*
- ★ *Test leads, including prods and crocodile clips, must be in good order; clean and having no broken or cracked insulation.*
- ★ *Never lock the 'TEST' button in the 'on' position unless it is absolutely necessary. Be extremely careful not to cause a hazard if this is done.*
- ★ *Insulation tests MUST NOT be carried out while the battery charger supply lead remains connected to its socket.*

Refer also to page 10 for further explanations and other precautions.

The warnings and precautions must be read and understood before the instrument is used. They must be observed during use.

Contents

General Description

The BM11 is a battery operated, portable, high voltage insulation tester measuring up to 100 GΩ resistance. Four test voltages are available 0,5 kV, 1 kV, 2,5 kV and 5 kV each with the same analogue resistance measuring range. The tester will also act as a voltmeter reading up to 1000 V a.c. or d.c. and thus providing two important features. Firstly, giving an automatic indication that the equipment on test is de-energised before testing commences, and secondly acting as a capacitive circuit discharge monitor. The tester automatically becomes a voltmeter when the 'TEST' push-button is not pressed.

The power is obtained from rechargeable batteries and the tester has an integral battery charger unit operating from a 100 V — 250 V, 50 Hz — 60 Hz mains power supply. Indication is given by the pointer, when the battery is approaching its fully exhausted state, but also a separate battery check is provided.

The instrument circuitry is divided into two parts, a high voltage generator and a measurement circuit. The high voltage is obtained from a stored energy inverter while an 'electronic cross-coils' circuit, (an electronic version of the well proven Evershed Cross-coils ohmmeter), is used for the measurement and yields the readings directly in ohms. The inverter circuit makes efficient use of the available battery power while giving rapid charging of capacitive circuits under test. These circuits are automatically discharged after testing when the 'TEST' push-button is released.

The tester is contained in a robust, moulded plastic case with a carrying handle and has a hinged, detachable lid for protecting the front panel.

The controls, meter and terminals are mounted on the front panel. A five position rotary switch is provided for selecting the test voltage required or the battery check facility. The 'TEST' push-button must be pressed to energise the circuit and perform an insulation test. It is recessed into the panel to reduce the risk of accidental operation and can be locked in the pressed ('on') position by a clockwise rotation. Three screw-down type terminals are provided marked '+' '−' and 'G'. The equipment to be tested is connected to the '+' and '−' terminals. 'G' is a guard terminal, to enable errors caused by surface leakage to be eliminated (see page 12 for details on the use of the guard terminal). The meter, a moving coil type, has a black scale plate, white markings and an orange knife edge pointer. The upper scale is for insulation resistance measurements and is calibrated from 100 kΩ to 100 GΩ with 0 and ∞ also marked, the lower scale marked 0 to 1000 is for voltage measurements. (If the selector switch is set to 'battery check', instead of one of the test voltage positions, this will have an effect on the voltage reading. However, a voltage indication will still be given). The mains input socket for battery charging is mounted below a removable sealed cover, where a red mains indicating lamp is also to be found.

The tester is supplied with three test leads terminated with clips and a mains supply lead for battery charging.

Note:— It is advisable to ensure that the battery is fully charged before embarking upon any tests.

Applications

The BM11 battery MEGGER® tester may be used for routine insulation resistance measurements on many components such as motors, generators, transformers, high voltage insulators, power cables and wiring installations. Because it is battery operated it is particularly suitable for service and field applications.

The tester can be employed in the routine maintenance of plant and installations, to make measurments showing the state of the insulation when in service and the amount of degradation that takes place due to the effects of corrosion, dirt, grease, moisture etc. From such results the future performance of these items can be estimated and interruptions or breakdowns avoided.

Step-voltage tests, whether these are at the full rating or below, can be used to indicate the condition of insulation subjected to moisture and dirt, or point to a weakness. A ratio of 1:5 in the test voltage is suitable and if the tests are carried out for a similar period of time, a difference between the resistance readings of the lower voltage test and higher voltage test, points to a weakness in the insulation. Absolute values of insulation resistance are not of great importance but the change in resistance is indicative of the trend in the insulation condition. Such tests are valuable when performed regularly on a scheduled basis and a record of results kept.

Dielectric Absorption testing, which involves insulation tests on capacitive circuits for several minutes, is also possible.

The safety of electrical installations and apparatus depends upon the condition of the insulation and it is essential that this is thoroughly checked when new equipment is installed. The test voltage applied should be high enough to break through any mechanical flaws arising from manufacture or installation.

The tester can also be used to monitor the improvement in insulation within motor, generator and transformer windings etc. that result from drying out procedures following their service in excessively humid atmospheres.

Specification

Ranges	
Insulation resistance range	100 kΩ to 100 GΩ at all test voltages.
Test voltage d.c.	500 V 1 kV 2,5 kV 5 kV.
Voltage range a.c. or d.c.	50 V to 1000 V.
Accuracy (at 20°C)	
Insulation resistance range	± 1,5% of arc length. (± 20% of reading from 1 MΩ to 10 GΩ).
Test voltage	± 5% on open circuit.
Short Circuit Current	1 mA nominal, 2 mA maximum.
Ripple Content	< 10 V pk-pk worst case (R < 10 MΩ).
Capacitor Charging Time	< 18s to charge a 2 μF capacitor to the 1 GΩ mark at 5 kV.
Capacitor Discharging Time	< 2s to discharge a 2 μF capacitor from 5 kV to 50 V. Automatic when test button is released. Discharge voltage monitored on the meter.
Hum Rejection (50 Hz–60 Hz)	Will measure with up to 2 mA r.m.s. hum current (a.c. interference) on 5 kV range.
Maximum Continuous Overload (externally applied voltage)	1 kV for test terminals 250 V for guard terminal
Temperature Coefficient	< 0,04% of arc length/°C (< 0,5% of reading /°C from 1 MΩ to 10 GΩ)
Temperature Range	operating − 15 °C to + 55 °C storage − 40 °C to + 65 °C
Scale Length	123 mm

Specification

Power Supply

NiCd battery pack of 2 Ah capacity
Battery life:– typically 8 h continuous (varying between 2 h and 20 h depending upon load conditions)
Battery charging:– built-in charging unit, operating from 100 V — 250 V a.c. supply, 50 Hz or 60 Hz
Charging time:– 16 h
Low battery voltage indication:– small oscillations of the pointer occur with an approx. 80% exhausted battery. Large pointer oscillations occur when the battery must be recharged.

Dimensions

344 x 245 x 158 mm
(13½ x 9⅝ x 6¼ in)

Weight

4,8 kg (10½ lb) excluding leads

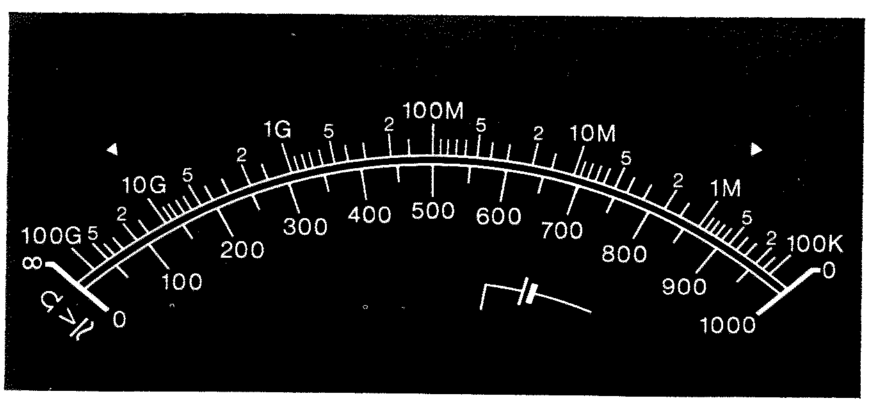
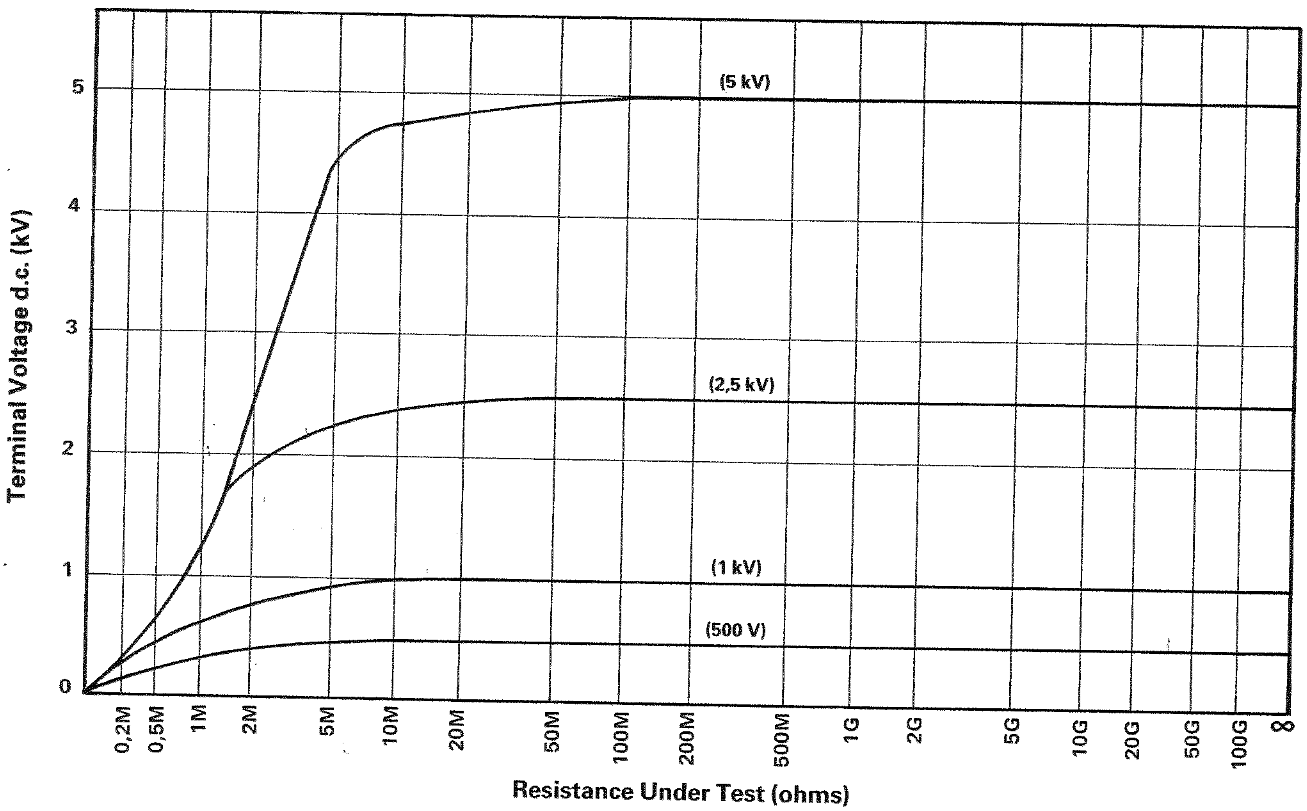


Illustration of BM11 scale (not full size)



Typical terminal voltage characteristics

Operation

WARNING

1. The equipment to be tested must be de-energised. Before making insulation tests, disconnect and isolate apparatus that is the subject of the test.
2. Before making any insulation measurements the battery charger power supply lead MUST be removed from the instrument and the battery charger socket cover replaced.
3. In connecting the instrument to the circuit care must be taken to ensure that there is no hazard to the user due to the voltage produced at the instrument terminals, which can be up to 5 kV.
4. The instrument generates very high voltages which, applied to capacitive loads such as long lengths of cable, will usually produce a lethal charge within half a second of pressing the 'TEST' push-button. If the capacitive load becomes disconnected during a test it will be left in a charged state. Care must be taken to avoid this. Also when testing capacitive circuits, check that the meter reads <50 V before disconnecting the instrument after carrying out a test.
5. For prolonged tests, e.g. on capacitive circuits, the 'TEST' push-button may be locked down by pressing and then turning it clockwise with the thumb or fore-finger. Care should be taken, with the instrument in this operating mode, that no harm or damage is done if it is left unattended, because it is producing a dangerously high voltage. To prevent excessive discharge to the point of causing possible damage to the battery, it is advisable to check the instrument every 15 minutes.

For optimum safety, never lock the push-button unless it is absolutely necessary. Care should be taken that excessive voltages are not applied to the terminals. Maximum continuous voltage that may be applied, (from an external source), between the '+' and '−' terminals is 1000 V and between the guard 'G' and '−' terminals is 250 V. If the meter indicates a voltage >1000 V the source of voltage must be removed as soon as possible (5 kV applied between '+' and '−' will cause damage after approx. 5s). Maximum permissible current injected into the terminals from a high impedance source is 2 mA.

THE DETACHABLE LID

The lid hinges are fitted with spring loaded clips and are designed in this way for two reasons. Firstly, if the lid is accidentally thrown open to its full extent, the hinges will not be strained or broken but the lid will be safely unclipped. Secondly, the lid can purposely be removed, if required, when the tester is in use by simply opening it up to its full extent and gently pressing down on the opening edge while holding the tester body firm. The hinges will then unclip.

To replace the lid, hold it vertically and push the hinges back into their clips again while restraining the instrument. Then fold the lid shut.

PRELIMINARY CHECKS

1. Check that the meter pointer rests over the '∞' mark on the upper scale with nothing connected to the terminals and the 'TEST' push-button **not** pressed. If necessary set the pointer with the mechanical adjuster situated below the meter, using a small screwdriver.

2. Turn the test voltage selector switch to the battery check position '⊣⊢'. Press the 'TEST' push-button and check that the meter reads to the right of the battery check mark on the scale shown thus ⊣⊢ . Release the push-button.

3. Connect the test leads to the '+' and '−' terminals and ensure that the clips are not touching anything. Set the test voltage selector switch to the appropriate voltage required. Press the 'TEST' push-button and observe the meter reading. The pointer should come to rest very close to the '∞' mark on the scale. If it does not, leakage is occurring between the test leads, test clips or possibly the instrument terminals. Release the push-button and check to find the leakage source.

4. With the test leads still connected to the instrument, join together the '+' and '−' test lead clips. Press the 'TEST' push-button and check that the meter reading is zero on the upper scale. Release the push-button. If the reading is not zero the test leads are suspect and should be inspected for a fault, i.e. open circuit.

MAKING AN INSULATION TEST TO EARTH

1. Perform the Preliminary Checks as given above

2. Connect the '+' test lead to the equipment to be tested, and the '−' test lead to earth (frame of the equipment etc).

   Note:— (i) if the equipment on test is not de-energised the voltage present will be automatically indicated on the lower scale of the meter. Do not press the 'TEST' push-button, but switch the circuit off and ensure that no voltage is present before proceeding with a test.

   (ii) If the equipment to be tested is known to be de-energised yet a voltage reading is obtained, this is indicative of the presence of a.c. interference currents caused by capacitive or inductive coupling to live circuits (see page 13).

   (iii) Although it is normal to connect the '−' terminal to earth, the '+' terminal might equally well be used. Accuracy of measurement will not be affected.

3. With the correct test voltage selected, press the 'TEST' push-button.

4. Read the value of the insulation resistance directly from the upper scale.

   Note:— If, when taking a reading, the pointer displays small oscillations, this is an indication that the battery is becoming exhausted. When the pointer oscillations become large the battery must be recharged before any more tests are carried out. For battery charging instructions see page 13.

5. Release the push-button and wait until the meter voltage reading is less than 50V (shown on the lower scale) before disconnecting the test leads.

MAKING AN INSULATION TEST BETWEEN WIRES

1. Perform the Preliminary Checks as given above.

2. Connect one test lead to each conductor and then proceed as before in steps (3), (4) and (5) for an Insulation Test to Earth.

Operation

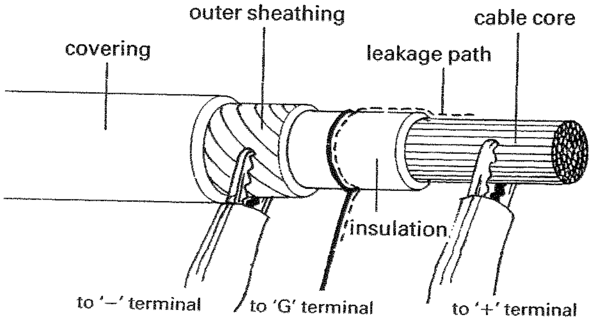
USING THE GUARD TERMINAL

For basic insulation tests the guard terminal will not be used.

Most insulation tests can be performed by connecting the specimen between the '+' and '−' terminals. These tests will show up any deficiencies in the insulation, whether they are caused by leakage through the insulator body or across its surface.

To distinguish between body leakage and surface leakage the guard terminal 'G' may be used. In this way surface leakage current is removed before it enters the measurement circuit via the '−' terminal.

In cable testing, there may be a path of leakage across the insulation between the bared cable and the external sheathing, perhaps due to the presence of moisture or dirt. Where it is required to remove the effect of this leakage, particularly at high testing voltages, a bare wire may be bound tightly around the insulation and connected via the third test lead to the guard terminal 'G'.



Since the leakage resistance is effectively in parallel with the resistance to be measured, the use of the guard causes the current flowing through the surface leakage to be diverted from the measuring circuit. The tester therefore, gives more nearly the true insulation resistance.

When the guard terminal is connected it will cause two other errors, which, although usually negligible, can affect the measurement if the surface leakage resistance is <20 MΩ approx. These are:

(i) The leakage resistance has a loading effect on the voltage at the '+' terminal which causes the actual voltage at the terminal to be slightly less than the voltage sensed by the reference circuit and results in a measurement error.

(ii) The leakage current shunts a small proportion of current away from the measuring circuit and results in a measuring error.

A 20 MΩ surface leakage resistance will produce a typical error of 0,5% of scale length. Serious errors will only occur if the surface leakage resistance is so low that the power available is insufficient to generate the required voltage across the surface leakage resistance. Refer to the graph of voltage characteristics on page 9.

LOW BATTERY INDICATION

If the pointer displays small oscillations (approx. 2 mm amplitude at 1 Hz) during an insulation test, this indicates that the battery is more than 80% exhausted. The instrument can still be used in this condition but the battery should be re-charged at the earliest opportunity.

If the pointer displays large oscillations (approx. 50 mm amplitude, thus making it impossible to take a reading) the instrument must not be used until the battery has been re-charged. It is preferable never to allow this condition to be reached as excessive discharge can cause permanent damage to the battery. If the instrument is stored the battery will lose its charge over a period of several months. This will not cause any damage to the battery but charging will be necessary before the instrument is used. Moderate over-charging will do no harm and the battery can be charged on a regular basis (e.g. monthly) to keep the instrument serviceable.

CHARGING THE BATTERY

Note:— The instrument should not be used for insulation testing whilst the battery is being charged.

1. Disconnect the tester from any external circuit and remove the test leads.
2. Remove the battery charger socket cover, situated adjacent to the terminals by pulling up on the two cover clips.
3. With a suitable mains supply plug connected to the battery lead, plug the lead into the instrument and then into a 100 V – 250 V, 50 Hz – 60 Hz mains power supply.
4. Switch the supply on and leave the battery to charge for 16 hours (power consumption is about 12 W). A red indicating light next to the charging socket will be illuminated while the battery is being charged.
5. After charging, switch off the mains supply, and remove the battery charging lead.
6. Before commencing insulation tests, replace the battery charger socket cover and secure it by pressing down on the two cover clips.
   Note:— When the charger socket cover is removed this opens a vent in the instrument and allows any moisture which may have accumulated to escape. It is therefore necessary to charge the battery in dry conditions and most important to replace the charger socket cover before the instrument is taken out for field use.

The battery should remain serviceable for at least five years if:

(a) it is never allowed to discharge completely.
(b) it is not subjected to high temperature for long periods of time. (Temperatures greater than 50 °C for more than 8 hours per day, will considerably reduce the battery life).

A.C. INTERFERENCE

The amount of a.c. interference that can be tolerated without seriously affecting accuracy can vary considerably according to the conditions of the test. As a general rule the maximum permissible a.c. interference current level is 2 mA on the 5 kV range and proportionally less at lower voltages. When the a.c. interference originates from a high impedance source the voltmeter can be used as a milliammeter with an approximate f.s.d. of 10 mA. For example if the meter reads 200 V this represents 2 mA and it should be possible to make a test on the 5 kV range. Excessive a.c. interference will normally result in an unstable reading.

If the a.c. interference current is unstable in amplitude, or if transient interference is present this will cause greater difficulty in obtaining measurements as any low frequencies will not be blocked by the input filter on the measurement circuit. This problem will be most acute when measuring very high values of resistance on low voltage ranges.

Operation

PREVENTIVE MAINTENANCE

It is good practice to make regular tests of the insulation resistance of all larger machinery and thus detect any incipient faults. When the tests are entered in the logbook a considerable variation between test results will be noted. It is therefore important to test under similar conditions each time and to note the current weather status.

Damp weather — or damp conditions of use or storage — can cause large reductions in insulation resistance. Drying out by heat or by operation for a period, should give a more consistent and appropriate insulation resistance value.

A counter effect to that above occurs because the insulation resistance of the varnishes used in the construction of machine windings becomes lower when hot than when cold. Thus for constant comparisons the temperature of the machine under test should also be noted.

The best plan is to make regular insulation checks as soon as possible after the machine has been shut down. The insulation resistance is then likely to be at its lowest operational value, this then would become the figure which would show any continuing mechanical depreciation or potential insulation breakdown.

If the machine stands idle in humid conditions a worse picture might well apply but this would normally be assumed to be safe during the running up to temperature, provided that the resistance at working temperature remained unchanged.

TESTING MOTORS AND GENERATORS

(1) Disconnect the equipment from the line by opening the main switch and removing the main fuses.

(2) Join together BOTH terminals on the motor side of the double pole main switch.

(3) With a contactor operated starter where all the lines to the motor are disconnected at off it is necessary to make tests to earth on both the incoming and outgoing terminals of the starter.

(4) Connect the '−' terminal of the BM11 MEGGER tester to earth using the frame of the motor or switch.

(5) Using the '+' terminal measure the resistance of each part of the circuit in the usual way. If the value is unsatisfactory then separate tests in starter, motor and cables must be carried out to locate the defect.

(6) If the motor itself is suspect, disconnect the supply cables and with one lead connected to the frame carry out the following tests.

(7) Test with the armature and field windings connected together.

(8) Test with the brushes lifted from contact with the commutator.

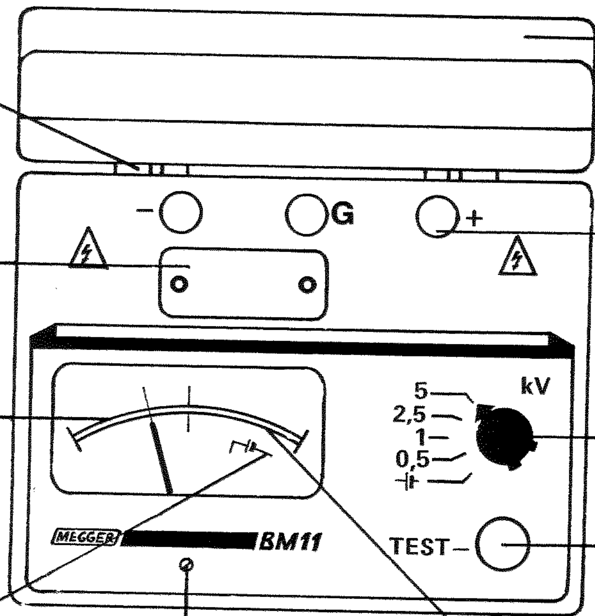
(9) Test on the armature only, section by section.

(10) If all resistances are low the fault can usually be remedied by complete and careful cleaning of the machine.
Equipment that has been in service for a period can accumulate metallic, or other conducting, dust especially when mixed with oil from bearings etc. The leakage paths from such deposits are eliminated by thorough cleaning.

Outline Diagram

detachable hinges
charnières séparables
lösbare scharniere
bisagras desmontables

hinged lid
couvercle monté sur charnières
schwenkbarer deckel
tapa abisagrada



terminals
bornes
anschlußklemmen
terminales

battery charger socket cover
cache-prise chargeur de batteries
abdeckung der batterie-ladebuchse
tapa de toma para
cargador de baterias

insulation resistance scale
echelle d'isolement
isolations-widerstandsskala
escala de resistencia de
aislamiento

test voltage selector switch
sélecteur de tension d'essai
prüfspannung-wahlschalter
selector de voltaje de prueba

'TEST' push-button
bouton poussoir de
mise en service
'TEST' drucktaste
botón 'TEST'

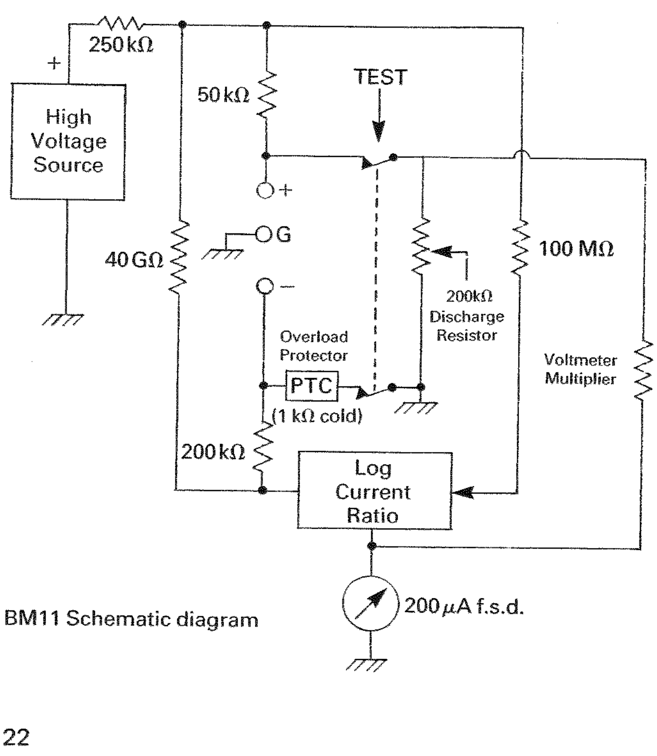
battery check
indicateur de charge des batteries
batterieprüfung
indicatador de carga de bateria

meter mechanical adjuster
réglage mécanique du zéro
mechanische nullpunkteinstellung
adjuste del cero mecánico

a.c. and d.c. voltage scale
eschelle de tension,
en courants alternatifs et continus
wechsel- und gleichspannungsskala
escala de voltaje c.a. y c.c.

Circuit Description

(see also the circuit diagram)
There are two main sections within the tester, the inverter, producing the high test voltage, and the current measuring circuit. The high voltage '+' terminal is positive with respect to the guard 'G' and '−' (measurement) terminals.

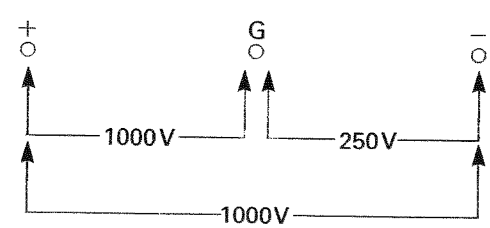


BM11 Schematic diagram

The inverter operates in three modes:
(i) Constant output voltage for low loads, i.e. resistances >10 MΩ.
(ii) Constant output power for heavy loads, i.e. resistances approx. 5 MΩ.
(iii) Constant output current for very heavy loads and short circuit.

The measurement circuit uses a pair of matched transistors to produce a voltage proportional to the logarithm of the ratio of leakage current (current through test sample) to applied voltage. The scale shape is of the basic form $\frac{1}{5}\log_{10}\frac{100}{R}$ where R is the resistance of the test samples in MΩ. Deliberate cramping at each end of the scale enables the 0 and ∞ marks to be shown and still give five decades of resistance measurement.

The maximum allowable continuous voltage that may be applied to the test terminals is:–



The maximum current through all terminals is 2 mA.

Battery life

Current is only drawn from the battery while the 'TEST' push-button is pressed. The battery life is typically 8 hours if the instrument is used at 5 kV test voltage, with varying resistive loads with parallel capacitance between 0 and 2 μF.

However, the instrument can supply 4,75 kV to a 10 MΩ load and if used in such a condition continuously will exhaust the battery in 2½ hours.

Note:— under short circuit conditions the 1 mA current limit comes into operation and the battery drain is then quite low.

A battery check facility is provided on the rotary switch. This checks the battery voltage with a dummy load when the 'TEST' push-button is pressed. However, checking nickel cadmium cells in this way is of very limited value as their voltage gives no indication of their state of charge other than showing if they are completely exhausted.

To give the user an indication when the battery is approaching an exhausted state a low battery detection system is used which involves causing part of the battery to drain at a slightly higher rate than the remainder. This part of the battery reaches the low voltage state first. This condition is detected, and an oscillator is activated which causes small, but visible oscillations on the meter pointer. When the remainder of the battery becomes so exhausted that there is insufficient voltage to operate the instrument properly, a voltage detector circuit causes large oscillations to be superimposed on the meter pointer thus preventing a measurement being made.

The only adjustment available to the operator is the mechanical pointer adjuster which is located on the front panel. This may need to be re-set to infinity if the instrument has been subjected to mechanical shock or vibration. The electronic circuits are sufficiently stable so that no adjustment should ever be required during normal use.

If a fault develops, the instrument should only be repaired by qualified personnel who are aware that dangerous voltages are developed in parts of the instrument circuit, and who will exercise extreme caution while working on the instrument when it has been removed from its case.

Components List

INSTRUMENTATION PRINTED CIRCUIT BOARD

R8	Resistor	5,6 kΩ ± 5%	⅓ W
R9	Resistor	47 kΩ ± 5%	⅓ W
R13	Resistor	560 Ω ± 5%	⅓ W
R14	Resistor	180 kΩ ± 5%	⅓ W
R15	Resistor	220 Ω ± 10%	7 W
R17	Resistor	3,3 Ω ± 5%	⅓ W
R18	Resistor	100 Ω ± 5%	⅓ W
R20	Resistor	8,2 kΩ ± 5%	⅓ W
R21	Resistor	8,2 kΩ ± 5%	⅓ W
R22	Resistor	100 Ω ± 5%	⅓ W
R23	Resistor	1 kΩ ± 5%	⅓ W
R24	Resistor	1 kΩ ± 5%	⅓ W
R28	Resistor	47 Ω ± 5%	⅓ W
R29	Resistor	4,7 kΩ ± 5%	⅓ W
R30	Resistor	1 kΩ ± 5%	⅓ W
R31	Resistor	2,7 kΩ ± 5%	⅓ W
R35	Resistor	22 Ω ± 5%	⅓ W
R37	Resistor	22 Ω ± 5%	⅓ W
R38	Resistor	22 Ω ± 5%	⅓ W
R39	Resistor	1,2 kΩ ± 5%	⅓ W
R46	Resistor	100 kΩ ± 5%	⅓ W
R47	Resistor	15 kΩ ± 5%	⅓ W
R48	Resistor	100 kΩ ± 5%	⅓ W
R51	Resistor	220 kΩ ± 5%	⅓ W
R53	Resistor	310 kΩ ± 1%	¼ W
R54	Resistor	160 kΩ ± 1%	¼ W
R55	Resistor	27 kΩ ± 1%	¼ W
R56	Resistor	27 kΩ ± 1%	¼ W
R57	Resistor	36 kΩ ± 1%	¼ W
R58	Resistor	62 kΩ ± 1%	¼ W
R59	Resistor	47 Ω ± 5%	⅓ W
R61	Potentiometer	1 MΩ ± 20%	
R62	Resistor	50 MΩ ± 5%	½ W

R63	Resistor	56 kΩ ± 5%	⅓ W
R64	Potentiometer	10 kΩ ± 20%	
R65	Resistor	56 kΩ ± 5%	⅓ W
R67	Resistor	33 kΩ ± 2%	⅓ W
R71	Resistor	3,9 MΩ ± 5%	⅓ W
R72	Resistor	33 kΩ ± 2%	⅓ W
R73	Potentiometer	10 kΩ ± 20%	
R74	Resistor	3,3 kΩ ± 5%	⅓ W
R75	Resistor	10 kΩ ± 5%	⅓ W
R76	Resistor	33 kΩ ± 2%	⅓ W
R77	Resistor	1 MΩ ± 5%	⅓ W
R78	Resistor	47 kΩ ± 5%	1 W
R79	Resistor	3,9 kΩ ± 5%	⅓ W
R80	Potentiometer	100 kΩ ± 20%	
R81	Resistor	1 MΩ ± 5%	⅓ W
R82	Thermister	1 kΩ cold	
R83	Resistor	100 kΩ ± 5%	⅓ W
R84	Resistor	100 kΩ ± 5%	⅓ W
R85	Resistor	1 MΩ ± 5%	⅓ W
R86	Resistor	100 kΩ ± 5%	⅓ W
R87	Resistor	12 kΩ ± 5%	⅓ W
R88	Platinum Resistor (100 Ω at 0°C)		
R90	Select on test		
R91	Select on test		
R92	Resistor	2,2 kΩ ± 1%	¼ W
R93	Resistor	1 MΩ ± 5%	⅓ W
R95	Resistor	27 kΩ ± 5%	⅓ W
R96	Potentiometer	500 Ω ± 20%	
R97	Resistor	220 kΩ ± 5%	⅓ W
R98	Resistor	10 MΩ ± 5%	⅓ W
R99	Resistor	10 MΩ ± 5%	⅓ W
R101	Resistor	3,3 MΩ ± 5%	⅓ W
R103	Resistor	3,3 kΩ ± 5%	⅓ W
R104	Resistor	220 kΩ ± 5%	⅓ W

R106	Resistor	27 kΩ ± 5%	⅓ W
R108	Resistor	100 kΩ ± 5%	⅓ W
R112	Resistor	14 kΩ ± 1%	¼ W
R113	Potentiometer	100 kΩ ± 20%	
R114	Resistor	390 kΩ ± 5%	⅓ W
R115	Resistor	6,8 kΩ ± 5%	⅓ W
R116	Resistor	100 kΩ ± 5%	⅓ W
R117	Resistor	390 Ω ± 2%	⅓ W
R118	Resistor	27 kΩ ± 5%	⅓ W
R119	Potentiometer	100 kΩ ± 20%	
R120	Resistor	220 kΩ ± 5%	⅓ W
R129	Resistor	2,2 kΩ ± 5%	⅓ W
R130	Resistor	3,9 kΩ ± 1%	¼ W
R131	Potentiometer	1 kΩ ± 20%	
R132	Resistor	3,9 kΩ ± 1%	¼ W
R133	Resistor	14 kΩ ± 1%	¼ W
R135	Resistor	10 kΩ ± 5%	⅓ W
R136	Resistor	10 MΩ ± 5%	⅓ W
R137	Resistor	220 kΩ ± 5%	⅓ W
R138	Resistor	1 MΩ ± 5%	⅓ W
R139	Resistor	13 kΩ ± 2%	⅓ W
R140	Resistor	6,8 Ω ± 10%	7 W
R141	Resistor	47 kΩ ± 5%	⅓ W
R142	Resistor	47 kΩ ± 5%	⅓ W

C2	Capacitor	100 µF	16 V electrolytic
C7	Capacitor	0,1 µF ± 10%	63 V
C8	Capacitor	470 µF	40 V electrolytic
C9	Capacitor	0,1 µF ± 10%	63 V
C11	Capacitor	0,01 µF ± 10%	63 V
C12	Capacitor	0,01 µF ± 10%	63 V
C17	Capacitor	100 µF	16 V electrolytic
C18	Capacitor	100 µF	16 V electrolytic
C19	Capacitor	0,1 µF ± 10%	63 V
C20	Capacitor	0,1 µF ± 10%	63 V
C21	Capacitor	0,1 µF ± 10%	63 V
C25	Capacitor	1 µF ± 20%	400 V
C26	Capacitor	1 µF ± 20%	400 V
C27	Capacitor	47 pF ± 2%	63 V
C28	Capacitor	1 µF ± 20%	400 V
C29	Capacitor	1 µF ± 20%	400 V
C30	Capacitor	0,1 µF ± 10%	100 V
C38	Capacitor	0,47 µF ± 10%	10 V
C39a	Capacitor	0,01 µF ± 10%	63 V
C39b	Capacitor	0,01 µF ± 10%	63 V
C40	Capacitor	0,1 µF ± 10%	100 V
C41	Capacitor	0,1 µF ± 10%	100 V
C42	Capacitor	0,01 µF ± 10%	63 V
C43	Capacitor	0,01 µF ± 10%	630 V d.c. 300 V a.c.

D1 to D4	Diode	1N4002
D7	Zener diode	BZY88C9V1
D9	Diode	1N4148
D10	Diode	1N4002
D12	Diode	1N4148
D13	Diode	1N4148
D16	Diode	1N4002
D17	Diode	1N4002
D21	Diode	BC183
D22	Diode	BC183
D22a	Diode	BC183
D30 to D35	Diode	1N4148
D36	Zener diode	6,4 V 1N4565
D37	Diode	1N4002

Components List

TR5	Transistor	BC213	
TR6	Transistor	BC183	
TR7	Transistor	FT2955	
TR8	Transistor	BC183	
TR9	Transistor	BC213	
TR11	Transistor	2N3053	
TR14	Transistor	BC213	
TR16	Transistor	BC213	
TR19	Transistor	BC183	
TR21	Transistor	FT2955	
TR22	Transistor	BC183	
TR26	Transistor	BC213	
TR27	Transistor	BC183	Matched to 2 mV
TR28	Transistor	BC183	Matched to 2 mV
TR29	Transistor	BC213	
TR30-TR34	Transistor	BC183	
TR35	FET	J113	

IC3	Integrated circuit	CA3140
IC4	Integrated circuit	IC4001
IC5	Integrated circuit	CA3140

SVP1	Surge voltage protector	part no. 28863-285
T2	Low voltage transformer	part no. 6231-067
SW1B	Micro switch	part no. 25475-581
S2	Rotary switch	part no. 25462-887

HIGH VOLTAGE PRINTED CIRCUIT BOARD

R1	Resistor	270 kΩ ± 5%	⅓ W
R2	Potentiometer	100 kΩ ± 20%	
R3	Resistor	270 kΩ ± 5%	⅓ W
R3a	Resistor	470 kΩ ± 5%	⅓ W
R4	Resistor	4,7 kΩ ± 5%	⅓ W
R5	Resistor	150 kΩ ± 5%	⅓ W
R6	Resistor	27 kΩ ± 5%	⅓ W
R7	Resistor	100 kΩ ± 5%	⅓ W
R10	Resistor	1,5 kΩ ± 5%	⅓ W
R11	Resistor	3,9 kΩ ± 5%	⅓ W
R12	Resistor	1,8 kΩ ± 5%	⅓ W
R16	Resistor	680 Ω ± 5%	⅓ W
R16a	Resistor	470 kΩ ± 5%	⅓ W
R19	Resistor	180 Ω ± 5%	⅓ W
R25	Resistor	680 Ω ± 5%	⅓ W
R26	Resistor	22 Ω ± 5%	⅓ W
R27	Resistor	2,2 kΩ ± 5%	⅓ W
R32	Resistor	1 kΩ ± 5%	⅓ W
R33	Resistor	47 kΩ ± 5%	⅓ W
R34	Resistor	47 kΩ ± 5%	⅓ W
R36	Resistor	4,7 kΩ ± 5%	⅓ W
R40	Resistor	680 Ω ± 5%	⅓ W
R41	Resistor	4,7 kΩ ± 5%	⅓ W
R42	Resistor	2,2 kΩ ± 5%	⅓ W
R43	Resistor	27 kΩ ± 5%	⅓ W
R44	Resistor	27 kΩ ± 5%	⅓ W
R45	Resistor	27 kΩ ± 5%	⅓ W
R49	Resistor	1,5 kΩ ± 5%	⅓ W
R50	Resistor	10 Ω ± 5%	⅓ W
R50a	Resistor	3,3 kΩ ± 5%	⅓ W
R53	Resistor	100 Ω ± 5%	⅓ W
R60	Resistor	10 Ω ± 5%	⅓ W
R66	Resistor	39 Ω ± 5%	⅓ W
R68	Resistor	1 kΩ ± 5%	⅓ W
R69	Resistor	1 kΩ ± 5%	⅓ W
R70	Resistor	27 kΩ ± 5%	⅓ W
R89	Resistor	100 MΩ ± 2% (5 kV max., voltage coeff. 3 ppm/V)	
R94	Resistor	100 MΩ ± 2% (5 kV max., voltage coeff. 3 ppm/V)	
R100	Resistor	200 MΩ ± 5% (5 kV)	
R102	Resistor	82 kΩ ± 5%	1 W

R105	Resistor	82 kΩ ± 5%	1 W
R107	Resistor	82 kΩ ± 5%	1 W
R111	Resistor	47 kΩ ± 5%	1 W
R121	Resistor	39 kΩ ± 5%	2 W
R122	Resistor	39 kΩ ± 5%	2 W
R123	Resistor	1,8 MΩ ± 5%	(5 kV)
R124	Resistor	39 kΩ ± 5%	2 W
R125	Resistor	39 kΩ ± 5%	2 W
R126	Resistor	39 kΩ ± 5%	2 W
R127	Resistor	4,7 kΩ ± 5%	⅓ W
R128	Potentiometer	1 MΩ ± 20%	
R143	Resistor	100 kΩ ± 5%	⅓ W
R144	Resistor	1 kΩ ± 5%	⅓ W
C1	Capacitor	0,01 μF ± 10%	63 V
C3	Capacitor	0,1 μF ± 10%	100 V
C4	Capacitor	470 pF ± 5%	100 V
C5	Capacitor	470 pF ± 5%	100 V
C6	Capacitor	470 pF ± 5%	100 V
C10	Capacitor	0,1 μF ± 10%	63 V
C13	Capacitor	47 pF ± 2%	63 V
C14	Capacitor	0,1 μF ± 10%	63 V
C15	Capacitor	0,1 μF ± 10%	63 V
C16	Capacitor	470 pF ± 5%	100 V
C22	Capacitor	100 μF	16 V electrolytic
C23	Capacitor	100 μF	16 V electrolytic
C24	Capacitor	100 μF	16 V electrolytic
C31	Capacitor	0,047 μF	(1,5 kV)
C32	Capacitor	0,047 μF	(1,5 kV)
C33	Capacitor	0,047 μF	(1,5 kV)
C34	Capacitor	0,047 μF	(1,5 kV)
C35	Capacitor	0,047 μF	(1,5 kV)
C36	Capacitor	0,047 μF	(1,5 kV)
C37	Capacitor	0,047 μF	(1,5 kV)
C45	Capacitor	0,1 μF ± 10%	63 V
C46	Capacitor	2,2 μF	63 V electrolytic

C47	Capacitor	0,01 μF ± 10%	63 V
C48	Capacitor	0,47 μF ± 10%	10 V
D5	Diode	1N4148	
D6	Diode	1N4148	
D8	Zener diode	BZY88 C5V1	
D14	Zener diode	1N4162B	
D15	Diode	1N4002	
D18	Zener diode	BZX79C68	
D19	Diode	1N4148	
D20	Diode	1N4148	
D23 to D29	Diode	SL500	
D38 to D40	Diode	1N4148	
D41	Zener diode	BZY88C9V1	
TR1	Transistor	BC183	
TR2	Transistor	BC183	
TR3	Transistor	BC213	
TR4	Transistor	BC183	
TR10	Transistor	BC213	
TR12	Transistor	BC213	
TR13	Transistor	BC183	
TR15	Transistor	BC213	
TR17	Transistor	BC183	
TR18	Transistor	BC183	
TR20	Transistor	2N3053	
TR23	Transistor	BDX36	
TR24	Transistor	BC213	
TR25	Transistor	BC183	
TR36	Transistor	BC183	
IC1	Integrated circuit	CA3140	
IC2	Integrated circuit	IC74LSO2	
T1	Transformer	240 V : 12 V	12 VA

Circuit Diagram for BM11