TECHNICAL MANUAL

OPERATOR'S, ORGANIZATIONAL, DIRECT

SUPPORT, AND GENERAL SUPPORT

MAINTENANCE MANUAL

OHMMETER ZM-21/U

(NSN 5950-00-645-2191),

OHMMETER ZM-21A/U

(NSN 6625-00-643-1030),

AND

OHMMETER ZM-21B/U

(NSN 6625-00-581-2466)

HEADQUARTERS, DEPARTMENT OF THE ARMY

13 JANUARY 1977

WARNING

DANGEROUS VOLTAGES EXIST IN THIS EQUIPMENT

Do not come in contact with test leads or terminals during operation. Potentials as high as 500 volts exist during operation,

DON'T TAKE CHANCES!

TECHNICAL MANUAL
No. 11-6625-298-14

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D. C., *13 January 1977*

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AND

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REPORTING OF ERRORS

You can improve this manual by recommending improvements using DA Form 2028-2 (Test) located in the back of the manual. Simply tear out the self-addressed form, fill it out as shown on the sample, fold it where shown, and drop it in the mail.

If there are no blank DA Form 2028-2 (Test) forms in the back of your manual, use the standard DA Form 2028 (Recommended Changes to Publications and Blank Forms) and forward to the Commander, US Army Electronics Command, ATTN: DRSEL-MA-Q, Fort Monmouth, NJ 07703.

In either case, a reply will be furnished direct to you.

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***This manual supersedes so much of TM 11-2050, 1 November 1954, including all changes, as pertains to Ohmmeter ZM-21A/U.**

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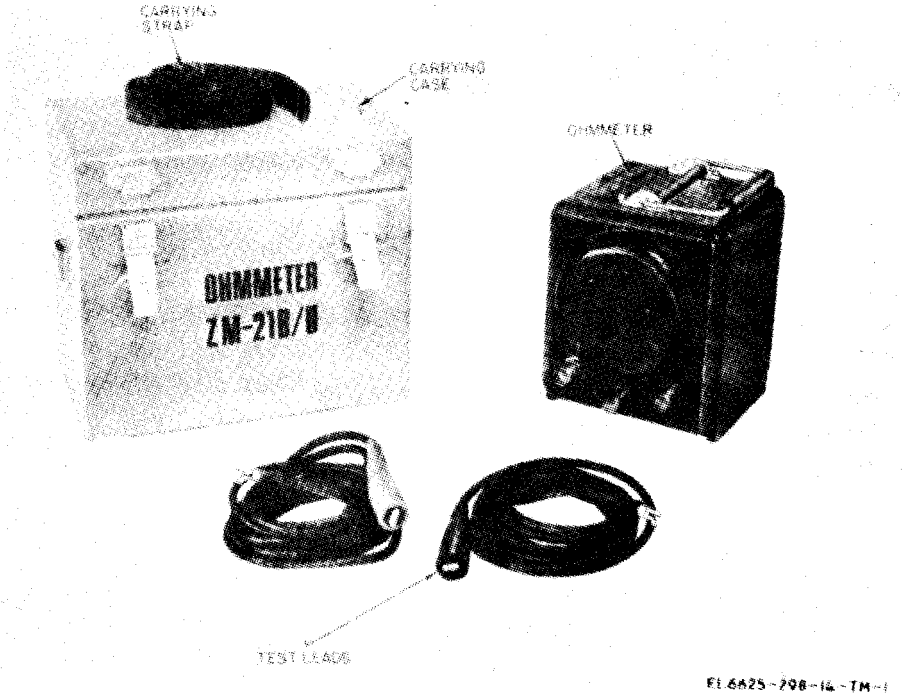

Figure 1-1. Ohmmeter ZM-21B/U.

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1-1. Scope

a. This manual describes Ohmmeter ZM-21/U, ZM-21A/U, and ZM-21B/U (ZM-21 (*)/U) and its operation, functioning; and operator, organizational, and general support maintenance. There is no direct support maintenance authorized for this equipment.

b. A list of references is contained in appendix A.

c. The maintenance allocation Chart (MAC) appears in appendix C.

1-2. Indexes of Publications

a. DA Pam 310-4. Refer to the latest issue of DA Pam 310-4 to determine whether there are new editions, changes, or additional publications pertaining to this equipment.

b. DA Pam 310-7. Refer to DA Pam 310-7 to determine whether there are modification work orders (MWOs) pertaining to this equipment.

1-3. Forms and Records

a. *Reports of Maintenance and Unsatisfactory Equipment.* Maintenance forms, records, and reports which are to be used by maintenance personnel at all maintenance levels are listed in and prescribed by TM 38-750.

b. Report of Packaging and Handling Deficiencies. Fill out and forward DD Form 6 (Packaging Improvement Report) as prescribed in AR 700-58/NAVSUPINST 4030.29/AFR 71-13/MCO P4030.29A, and DSAR 4145.8.

c. Discrepancy in Shipment Report (DISREP) (SF361). Fill out and forward Discrepancy in Shipment Report (DISREP) (SF 361) as prescribed in AR 55-38/NAVSUPINST 4610.33A/AFR 75-18/MCO P4610.19B, and DSAR 4500.15.

1-4. Administrative Storage

For procedures, forms, records, and inspections required during administrative storage of this equipment, refer to TM 740-90-1.

1-5. Destruction of Army Materiel

Demolition and destruction of electronic equipment will be under the direction of the commander and in accordance with TM 750-244-2.

Section II. DESCRIPTION AND DATA

1-6. Description

a. Ohmmeter ZM-21/U, ZM-21A/U, and ZM-21B/U (fig. 1-1) are a self-contained, portable, constant-voltage, insulation-resistance measuring sets (hereinafter referred to as ohmmeter). Figure 1-1 illustrates ZM-21B/U, all other models are similar in outward appearances. The ohmmeter consists of a high-range ohmmeter of special design, a hand-operated, direct current (dc) generator, a controller (controller in ZM-21A and ZM-21B only), and a resistance network housed in a bakelite case. Three terminals are provided for external connections. On the top is a handle and a hinged protective cover for the meter window glass. Printed on the back of the hinged protective cover are condensed instructions for operation.

b. The test leads that come with the ohmmeter are six feet long with spade clips at one end and spring clips at the other end. The spring clips are covered with rubber covers, one black and one red.

c. The carrying case is a gray, enamel-painted metal box (ZM-21/U and ZM-21A/U) with a webbed carrying strap and two latches the carrying case for the ZM-21B/U is made of plastic.

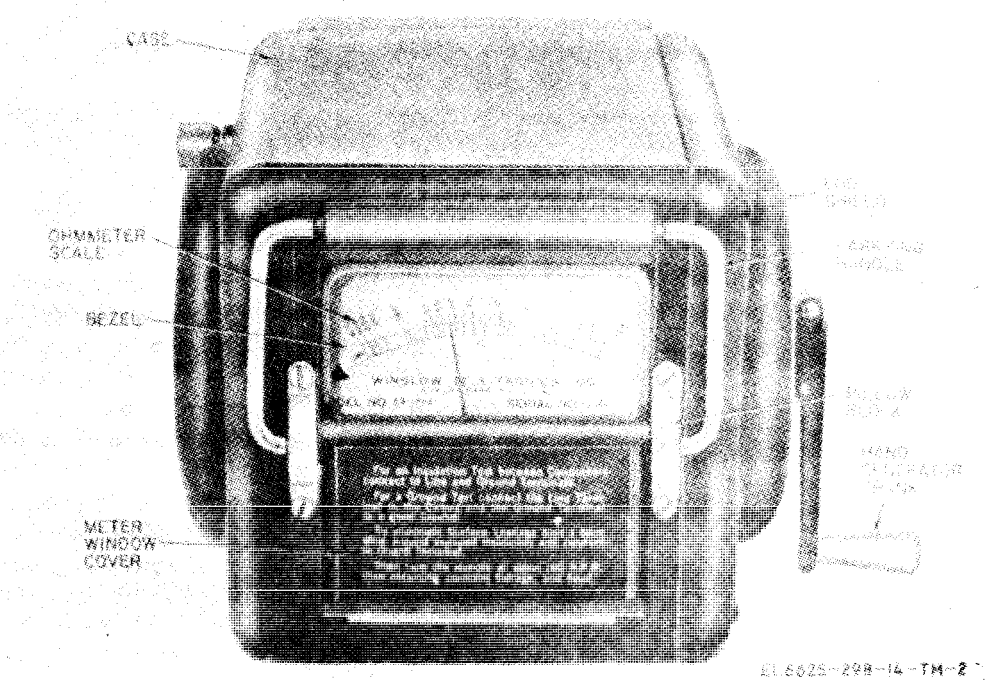

Figure 1-2. Ohmmeter ZM-21(*)/U, exterior view.

1-7. Purpose and Use

a. Ohmmeter (fig. 1-2) is used to determine the insulation condition of telephone cables, of transformers, between windings and ground of rotating equipment, and of all other types of electrical equipment for which insulation resistance is an important factor.

b. The ohmmeter applies a high potential to equipment under test in order to detect low insulation resistance which may not indicate satisfactorily on a low potential ohmmeter.

c. Regular use of the ohmmeter can minimize failure in circuits or equipment caused by faulty insulation. A sudden lowering of insulation resistance indicates a fault that should be investigated immediately.

1-8. Tabulated Data

Resistance range . . . . . 0 through 1,000 megohms.
Test potential..... 500 volts dc ±5 percent (when measuring values below 2 megohms, the voltage drops materially).
Accuracy . . . . Within 1 percent of any cardinal calibration point.

NOTE

Insulation resistance above 1,000 megohms is indicated by a point marked infinity (∞) on the meter scale.

1-9. Items Comprising an Operable Ohmmeter ZM-21(*)/U

Refer to table 1-1 for items comprising an operable Ohmmeter ZM-21(*)/U.

Table 1-1. Items Comprising an Operable Ohmmeter ZM-21(*)/U

Qty	Item	Dimensions (in.)			Weight	Volume (cu. ft)
		Length	Height	Width		
1	Ohmmeter ZM-21(*)/U	7½	6	7¼	10.7	0.2
1	Carrying case	10	7	8½	5.5	0.34
1	Cord CD-478 (black)	72	.....	.....	0.11	
1	Cord CD-478 (red)	72	.....	.....	0.11	

CHAPTER 2

SERVICE UPON RECEIPT AND INSTALLATION

Section I. SERVICE UPON RECEIPT OF MATERIEL

2-1. Unpacking.

a. Refer to figure 2-1, and follow the steps below when unpacking the ohmmeter.

(1) Break and fold back the metal straps.

(2) Remove the nails from the top of the wooden packing crate with a nail-puller, and remove the top. Do not attempt to pry off the sides or top; such action may damage the equipment.

(3) Remove the packaged equipment and cut the tape that seals the carton.

(4) Cut the barrier material along the seam, and remove the inner corrugated carton.

(5) Open the inner corrugated carton, and remove the ohmmeter in its carrying case, the two test leads, and the technical publication.

(6) Open the carrying case, remove the ohmmeter and desiccant bags and check the equipment , as specified in paragraph 2-2.

b. The ohmmeter may be received as a domestic shipment, without a wooden crate. The unpacking instructions given in a above apply also to unpacking domestic shipments. If heavy wrapping paper has been used in lieu of cartons, remove it carefully and check the contents as in paragraph 2-2.

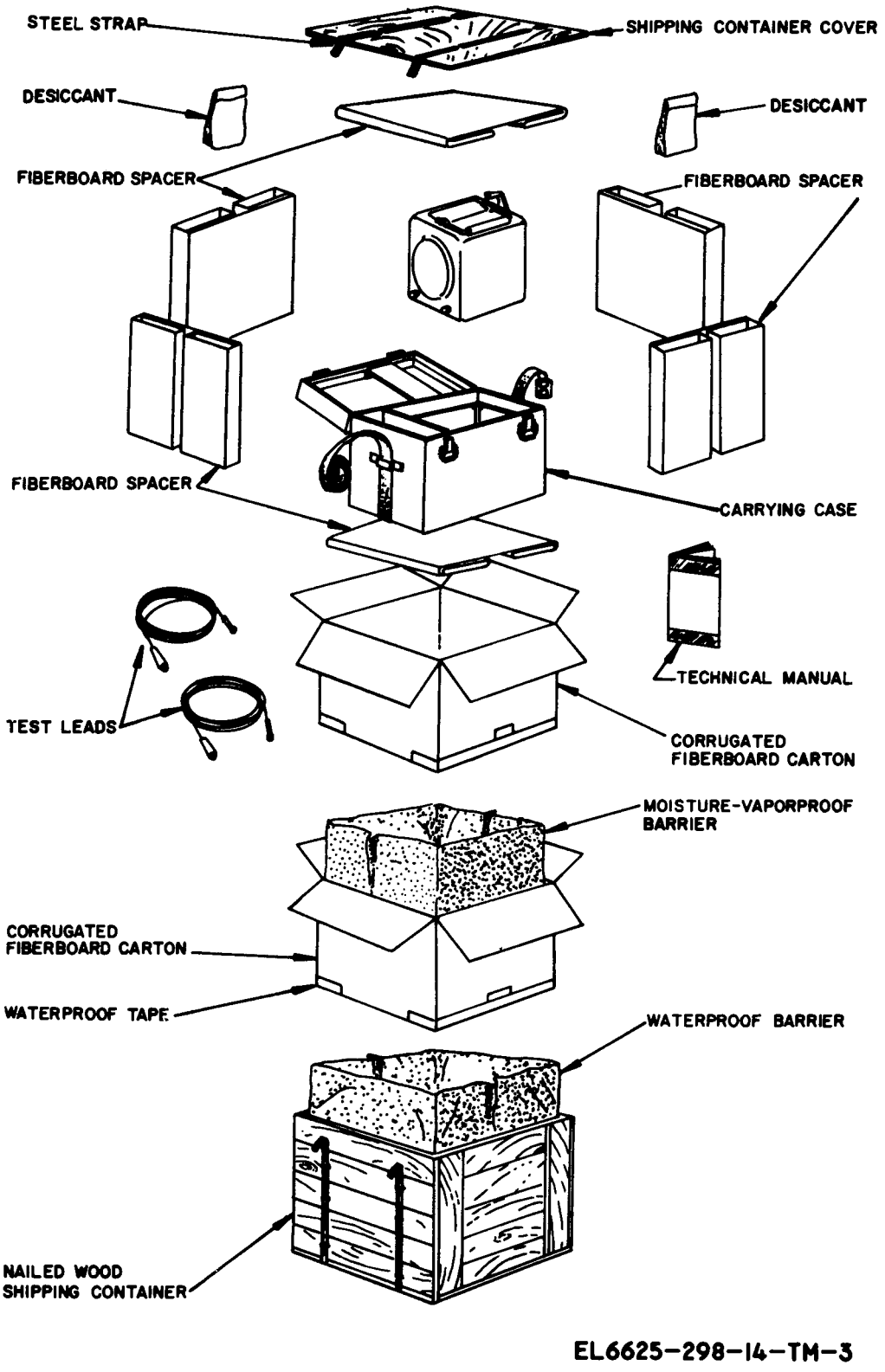

Figure 2-1. Packaging of Ohmmeter ZM-21/U.

2.2. Checking Unpacked Equipment

a. Inspect the equipment for damage incurred during shipment. If the equipment has been damaged, report the damage on DD Form 6, as in paragraph 1-3.

b. Check the equipment against the component listing in table 1-1 and on the packing slip to see if the shipment is complete. Report all discrepancies in accordance with paragraph 1-3. The equipment should be placed in service even though a minor assembly or part that does not affect proper functioning is missing.

c. Check to see whether the equipment has been modified. Equipment which has been modified will have the MWO number on the front panel, near the nomenclature plate.) Check also to see whether all currently applicable MWOs have been applied. (Current MWOs applicable to the equipment are listed in DA Pam 310-7).

Section II. INSTALLATION

2-3. Tools, Test Equipment, and Materials Required for Installation

Since Ohmmeter ZM-21(*)/U is intended primarily for field use, there are no installation procedures requiring tools or equipment.

2-4. Preliminary Adjustment of Equipment

a. Perform the following preoperational procedures:

(l) Unfold the hand generator crank to bring it to its proper operating position.

(2) Connect the spade-type terminals of the test leads to the line and ground terminals.

b. For a simple check of the equipment, proceed as follows:

NOTE

The ohmmeter should be operated while at rest on a firm level surface,with the indicator in a horizontal plane. Do not place it in or near a strong magnetic field.

(1) With the equipment prepared as in a above, turn the hand generator crank at operating speed (approx 160 rpm). With the leads disconnected the ohmmeter should indicate an infinite resistance.

(2) Short circuit the test leads by clipping them together, and turn the hand generator crank at operating speed. The ohmmeter should indicate zero resistance.

(3) If a further check is desired, and a resistor of known value is available, connect it between the test leads and turn the hand generator crank. The ohmmeter should indicate the known value of the resistor.

CHAPTER 3

OPERATING INSTRUCTIONS

Section I. CONTROLS AND INSTRUMENTS

3-1. General

The ohmmeter controls and instruments used by the operator are illustrated in figures 1-1 and 1-2 and the function of each control or instrument is listed in table 3-1.

Table 3-1. Controls and Instruments

Control or instrument	*Function*
GROUND terminal	Provides common ground connection between component being tested and test equipment case.
LINE terminal	Used when taking readings of external resistance or insulation resistances connected across line and ground terminals.
GUARD terminal	Used to guard against surface leakage resistance. Prevents leakage from entering resistance measuring circuit.
Handcrank	When rotated at approximately 160 rpm, generator produces 500 vdc.
Meter scale ZERO to INFINITY.	Provides a visual indication of resistance value under test.
Carrying handle	Used when carrying test equipment.
Test leads	Used to provide connections between test equipment and component being tested.

Section II. OPERATION UNDER USUAL CONDITIONS

3-2. General

Make all measurements with the hand generator crank rotated clockwise fast enough (at approximately 160 revolutions per minute (rpm)) to cause the centrifugal clutch to slip. When the clutch slips, maximum steady voltage is being delivered. The position of the pointer on the scale indicates insulation resistance values in megohms. Be careful to read the scale directly above the pointer and the scale, otherwise, readings may be in error because of parallax.The tests described in paragraphs 3-6 through 3-16 are general and cover equipment of all types and designs. Before testing the insulation of any equipment refer to the technical manual covering the specific equipment under test for definite insulation resistance values and voltage ratings.

3-3. Preoperational Check

Before connecting the ohmmeter to the equipment to be tested, make the following checks to determine whether the ohmmeter is operating properly.

a. Full Scale Check. With no connection to the ohmmeter terminals, crank the hand generator at operating speed. The pointer will indicate INFINITY if the test set is in good operating condition.

b. Zero Check. Short the LINE and GROUND terminals by connecting them and turn the hand generator crank at operating speed. The pointer will indicate ZERO if the ohmmeter is in good operating condition.

3-4. Guard Connection

a. To obtain a true resistance value of the insulation under test, both the insulation and the measuring instrument must be protected against surface leakage to eliminate possible errors. The ohmmeter has an internal protective or guard system for this purpose. The guard system is connected to the GUARD terminal so that protection against surface leakage can be extended to the insulation under test. Any leakage current between the base of the insulator and its terminal will recarried back to the test set through the GUARD terminal, and the internal guard circuit of the test set will prevent this leakage from entering the measuring circuit.

b. When using guarded connections, readings are of the insulation resistance only and do not take into account the parallel shunting resistance

of surface conditions. A measurement taken with a GUARD connection and compared to a measurement of the same equipment taken without a GUARD connection will establish whether low insulation resistance readings are caused by poor insulation or bad surface conditions. If readings taken with guarded connections are higher than those without guarded connections, the surface of the equipment has a low resistance.

3-5. Insulation Resistance

All tests shall be made with the hand generator crank rotated at approximately 160 revolutions per minute. Since the meter scale is calibrated in megohms, the position of the pointer on the scale indicates insulation resistance values directly in megohms. Indications shall be read with the eyes directly above the pointer and the scale to prevent errors. Types of operation described in subsequent paragraphs are necessarily general to cover equipment of all types and designs. Before testing any specific equipment, refer to the technical manual covering the equipment for definite insulation resistance standards.

a. Unit of Measurement. Insulation resistance is that property of an insulating material which opposes the passage of electrical current. It is expressed in ohms or megohms. Insulation resistance increases as the thickness of the insulating material increases but decreases as the area of material under test increases. *For example,* if an insulating material covering a given surface and having a resistance of 100 megohms is extended to 10 times its area, the insulation resistance will drop to 10 megohms. Thus, one mile of* spinal-four cable may measure 1,000 megohms but 10 miles will measure 100 megohms. If the insulating material is doubled in thickness, however, the area having an insulation resistance of 100 megohms now will have a resistance of 200 megohms, and the area having an insulation resistance of 10 megohms will have a resistance of 20 megohms.

b. Conditions Affecting Insulation Resistance.

(1) *Temperature.* The temperature coefficient of the resistance of an insulating material is negative and numerically large. Therefore, even a small increase in temperature will cause a relatively large decrease in insulation resistance. Always make measurements at the same temperature, if possible, because insulation resistance drops at high temperatures. *For example,* the insulation resistance between the stator winding of a slow-speed generator and the frame is 100 megohms at 80° F., but falls to 10 megohms at 140° F.

(2) *Moisture and humidity.* Chemically pure water is a non conductor; however, the impurities that water absorbs from the atmosphere and other sources cause it to be partially conductive. Therefore, moisture will become a conductor in parallel with the insulation and will cause a decided drop in insulation resistance. This is a temporary condition and may be remedied by drying the equipment.

(3) *Chemical fumes.* Strong acid or alkali fumes attack insulation and permanently lower its insulation resistance.

(4) Surface conditions. Dirt, especially when mixed with oil, or with a copper or carbon dust, forms a low-resistance path across the insulation, lowering its resistance.

c. Values of Insulation Resistance. Since insulation resistance is affected by varying conditions *(b* above), no constant rules can be established to govern its value. Certain minimum values have, however, been established arbitrarily for different types of cable and equipment (para 3-12). Actual values of insulation resistance are not as important as changes in insulation resistance. Periodic tests should be made and the results recorded together with information regarding climatic conditions at the time tests are made.

3-6. Insulation Test of Ac and Dc Rotating Machines Rated 600 Volts or Less

a. Connect a test lead from the LINE terminal of the ohmmeter to a lead, an exposed conductor, or the commutator of the machine (fig. 3-1).

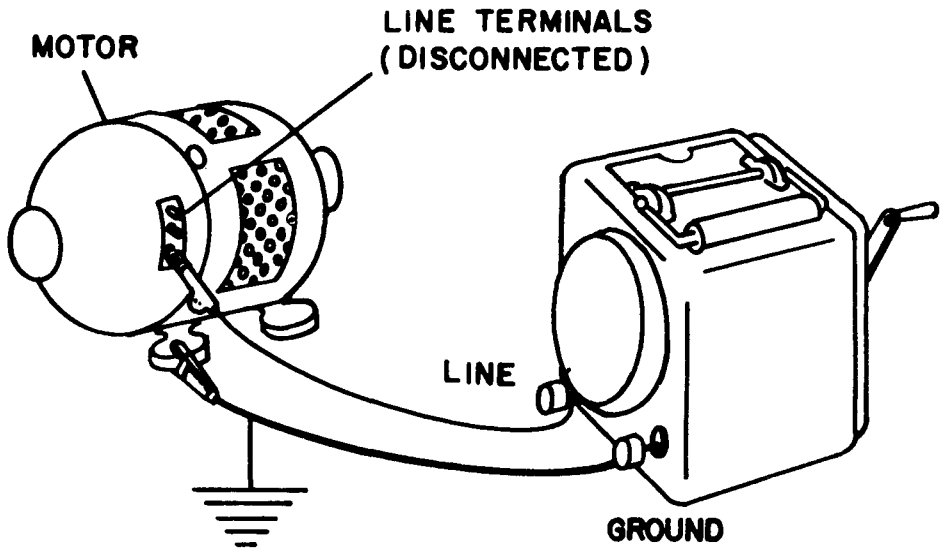

Figure 3-1. Connections for testing a.c. or d.c. rotating machines.

b. Connect another test lead from the GROUND terminal to the shaft or frame of the equipment under test. Be sure that the surface to which the connection is made is free of paint or any other substance that is a nonconductor.

c. Turn the hand generator crank at operating speed. If the machine is cold, the indication should be between 1 and 10 megohms. If the machine is warm, the indication will be lower. Also, a large machine will have a lower insulation resistance than a small machine.

d. If all the circuits in the machine are not interconnected as in separately excited generators, measure each circuit individually.

3-7. Insulation Test *of Ac* and Dc Rotating Machines Rated Over 800 Volts

a. Connect the equipment and test as directed for machines at 600 volts or less (para 3-6 above).

b. Turn the hand generator crank at operating speed. If the machine is cold, readings should range between 10 and 100 megohms. Readings will be lower if the equipment is warm.

c. Direct current (dc) fields on ac machines should indicate between 1 and 10 megohms.

3-8. Insulation Test of Transformers

a. Connect a test lead from the GROUND terminal of the ohmmeter to the core or case of the transformer (fig. 3-2).

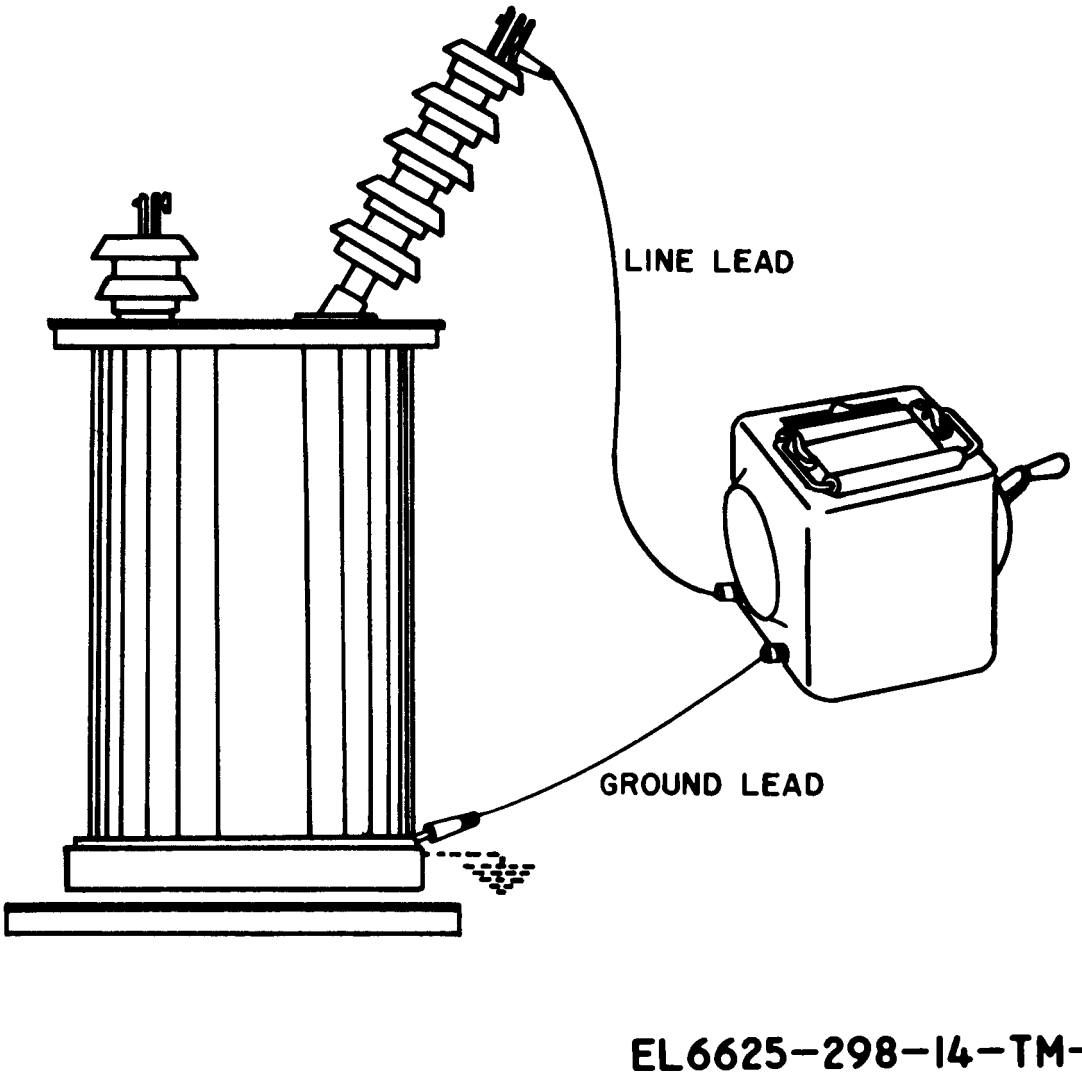

Figure 3-2. Connection for testing transformers.

b. Measure the high- and low-voltage windings separately. Connect a test lead from the LINE terminal of the ohmmeter, first to the low-voltage windings and then to the high-voltage windings.

c. Measure between windings by connecting the GROUND lead from the ohmmeter to one winding of the transformer, and another test lead from the LINE terminal of the ohmmeter to the other winding.

d. Turn the hand generator crank at operating speed. Indications for all measurements should be 100 megohms or more on air core transformer. Indications on oil-filled transformer will be considerably lower. Extremely low readings indicate the presence of moisture in the oil and indicate that the oil should be changed.

3-9. Insulation Test of Capacitors

WARNING

Discharge the capacitor after an insulation resistance test has been made, or disconnect the leads one at a time. Short out the capacitor. Contact with a fully charged capacitor can cause a dangerous shock.

CAUTION

Do not exceed the voltage rating of the capacitor under test.

a. Connect a test lead from the GROUND terminal of the ohmmeter to the case of the capacitor (fig. 3-3).

b. Connect another lead from the LINE terminal of the ohmmeter to one of the terminals of the capacitor.

c. Turn the hand generator at operating speed. The indication obtained is the insulation between the capacitor and its case. The indication should be 500 megohms or more.

d. Remove the GROUND lead from the case of the capacitor and connect it to the remaining terminal of the capacitor.

NOTE

The ohmmeter pointer will dip toward zero when the crank is first turned, but will move up the scale as the capacitor becomes charged with the test potential. The capacitor must be fully charged with the test potential before a reading may be taken. To be sure that the capacitor is fully charged, turn the generator crank for one minute.

e. Turn the crank handle at operating speed. The insulation reading should be 500 megohms or greater.

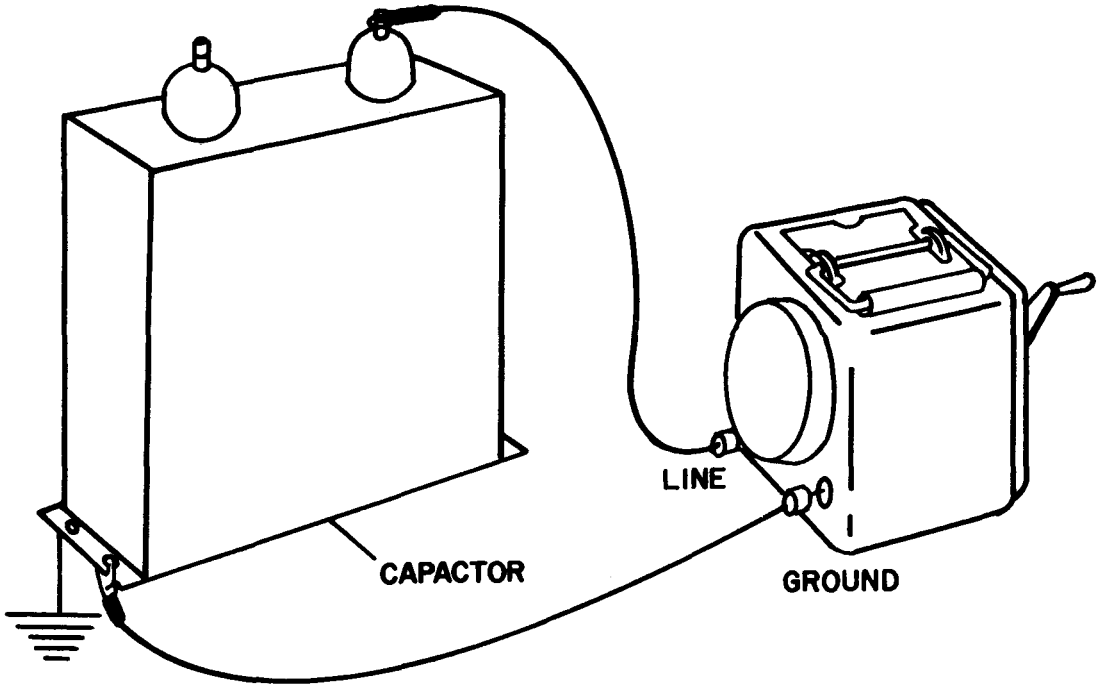

Figure 3-3. Connections for testing capacitors.

3-10. Insulation Test of Insulating Bushings

a. Connect a test lead from the GROUND terminal of the ohmmeter to the base of the bushing.

b. Connect another test lead from the LINE terminal of the ohmmeter to the bushing terminal.

c. Turn the hand generator crank at operating speed. If the bushing under test is the dry type, the reading should be INFINITY or near INFINITY. If the bushing under test is the filled type, the reading should be near 1,000 megohms.

d. If the reading is lower than near INFINITY for a dry-type bushing or 1,000 megohms for a filled-type bushing, connect the third test lead to

the GUARD terminal of the ohmmeter and to a point approximately at the center of the bushing. Make this connection by wrapping the bushing with tinfoil or with a cloth saturated with salt water and connecting the test clip to the tinfoil or cloth.

e. Operate the hand generator crank. If the reading taken with the GUARD terminal connected is approximately the same as the first reading, the low resistance is caused by a fault in the bushing. If the reading is considerably higher, the low resistance formerly observed is caused by surface leakage. When low resistance is caused by surface leakage, the bushing is serviceable but should be cleaned.

CAUTION

Use the GUARD connection if insulation tests are made on a damp or humid day. Surface leakage always will be high under such conditions.

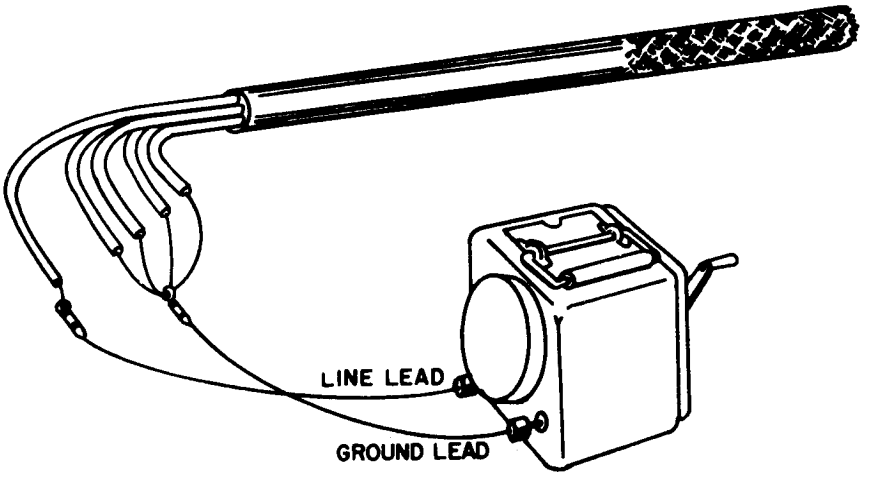

Figure 3-4. Connections for cable testing.

3-11. Insulation Test of Power Cables and Wires

NOTE

Disconnect equipment from the powerline while insulation resistance measurements are being made.

a *Power Cables.*

(1) *Connections for measurement of one conductor to all other conductors.*

(a) Connect a test lead from the LINE terminals of the ohmmeter to the conductor to be measured (fig. 3-5).

(b) Tie all other conductors together, and connected them to the GROUND terminal of the ohmmeter.

(c) Connect a teat lead from the GUARD terminal to the cable sheath. Use of the GUARD terminal prevents error caused by parallel ground leakage.

(2) *Connections for measurement of one conductor to ground.*

(a) Connect a test lead from the LINE terminal of the ohmmeter to the conductor to be measured (fig. 3-5).

(b) Connect a test lead from the GROUND terminal to the shield of the cable.

(c) Tie all other conductors together and connect them to the GUARD terminal. Use of the GUARD terminal prevents error caused by leakage in the parallel circuits.

(3) *Operation.*

(a) Turn the hand generator crank at operating speed. A short length of cable usually will have an insulation resistance value of 1,000 megohms or more. The insulation resistance value of a long cable usually will be considerably lower than that of a short cable.

NOTE

When testing the insulation of a long cable, operate the hand generator for approximately 1 minute before taking a

reading. This will eliminate any error that might be caused by the electrostatic capacity of the cable.

(b) After all measurements are completed, discharge the cable by grounding all conductors.

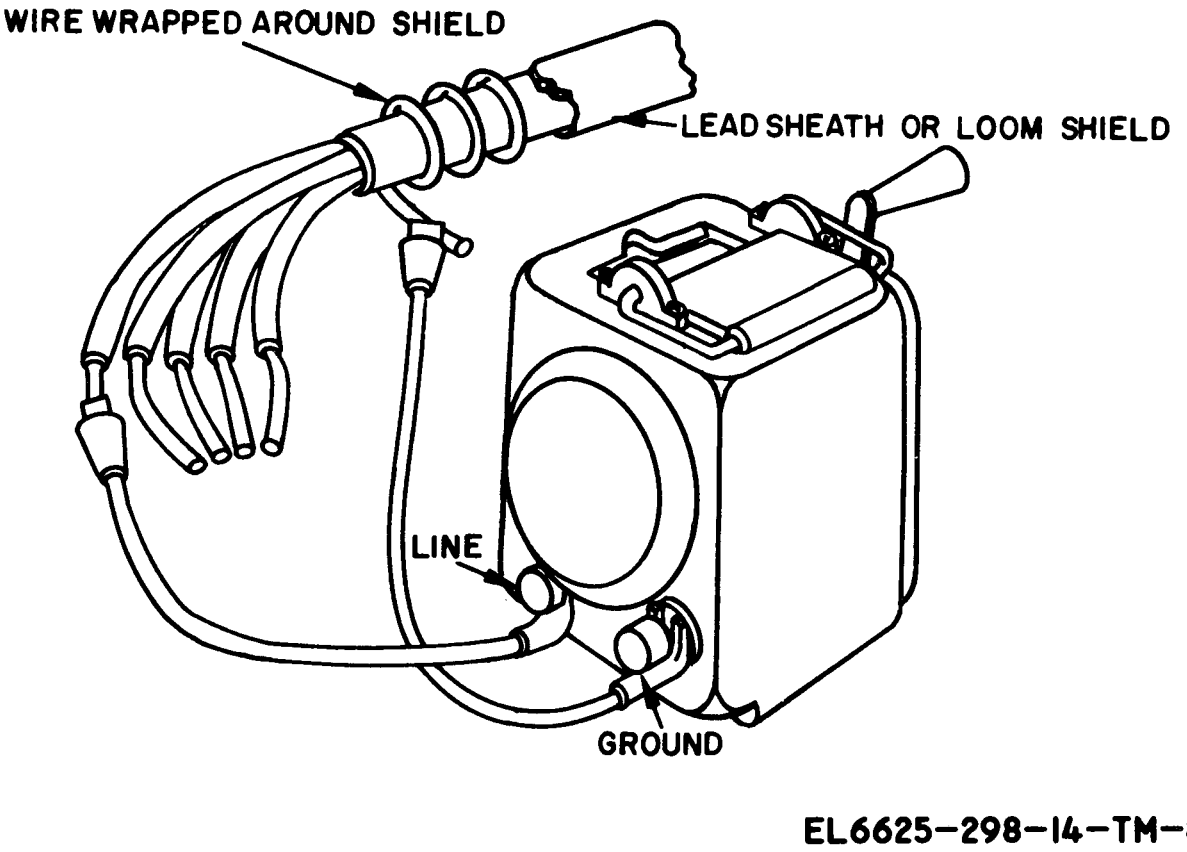

Figure 3-5. Connections for measuring one cable conductor to ground.

b. Power Wires. Test the insulation of individual power wires in the same manner as cable conductors *(a* above). Make the GROUND connection to the outer sheath, or jacket, of the wire.

3-12. Insulation Test of Telephone Cables and Wires and Minimum Insulation Resistance values

a. Testing Insulation Resistance.

(1) Test the insulation of exchange cables in the same manner as power cables (para 3-11a *above).* The conductors of these cables, when new, should have an insulation resistance of at least 500 megohm-miles.

NOTE

A conductor is said to have an insulation resistance value of 500 megohm-miles when the insulation resistance of a 1-mile length is 500 megohms. Because short cables usually have a higher insulation resistance value, a 2-mile length will have en insulation resistance of 250 megohms, a 10-mile length will have an insulation resistance of 50 megohms, etc.

(2) When testing the insulation resistance of large exchange cables, divide the pairs into bunches of 25 to 100 pairs per bunch. Test each bunch as a single conductor of a power cable.

(3) If the insulation resistance of a bunch is not lower than a single pair, assume that the insulation resistance of all pairs in that bunch is satisfactory.

(4) If the insulation resistance of a bunch is less than that given in the table 3-2 below, separate the wires and measure each separately against all other wires grounded to that sheath.

Each wire should give a reading as high as that given in the table.

(5) If the insulation resistance of any individual wire is less than that given in the table, disconnect all other bunches from the sheath and measure the wire against these bunches and against the sheath. This will determine if the trouble is between wires, or between the wire and the sheath, or both.

(6) After testing all the bunches, measure a few wires of each bunch against the remaining wires of the bunch to determine whether any of the conductors have a low insulation resistance.

b. Insulation Resistance Requirements for Telephone Cables. Table 3-2 below gives the insulation resistance requirements for telephone cables based on a standard required insulation resistance of 500 megohms per mile of cable. Given values are the minimum insulation between one wire and the sheath, with all other wires of the cable grounded to the sheath at a temperature of 60° F.

NOTE

The set shall be operated for one minute before readings are taken.

Table 3-2. Required Insulation Resistance for Telephone Cables

Length of cable (ft)	Required insulation resistance (meg)	Length of cable (mi)	Required insulation resistance (meg)
500	5,250	1	500
1,000	2,640	2	250
1,500	1,760	3	167
2,000	1,230	4	125
3,000	880	5	100
4,000	660	6	88.3
5,000	528	7	71.3
6,000	440	8	62.5
7,000	377	9	55.5
8,000	330	10	50
9,000	293	11	45.4
10,000	264	12	41.7

c. Insulation Resistance Requirements for Spiral-Four Cable.

(1) *General.* Spiral-four cable consists of four individually insulated conductors in a braided metal sheath. Cable WC-548 has a heavy rubber jacket; Cable WF-8/G has a polyethylene plastic covering. For a complete test of the insulation resistance of spiral-four cable, measure each conductor in turn with the other three conductors connected to the braid. Thus a complete test can be made in four measurements.

(2) *Cable WC-548.*

(a) Insulation resistance requirements for various lengths of new cable WC-548 are as follows:

Cable length (mi)	Insulation resistance(meg)
¼	750
1	200
25	10

(b) In the case of working cable, the insulation resistance of one 1/4-mile Cable Assembly CC-358 should not drop below 10 megohms, and the insulation resistance of a 25-to 30-mile repeater section should not drop below 1 megohm.

(3) *Cable WF-8/G.*

(a) New Cable WF-8/G, either in 1/4-mile lengths of Cable Assembly CX-1065/G of four cable assemblies coupled together during initial installation, should show an insulation resistance above 1,000 megohms. For lengths greater than 1 mile, the minimum insulation resistance can be found by dividing 1,000 by the number of miles in the cable. For example, if a 10-mile length of Cable WF-8/G is to be tested– 1,000 ÷ 10 = 100 megohms, the minimum insulation resistance for 10 miles.

NOTE

Manufacturing specifications require a minimum resistance of 5,000 megohms per 1,000 feet. Insulation resistance above 1,000 megohms is indicated by INFINITY on the meter scale of the ohmmeter.

(b) A cable line may develop low insulation resistance and deteriorate to a point where it can no longer be useful. When this happens, the cause of the drop in insulation resistance to below one megohm must be located and removed.

d. Computing Minimum Insulation Resistance. The minimum insulation resistance for any length or size of cable may be found as follows:

(1) The required minimum insulation resistance between one wire, one foot long and the cable sheath is 2,640,000 megohms. To find the required minimum insulation resistance for one insulated conductor of any length, divide 2,640,000 by the length of the conductor expressed in feet.

For example, to find the required insulation resistance between one conductor and the cable sheath of a cable 672 feet long:

2,640,000 ÷ 672 = 3,928.57 megohms.

(2) In the case of a multiple-pair cable, to find the minimum insulation resistance of the entire cable to the cable sheath, divide the requirement for one conductor by the total number of conductors in the cable. *For example,* the total number of conductors in a 51-pair cable would be 51 x 2 or 102 conductors. Thus, the minimum insulation ressitance requirement for a 51-pair cable 672 feet long ((1) above) would be:

3,928.57 ÷ 102 = 38.51 megohms.

3-13. Test of Wiring Installations.

Wiring systems are tested to see whether they are free from short circuits and grounds. Remove fuses and open switches before making tests.

a. Testing for G. ounds.

(1) Connect the GROUND terminal of the ohmmeter to a good ground.

(2) Connect the LINE terminal to a wire of the wiring system that is being checked for grounds. Measure one wire at a time. A low reading indicates that the wire is grounded. A high reading indicates that there is no ground and that the insulation is good.

b. Testing for Short Circuits.

(1) Connect the LINE terminal of the ohmmeter to one wire of the wiring system.

(2) Connect the GROUND terminal to the other wire.

(3) Wire circuits of No. 12 or No. 14 AWG wire should have a resistance of approximately 1 megohm. The insulation resistance of wires of larger gauge is based on current capacity and should read approximately as follows:

NOTE

Circuits with a current capacity above 100 amperes cannot be measured on the ohmmeter. The lowest calibration point of the ohmmeter is 100,000 ohms (0. 1 megohm).

3-14. Test of Electrical Instruments

The insulation resistance between all connected electrical circuits of an electrical instrument and the case should be no lower than 20 megohms. If the instrument has both a current and a voltage circuit, the insulation resistance between the current circuit and the voltage circuit should be no lower than 5 megohms.

3-15. Insulation Test of Tools and Appliances

The insulation resistance values of tools and appliances should be approximately the same as the insulation resistance value of the wiring system to which they are attached. Tests for short circuits and grounds are made in the same manner as tests of wiring installations (para 3-13).

3-16. Measurement of Resistors

The resistance value of resistors can be found with the ohmmeter if within the megohm range. The resistor must be disconnected from its circuit and all power turned off. Connect the LINE terminal to one side of the resistor and connect the GROUND terminal to the other side. Operate the ohmmeter. The reading will be directly in megohms.

3-17. Insulation Resistance Values of Equipment Under Test

Whenever possible, take minimum insulation resistance values of equipment being tested from the specifications covering such equipment. If specifications are not available, use table 3-3 which consists of accepted minimum requirements.

Current capacity (amperes)	*Insulation resistance (ohms)*
25 through 50	250,000
51 through 100	100,000

Table 3-3. Minimum Insulation Resistance Value

Type of equipment	*Type of test*	*Insulation resistance (megohms)*
Multiple conductor cables, such as those used to interconnect various parts of radio equipment. (Test with plugs, jacks, and other fittings attached.)	Between single conductor and shield.	100 to 1,000
	Conductor to all other conductors.	100 to 500
Complete power circuits (current capacity 5 to 50 amps).	Conductor to conductor or conductor to ground.	0.2 to 2.
Complete power circuits (current capacity 100 amps more).	Conductor to conductor or conductor to ground.	0.1 to 1.
Rotating equipment	Between ground and all circuits of equal potential above ground connected together.	Minimum insulation resistance = Rated voltage of equipment kVa (or kW) rating + 1,000.

Table 3-3. Minimum Insulation Resistance Value—Continued

Type of equipment	Type of test	Insulation resistance (megohms)
Transformers, chokes, and similar apparatus.	Winding to winding or winding to frame.	Minimum insulation resistance = Rated voltage of equipment kVa (or kW) rating + 1,000.
Ammeters, voltmeters, wattmeters, etc.	Between all circuits in case to ground.	20 minimum.
	Between different circuits.	5 minimum.

3-18. **Locating Low Insulation**

a. General. The ohmmeter may be used to locate low cable insulation caused by moisture. Such a trouble can be burned in by applying high voltage directly across the fault. This breaks down the insulation at the fault and permits the bare wires to make metallic contact. When a solid ground or short circuit has developed, the fault can be located with a Wheatstone bridge test set or by using tone and an exploring coil.

b. Procedure. To burn in trouble using the ohmmeter, proceed as follows:

(1) Connect the wire under test to the GUARD terminal of the ohmmeter.

(2) Connect the cable sheath to the GROUND terminal.

(3) Turn the hand generator crank at operating speed. Full generator voltage (500 volts) is applied directly across the fault. The current ballast resistors are not in the circuit and there will be no reading on the ohmmeter scale.

3-19. Stopping Procedure

When measurements have been completed, disconnect all test leads from the ohmmeter and from the equipment being tested. Close the hinged cover; place the ohmmeter and leads in the carrying case.

Section III. OPERATION UNDER UNUSUAL CONDITIONS

3-20. General

When operating the ohmmeter in regions where extreme cold, heat, humidity, moisture, or sand conditions prevail, special precautions must be taken to keep the equipment in operating condition at all times. Paragraphs 3-21 through 3-23 contain instructions for minimizing the effect of these unusual operating conditions.

3-21. Operation in Arctic Climates

Because the ohmmeter is intended for both indoor and outdoor use, the equipment may be exposed to extreme cold in actual operation as well as in storage and in transport. When operated at extremely low temperature, the hand generator crank will not operate as easily as at normal room temperatures. The generator drive assembly parts may break. If the ohmmeter is operated in a warm place after exposure to the cold, moisture will condense on the equipment until the equipment reaches room temperature. This condition also arises when the equipment warms up during the day after a cold night. When the ohmmeter has reached room temperature, dry it thoroughly. Perform preventive maintenance operations (para 4-3) frequently to keep the unit as moisture-free as possible.

3-22. Operation in Desert Climates

The main problem when operating the ohmmeter in desert climates is to prevent dirt, dust, and sand from filtering into the equipment. Keep the equipment in the carrying case with the lid closed and latched at all times when not in use, and cover with canvas or other material.

3-23. Operation in Tropical Climates

The main difficulty encountered in the operation of the ohmmeter in tropical climates is high relative humidity. Although it is sealed against humidity, moisture still will condense on the outside of the instrument case whenever its temperature becomes lower than the temperature of the air. Mositure collecting between the binding posts lowers the resistance between them and will cause faulty readings. Dry the case with a dry cloth before attempting to make teats with the equipment. Inspect the equipment frequently to keep it free from rust, corrosion, and fungus growth. Perform preventive maintenance operations (para 4-3) frequently to keep the unit as moisture-free as possible.

CHAPTER 4

OPERATOR AND ORGANIZATIONAL MAINTENANCE INSTRUCTIONS

Section I. TOOLS AND EQUIPMENT

4-1. General

Tools and test equipment authorized for use by the operator and organizational technician are listed in appendix C.

Section II. PREVENTIVE MAINTENANCE CHECKS AND SERVICES

4-2. General

To be sure that the ZM-21(*)/U is always ready for operation, it must be inspected systematically so that defects may be discovered and corrected before they result in serious damage or failure. The necessary preventive maintenance checks and services to be performed are listed and described in tables 4-1 and 4-2. The item numbers indicate the sequence of minimum inspection requirements. Defects discovered during operation of the unit will be noted for future correction to be made as soon as operation has ceased. Stop operation immediately if a deficiency is noted during operation which would damage the equipment. Record all deficiencies together with the corrective action taken as prescribed in TM 38-750.

4-3. **Preventive Maintenance Checks and Services Periods**

Preventive maintenance checks and services of the ZM-21(*)/U are required daily, weekly, monthly, and quarterly. In addition, the weekly preventive maintenance checks and services must be performed under the following conditions:

a. Upon initial receipt.

b. Upon return from higher category maintenance.

Table 4-1. Operator/Crew Preventive Maintenance Checks and Services.

D–Daily Time required: 0.2 **w- Weekly** Time required: 0.4

Interval and sequence No.		ITEM TO BE INSPECTED PROCEDURE	Worktime (T/ H)
D	W		
1	1	**COMPLETENESS** Check to see that the ZM-21(*)/U is complete against the component listing in paragraph 1-9.	0.1
	2	**EXTERIOR SURFACES** Check to see that exterior is clean and free from dust, dirt, fungus, rust, and corrosion.	0.1
	3	**HARDWARE** Check to be sure that all screws and handles are securely fastened.	0.1
	4	**TEST LEADS** Check for loose clips and terminals, cleanliness of terminals, and breaks in the insulation.	
2	5	**OPERATION** While the ZM-21(*)/U is in operation, be alert for symptoms of trouble.	0.1

Table 4-2. Organisational Preventive Maintenance Checks and Services

M–Monthly **Q–Quarterly**

Time required: 0.3 **Time required: 0.2**

Interval and sequence No.		ITEM TO BE INSPECTED PROCEDURE	Worktime (T/H)
M	Q		
1		**INTERIOR OF UNIT** Carefully withdraw the chassis from case and check for loose connections, defective insulation, and cleanliness.	0.2
2		**METER** Check meter stop and pointer for damage.	
3		**CARRYING CASE** Check for chipped paint, dirt, dust, grease fungus, and corrosion. Check also that the foam rubber lining is fastened securely.	0.1
	1	**PUBLICATIONS** See that all publications are complete, serviceable, and current. Refer to DA Pam 310-4.	0.1
	2	**MODIFICATIONS** Check to see if the equipment has been modified. Refer to DA Pam 310-7.	0.1

Section III. TROUBLESHOOTING.

4-4. General

At the organizational level, the troubleshooting of this equipment is limited to the operational check described in paragraph 2-4b. If the pointer fails to indicate the proper resistances, forward the equipment to general support personnel for complete troubleshooting and repair.

Section IV. MAINTENANCE OF OHMMETER

4-5. Cleaning

Inspect the exterior of the ZM21(*)/U. The surface should be clean and free of dust, dirt, grease, and fungus.

a. Remove dust and loose dirt with a clean, soft cloth.

WARNING

The fumes of trichloroethane are toxic. Provide thorough ventilation whenever used. DO NOT use near an open flame. Trichloroethane is not flammable, but exposure of the fumes to an open flame or hot metal forms highly toxic phosgene gases.

b. Remove grease, fungus, and ground-in dirt from metal parts with a cloth dampened (not wet) with trichloroethane.

c. Remove dust or dirt from terminals with a soft brush.

CAUTION

Do not press on the meter face when cleaning. Damage to the equipment may result.

d. Clean the cables, meter glass, and exterior surface with a clean, soft cloth. Dampen the cloth with water, using mild detergent, if necessary, for more effective cleaning.

4-6. Touchup Painting

The bakelite case of the ZM-21(*) /U does not require painting. If the metal parts show signs of rust or corrosion, remove it with fine sandpaper. Brush two thin coats of paint on the bare metal to Protect it from further corrosion. Refer to TB 43-0118 for more detailed refinishing information.

CHAPTER 5

FUNCTIONING OF EQUIPMENT

5-1. Function

Ohmmeter ZM-21(*) /U measures high values of insulation resistance of all types of electrical equipment and wiring. The resistance across the input terminals is in series with the generator lead to the meter, thus affecting the current flow through the meter. A hand crank on the ohmmeter drives the dc generator with voltage being maintained at a constant level by an electronic controller circuit. The resistance range of the ohmmeter is from O through 1,000 megohms. The resistance is indicated by a meter of special design, and the indication given is as near as possible to a true representation of the insulation resistance of the equipment, wire, or cable under test.

5-2. Hand Generator

a. The dc hand generator consists essentially of a rotating armature in a fixed magnetic field. The armature has a 39-bar commutator running between two carbon brushes. When the armature is rotated in the magnetic field, an armature voltage is generated that is led out to the ohmmeter terminals through the carbon brushes. With the generator rotating at the proper speed, the predominant ripple frequency is approximately 1,200 hertz (Hz) with a peak-to-peak ripple voltage of approximately 6 volts. Because of the low ac component, no capacitor is required across the output of the generator.

b. The generator drive assembly of ohmmeter is shown in figure 5-1. The generator is driven by a hand-operated crank through a gear train and clutch assembly. The clutch assembly is adjusted so that it will not slip. On, earlier models of the ohmmeter (fig. 5-2) when the crank reaches an operating speed of approximately 160 rpm, centrifugal force disengages the clutch shoes from the hub in order to maintain constant voltage.

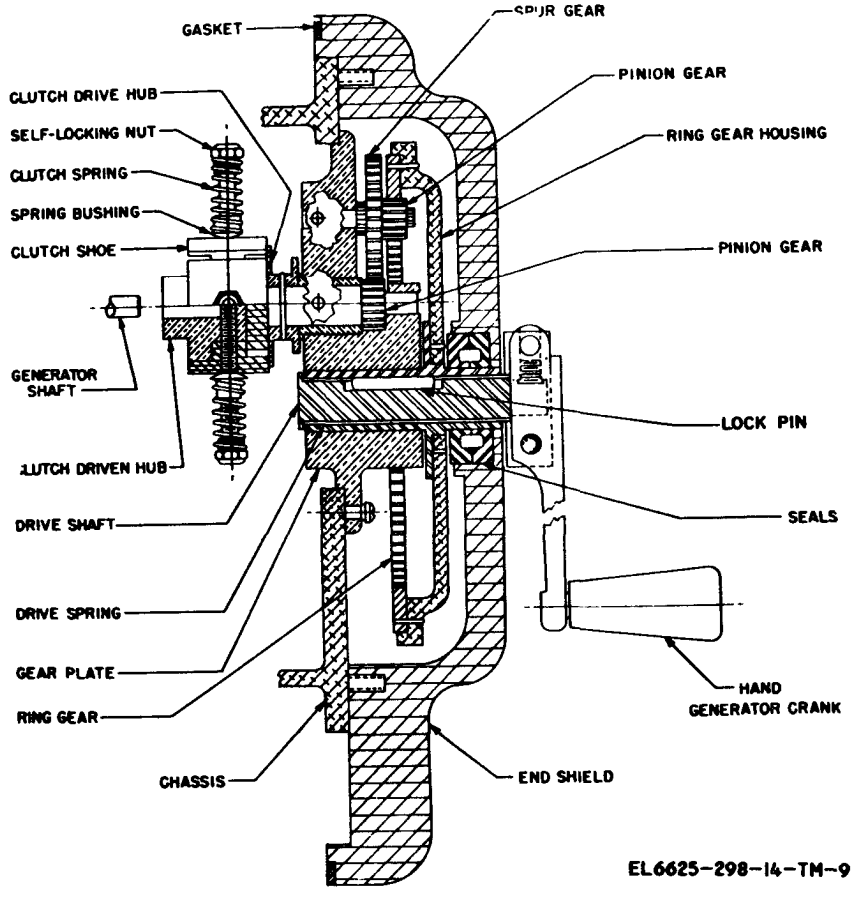

Figure 5-1. Generator drive assembly, Ohmmeter ZM-21A/U and ZM-21B/U

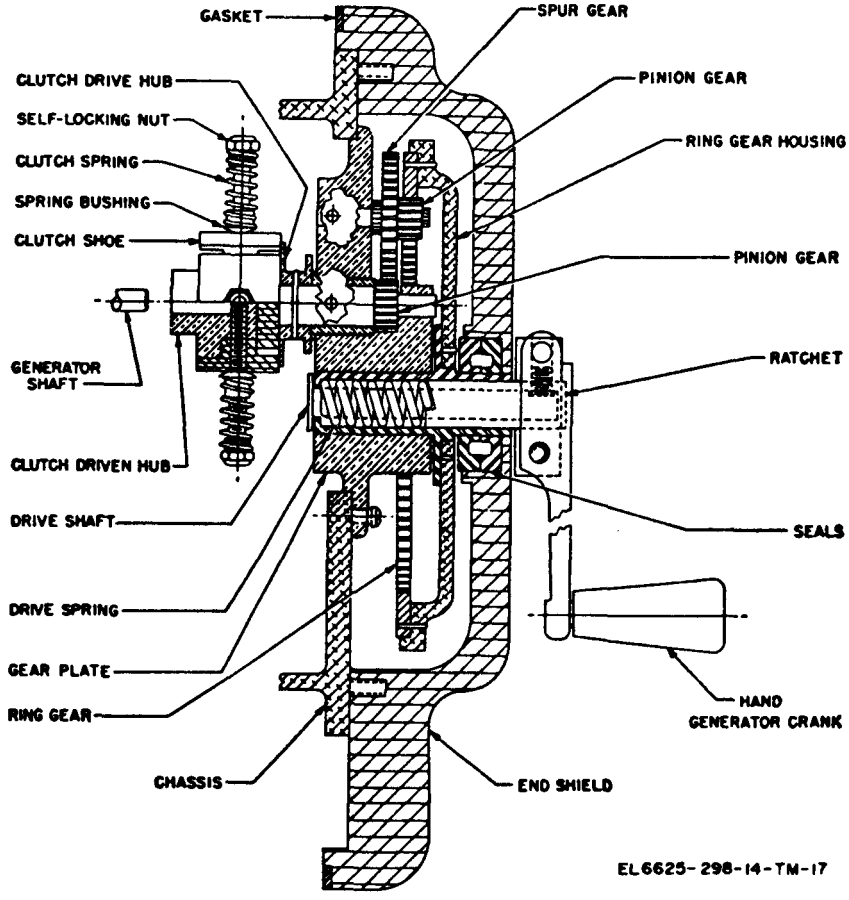

Figure 5-2. Generator drive assembly, Ohmmeter ZM-21/U.

5-3. Controller

The controller (fig. 5-3) is an electronic circuit contained in a sealed plastic box which limits the output voltage of the generator to 525 volts. It is actually a series voltage regulator with terminal 1 as the input, terminal 2 as the output, and terminal 3 as the common. The controller is used in some models of ZM-21A/U and all of ZM-21B/U.

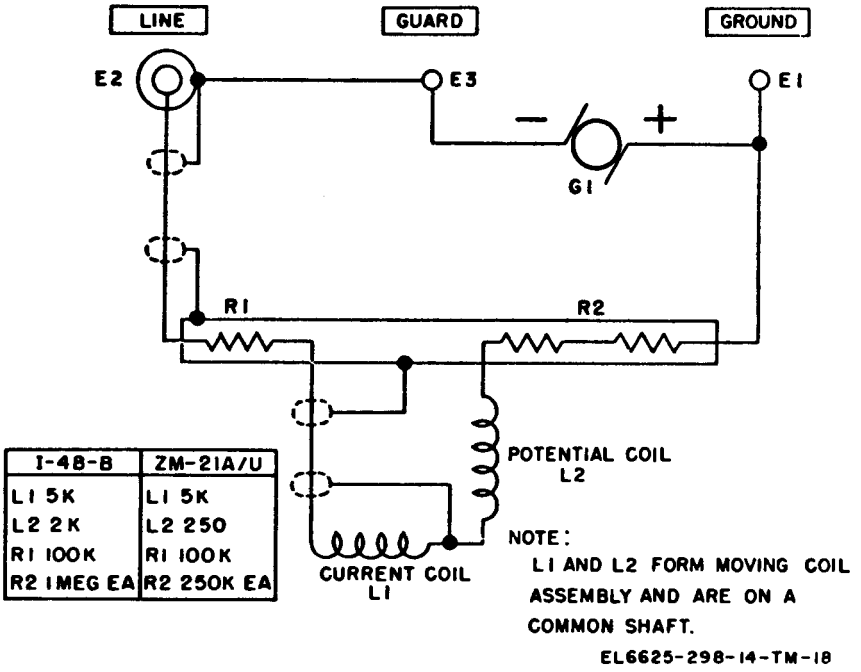

Figure 5-3. Ohmmeter ZM-21/U (and some earlier model ZM-21A/U). *schematic diagram.*

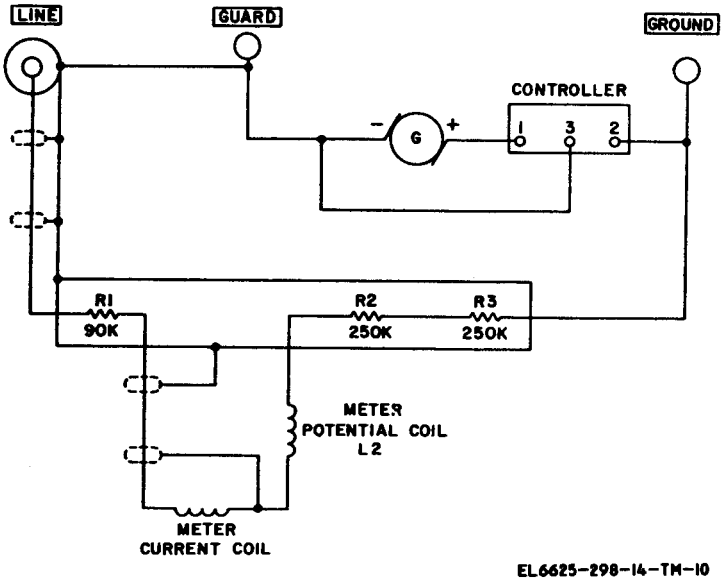

Figure 5-4. Ohmmeter ZM-21A/U and ZM-21B/U, schematic diagram.

5-4. Resistance Network

The resistance network of Ohmmeter ZM-21B/U consists of one 90,000 ohm resistor, R1, and two 250,000-ohnm resistors R2 and R3 (fig. 5-4). The two 250,000-ohm resistors are connected in series between one side of meter potential coil L2 of the ohmmeter and the positive side of the generator (through the controller). Resistor R1 is connected between one side of meter current coil L1 of the ohmmeter and the LINE terminal and acts as a protective resistance to guard against damage caused by excessive current flowing in coil L1.

5-5. Meter Movement

a. The meter movement is shown in figure 5-5. The indicating instrument consists of two coils, potential coil L2, and current coil L1. These coils, mounted on a common axis and connected so that they oppose each other in a definite ratio, rotate between two pole pieces in a magnetic field. One force tends to move the indicating pointer toward ZERO on the ohmmeter scale; the other force tends to move the pointer toward INFINITY.

b. Current flows to the indicator through flexible ligaments of practically zero torque which

connect the ohmmeter terminals to the moving coil assembly. The position at which the pointer finally comes to rest on the scale is determined by the resultant of the two opposing forces that move the coil assembly.

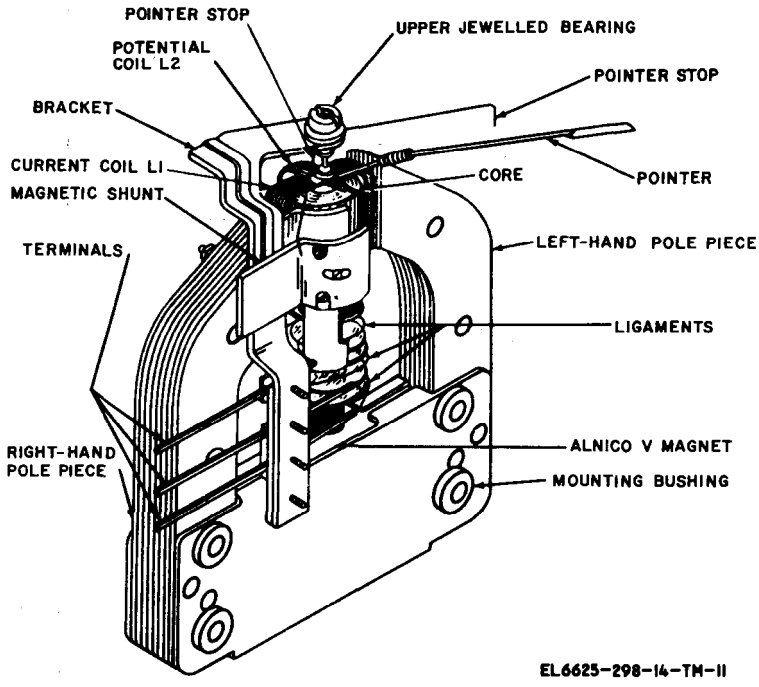

Figure 5-5. Meter assembly, Ohmmeter ZM-21B/U.

5-6. Working Circuit

a. The working circuit of the insulation resistance measuring set is designated in heavy lines in figure 5-6. The crank of the hand generator operated at a speed of 160 rpm rotates generator G1 at approximately 6,000 rpm. The generator output voltage is limited to 525 volts dc by the controller. With no connections made to the ohmmeter terminals, current flows from the negative (–) terminal of generator G1, through potential coil L2 of the meter, and through the resistors R2 and R3 (through the controller) to the positive (+) terminal of the generator. The magnetic field set up by potential coil L2 reacts with the field set up by the permanent magnet in such a way that the coil assembly and the pointer move in a counterclockwise direction until the pointer indicates infinity.

b. An unknown resistor connected between the line terminal and the ground terminal provide a another path for current flow. This path is from negative (–) terminal of generator G 1, through current coil L1 of the meter, resistor R1, the line terminal, and the ground terminal to the positive (+) side of generator G1 through the controller. The magnetic field set up by current coil L1 tends to move the coil assembly and the pointer in a clockwise direction. If the unknown resistance is low, most of the current flows through coil L1 and the pointer indicates a reading close to zero. If the value of the resistance is high, less current flows through coil L1 and the pointer moves from the zero end of the scale to indicate a point nearer infinity.

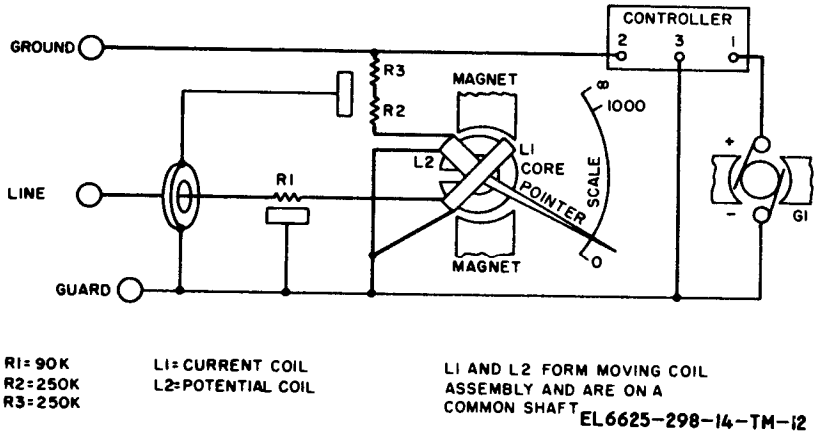

Figure 5-6. Functional diagram.

5-7. Guard Circuit

The guard circuit as shown in figure 5-6 increases the accuracy of the instrument by preventing leakage when making measurements over 100 megohms. The guard circuit consists of a metal ring around the line terminal and metal plates on which resistor R1, R2, and R3 are mounted. A brass tube connects the ring and plates together. The guard circuit prevents leakage current along the surface of the instrument case between the ground terminal and the line terminal from affecting the meter readings. Leakage current to the line terminal is picked up by the guard ring and led directly to the generator without going through resistor R1 and the meter coils.

CHAPTER 6

GENERAL SUPPORT MAINTENANCE INSTRUCTIONS

Section I. TOOLS AND EQUIPMENT

6-1. General

This chapter contains instructions for general support of Ohmmeter ZM-21*) /U. The types of repair that can be performed by units having general support responsibilities is limited only by the tools and test equipment available and by the skill of the technician.

6-2. Tools and Equipment

For a listing of tools and test equipment needed for general support maintenance, see appendix C.

Section II. TROUBLESHOOTING

6-3. Organization of Troubleshooting Procedures

a. General. The first step in servicing a defective ohmmeter is to sectionalize the fault. Sectionalization means tracing the fault to one of the major circuits responsible for the abnormal operation. The second step is to localize the fault. Localization means tracing the fault to a particular stage or network within one of the major circuits. The third step is to isolate the fault. Isolation means tracing the fault to the defective part responsible for the abnormal condition. Some faults, such as burned-out resistors, arcing, and shorted transformers often can be located by sight, smell, and hearing. The majority of faults, however, must be isolated by checking voltages and resistances.

b. Component Sectionalization, Localization, and Isolation. Listed below is a group of tests arranged to simplify and to reduce unnecessary work and to aid in tracing a trouble to a specific component. Follow the procedure in the sequence given. A technician must be careful not to cause further damage to the ohmmeter while it is being serviced.

(1) *Visual inspection*. The purpose of visual inspection is to locate faults without testing or measuring circuits. All visual signs should be observed and an attempt made to sectionalize the fault to a particular function.

(2) *Operational tests*. Operational tests frequently indicate the general location of trouble. In many instances, the tests will help in determining the exact nature of the fault.

(3) *Troubleshooting table*. Troubleshooting table 6-1 lists symptoms of common troubles and gives (or references) corrective measures. Such a table obviously cannot include all trouble symptoms that may occur. The technician should use this chart as a guide in analyzing symptoms that may not be listed.

(4) *Intermittent troubles*. In all the tests, the possibility of intermittent troubles should not be overlooked. If present, this type of trouble often may be made to appear by tapping or jarring the equipment. It is possible that some external connections may cause trouble. Test wiring for loose connections; move wires and components with an insulated tool, such as a pencil or fiber rod. This may show where a faulty connection or component is located.

c. *Ohmmeter*. A knowledge of the functioning of the ohmmeter is necessary for the technician. See paragraphs 5-1 through 5-7 for pertinent information. To supplement the troubleshooting table and to locate parts, refer to the following illustrations:

(1) Schematic diagram (fig. 5-5).

(2) Functional diagram (fig. 5-6).

(3) Illustrations showing location of parts (fig. 5-1, 5-5, 6-1, and 6-2).

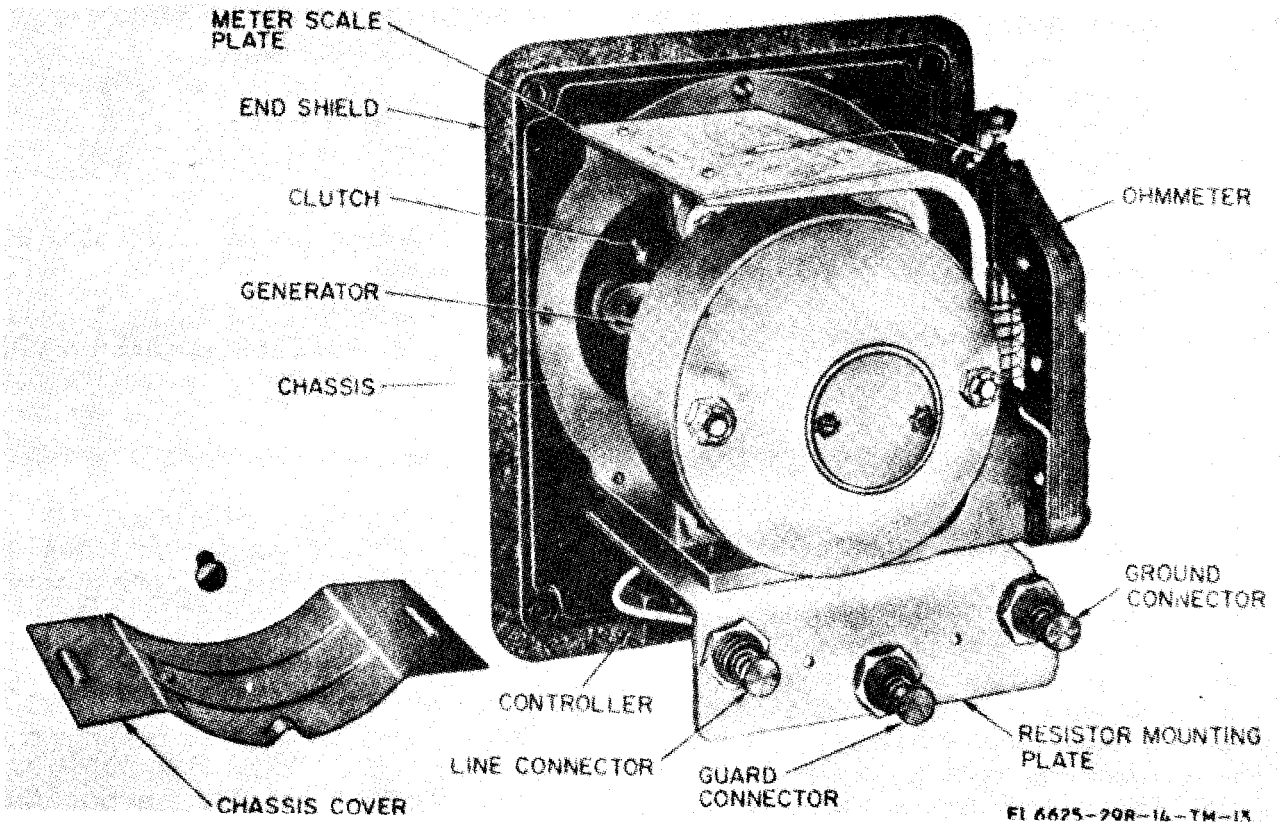

Figure 6-1. Ohmmeter, side of chassis.

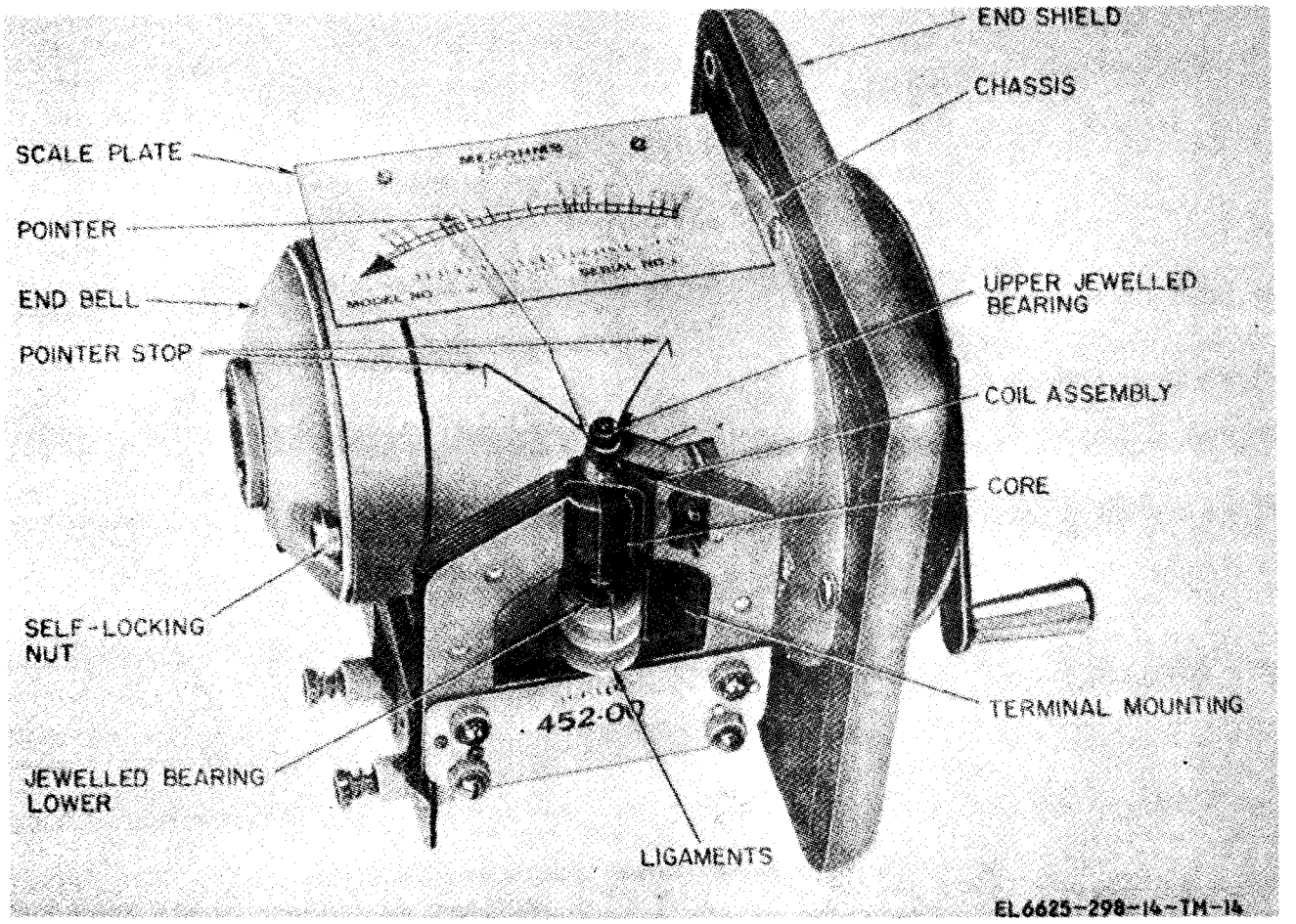

Figure 6-2. Interior view and housing.

6-4. Prelininary Inspection

a. Removal of Chassis.

(1) Break the wax seal covering the screw in the lower right hand corner of the end shield.

(2) Remove this screw and the other three screws that secure the end shield-chassis assembly to the case.

(3) Extend the hand generator crank until it is at right angles to the end shield.

CAUTION

Be careful not to damage the meter pointer.

(4) Grasp the crank and withdraw the end shield-chassis assembly from the case.

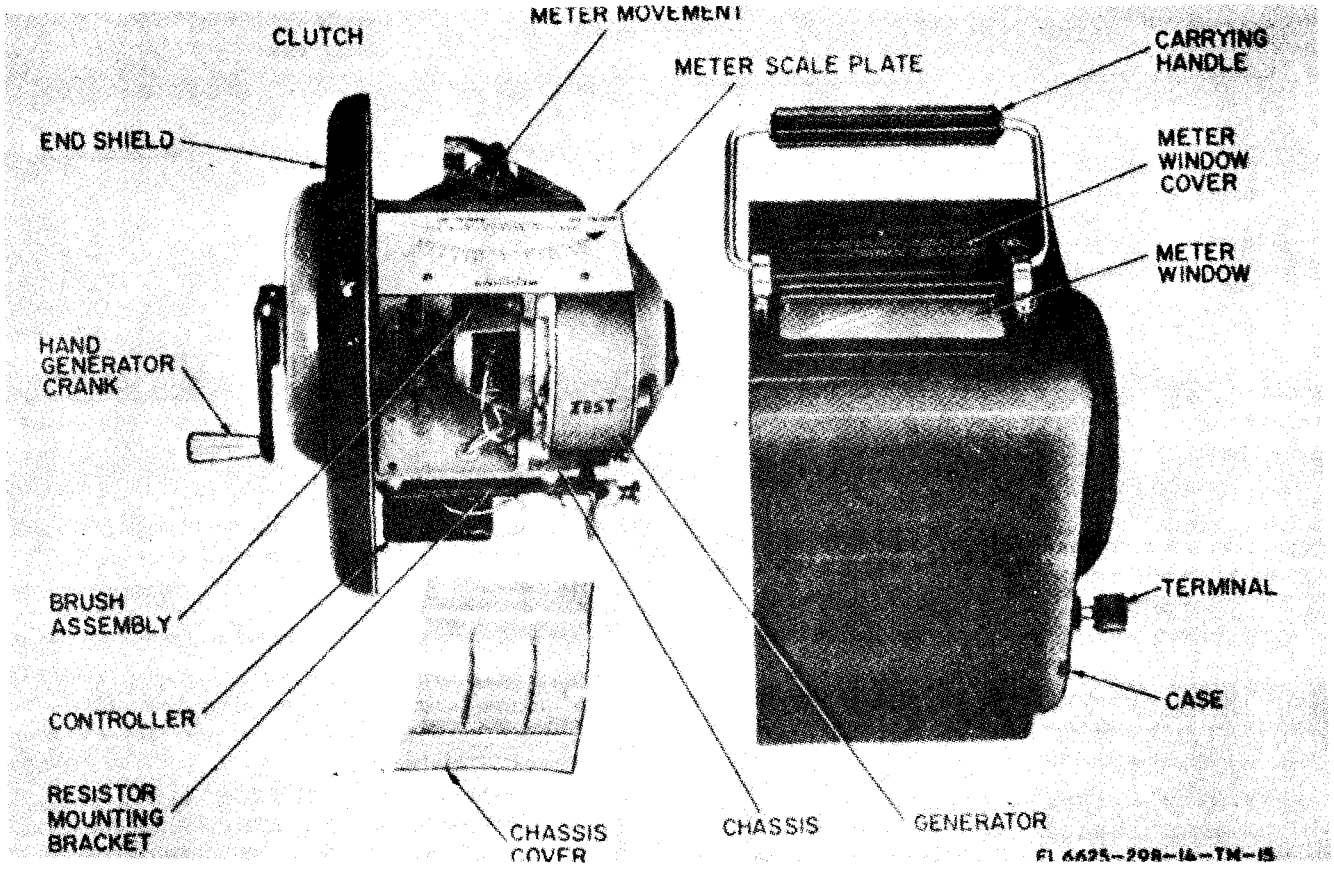

Figure 6-3. End shield and chassis assembly.

b. Removal of Chassis Cover.

(1) Remove the screw in the chassis directly in front of the small recessed portion of the chassis cover (fig. 6-3).

NOTE

Older models have a cover secured by four small screws.

(2) Gently pry up the cover on one side. The cover will snap out of the chassis.

c. Inspection. Make a preliminary inspection of the equipment to determine the extent of repair necessary.

(1) Inspect for broken insulation connections to terminals and other parts.

(2) Check for defective soldered connections.

(3) Examine wiring to see that no bare wire is touching other wires or chassis.

(4) Test operation of the hand generator by turning the crank; the shaft should move freely and smoothly.

(5) Inspect for loose or missing screws.

(6) Operate the unit according to the procedure paragraph 2-4b. This should provide an indication as to any trouble which might be present.

d. Reassembly of Equipment.

(1) Replace the chassis cover by pushing it gently into place.

(2) Replace the screws on the chassis in front of the chassis cover.

(3) Seat the gasket on the ridge on the inside face of the end shield. If the gasket is damaged replace it with a new one.

(4) Grasp the crank handle and carefully insert the chassis into the case.

(5) Replace the four screws on the end shield and tighten them securely.

Table 6-1. Troubleshooting

Malfunction	Probable cause	Corrective action
Meter will not indicate zero with ground terminal E1 connected to line terminal E2.	*a.* Defective resistor	*a.* Replace resistor.
	b. Loose connection to line or ground terminal.	*b.* Resolder connection.
	c. Loose connection to meter terminal.	*c.* Resolder connection.
	d. Loose connection or broken wire to generator.	*d.* Repair connection or replace wire.
	e. Defective meter armature	*e.* Replace armature (para 6-9).
Meter will not indicate infinity with no connnections to terminals.	*a.* Defective resistor	*a.* Replace resistor.
	b. Loose connection to meter terminal.	*b.* Resolder connection.
	c. Loose connection or broken wire to generator.	*c.* Repair connection or replace wire.
	d. Defective meter armature	*d.* Replace armature (para 6-9).
Meter indication incorrect when testing known resistance.	*a.* Defective resistor R1, R2, or R3.	*a.* Replace resistor.
	b. Defective meter armature	*b.* Replace armature (para 6-9).
Generator voltage low	*a.* Loose clutch adjustment	*a.* Tighten clutch (para 6-17).
	b. Defective or worn generator brushes.	*b.* Replace brushes (para 6-11).
	c. Defective generator armature.	*c.* Replace armature (para 6-10).
	d. Defective controller	*d.* Replace controller.
Generator voltage high	Defective controller	Replace controller.

6-5. Isolating Trouble

a. *Indicator Scale Test.* The indicator scale test may localize a faulty meter indication to the indicating instrument. Proceed as follows:

(1) Connect LINE and GROUND terminals to known resistances.

(2) Operate hand generator crank. Note any deviation between the known resistance values and the values indicated on the test set.

(3) The deviation from any marked point should not exceed 1/32 inch.

b. Output Voltage Test. The output voltage test may show that the generator is defective or that the controller requires replacement. Proceed as follows:

(1) Connect Multimeter ME-26/U to the ground and guard terminals.

(2) Turn hand generator crank until maximum voltage is obtained Note the output voltage.

(3) The output voltage of the generator should be between 500 and 550 volts dc.

(a) If the multimeter reading is above 550 volts dc; replace the controller.

(b) If the multimeter indicates less than 500 volts dc, check the output directly at the generator. If the output is still below 500 volts dc, replace the generator.

NOTE

Low output voltage that cannot be adjusted may be caused by an open current coil in the indicating instrument.

(c) If generator output is above 500 volts dc, replace the controller.

c. Resistance Network Test. Disconnect the three resistors R1, R2, and R3 (fig. 5-4) and Check each separately with Multimeter ME-26/U. The resistors should check to within one percent of their marked values. Normal values are given in figure 5-4.

d. Continuity Test. Check the continuity of the circuit, point-to-point, with Multimeter ME-26/U. Check for possible short circuits in the same manner.

e. Intermittent Trouble. In all tests, the possibility of intermittent trouble should not be overlooked. If present, this type of trouble may often be made to appear by tapping or jarring the equipment.

Section III. MAINTENANCE OF OHMMETER

6-6. Replacement of Parts

a. Repair of Ohmmeter ZM-21(*) /U shall be accomplished by competent personnel supplied with proper tools and equipment (listed in ap pendix C).

b. All parts are easily reached when the chassis assembly is removed from the case.

c. When removing wiring from terminals, tag each wire to be sure of correct reassembly.

d. Take care not to damage adjacent parts when removing, installing, or connecting new parts.

e. Replacement parts shall be identical to the original parts and shall be installed in the same physical position as the original.

f. When replacing wiring, each new piece of wire shall be the same length as the wire being replaced.

6-7. Replacement of Meter

a. Remove the chassis from the case according to instructions in paragraph 6-4a.

b. Unsolder the connections to the meter terminals (fig. 5-5); tag the wires so that they may be replaced properly.

c. Remove the mounting screws and bushings from the meter magnet, and remove the meter (fig. 5-5).

d. Install a new meter, using the same screws and bushings that were used to mount the old instrument. Resolder the equipment wiring to the meter terminals.

e. Replace the meter scale plate (fig. 6-2) with a blank scale plate. Calibrate and mark the new scale plate as shown in figure 6-4 according to directions given in paragraph 6-16.

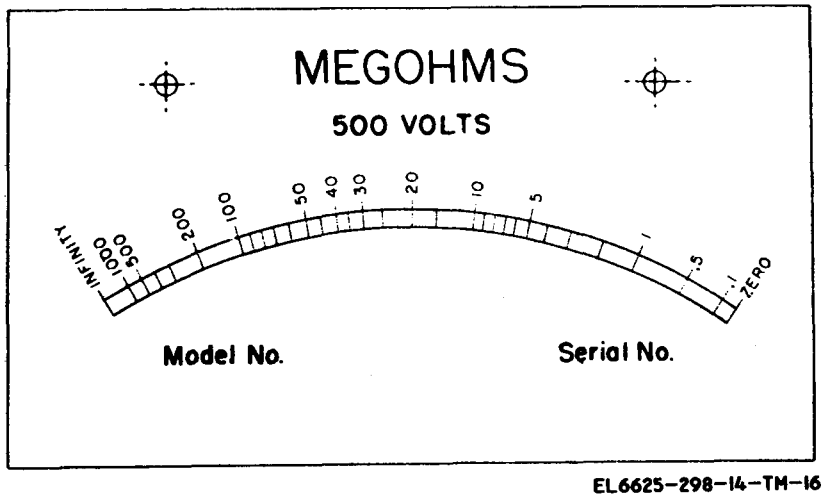

Figure 6-4. Meter scale.

6-8. Replacement of controller

a. Remove the chassis (para 6-4a).

b. Disconnect and tag the three wires leading to the controller.

c. Remove the two screws holding the controller to the chassis.

d. Reconnect the wires to the replacement controller and replace the screws that fasten the controller to the chassis.

6-9. Replacement of Hand Generator

a. Remove the chassis and chassis cover.

b. Remove the two snap buttons on the underside of the chassis.

c. Disconnect the leads from the generator brush-holder terminals.

d. Remove the self-locking nuts, two of which can be reached from the top of the chassis and the other two through the holes on the underside of the chassis from which the snap buttons have been removed.

e. Withdraw the generator from the chassis.

f. Knock out the taper pin that retains the clutch driven hub (fig. 5-1), and remove the hub.

g. Install the clutch hub and the new generator by drilling the generator shaft and pinning the hub to the shaft.

h. Place the new generator on the chassis, and replace the self-locking nuts. On the underside of the chassis, return the snap button to the holes from which they were removed.

i. Reconnect the leads to the generator brush-holder terminals.

6-10. Replacement of Meter Armature

a. Remove the meter (para 6-7).

b. Disconnect the ligaments and terminal from the moving coil assembly (fig. 5-5).

CAUTION

Be careful not to damage the coil pivots or the pointer.

c. Back off the upper jewelled bearing, and carefully withdrew the armature from the magnet.

d. Install a new armature, and replace the upper jewelled bearing. Reconnect the ligaments and terminals to the moving coil assembly.

e. Replace the meter and meter scale (pars 6-7). Calibrate and mark the new meter scale according to instructions given in paragraph 6-16.

6-11. Replacement of Hand Generator Armature

a. Remove the generator (para 6-9).

b. Remove the generator brush caps (fig. 6-3) and remove the brushes.

c. Remove the two self-locking nuts at the front end of the generator (fig. 6-1).

d. Withdraw the armature, and replace it with a new one.

e. Place the end bell in position, and replace the self-locking nuts.

f. Replace the generator brushes and brush cape.

g. Reinstall the generator as instructed in paragraph 6-9.

6-12. Replacement of Terminals

When replacing terminals be sure to install all washers and insulator bushings in the order in which they were originally installed. Observe this precaution especially in the case of the line terminal; this is the terminal on which the guard ring is mounted.

6-13. Replacement of Meter Window Glass

a. Remove the rectangular nickel-plated bezel from the top surface of the meter window.

b. Lift out the old meter window glass and clean away old insulating compound from around the meter scale aperture.

c. Spread new insulating compound around the scale aperture and press the new meter window glass in place.

d. Press the bezel down firmly over the glass.

6-14. Replacement of Meter Window Cover

a. Remove the four screws that hold the pillow blocks in place (fig. 1-2).

b. Lift off the pillow blocks.

c. Lift the old cover out of the recess above the meter window into which it fits.

d. Install a new cover and replace the pillow blocks.

6-15. Lubrication of the Ohmmeter

a. *General*. The generator ball bearings and the drive assembly gear train are lubricated by the manufacturer and ordinarily will require no further lubrication. When the generator is disassembled for repair, however, the following lubrication shall be performed at the general support maintenance level.

b. *Disassembly*. The ohmmeter shall be disassembled, inspected, and cleaned in accordance with instructions given in paragraphs 4-5 and 6-4. Remove four screws which hold chassis to the end shield. The chassis and end shield may now be separated, exposing all gearing. The internal or ring-gear will remain within the end shield (fig. 5-1 and 5-2).

CAUTION

Do not lubricate any portion of the clutch mechanism or the drive shaft and lock pin. This also applies to the ratchet and drive spring of older models.

c. *Lubrication*. Apply a small amount of grease (Aircraft and Instruments-GL) to the generator ball bearings and the entire drive assembly gear train. Wipe off excess with a clean, lint-free cloth. Grease (GL) is an all-weather lubricant; no special precautions are necessary when it is used in extreme climates.

6-16. Calibration and Marking of Meter Scale

***a*. Equipment *Required*.** In addition to Multimeter ME-26/U the following resistors are required.

(1) Ten resistors, 0.1 megohm, ± prercent.

(2) Ten resistors, 1 megohm ± percent.

(3) Ten resistors, 10 megohms ± percent.

(4) Ten resistors, 100 megohms ± percent.

NOTE

Before calibrating a new meter scale, check the output voltage of the ohmmeter (para *6-5 b)*. If the output voltage is above 550 volts or below 500 volts, replace the controller.

b. *Calibration*. To calibrate a blank meter scale, proceed as follows:

(1) Connect the line and ground terminals together and turn the hand generator crank at operating speed. The meter pointer should deflect to the right-hand end of the blank scale plate. This point is zero calibration on the scale; mark the point in pencil.

(2) Remove the connector between the line and ground terminals and again turn the hand generator crank at operating speed. The pointer should deflect to the opposite end of the blank scale plate. This is the infinity point on the scale; mark this point in pencil.

(3) Connect resistors *(a* above), singly or in series, to obtain the various values of resistance such as were indicated on the original scale (fig. 6-4). Connect the resistors between the line and ground terminals of the ohmmeter. Turn the hand generator crank at operating speed each time. Mark each resistance value on the blank scale plate in pencil.

c. *Marking*. Remove the meter scale plate from its bracket and draw in the new points of calibration with India ink. Use a straightedge and a draftsman's ruling pen.

6-17. Adjustment of Clutch

The clutch should be tightened all the way down to prevent slipping. The operating voltage is maintained by the controller, not by the clutch.

Section IV. GENERAL SUPPORT TESTING PROCEDURES

6-18. General

This section contains references for use by general support maintenance personnel to determine whether the performance of the repaired equipment is satisfactory for return to the users.

6-19. Test Procedure

Perform the tests in paragraph *6-5a* and *6-5b*.

APPENDIX A

REFERENCES

DA Pam 310-4	Index of Technical manuals, Technical Bulletins, Supply Manuals (types 7, 8, and 9), Supply Bulletins, and Lubrications Orders.
DA Pam 310-7	US Army Equipment Index of Modification Work Orders.
TB 9-6625-975-35	Calibration Procedure for Ohmmeters I-48, I-48-B, ZM-21A/U, ZM-21B/U (Winslow Model 5G1000), and Biddle Models 7676-1, 7679, 7679-1, and 7679-R.
TB 43-0118	Field Instruction for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelters.
TM 11-6625-203-12	Operator and Organizational Maintenance: Multimeters AN/URM-105 and AN/URM-105C Including Multimeters ME-77/U and ME-77C/U.
TM 11-6625-298-34P	Direct Support and General Support Maintenance Repair Parts and Special Tools Lists (Including Depot Maintenance Repair Parts and Special Tools): Ohmmeters ZM-21/U, ZM-21A/U, and ZM-21B/U, Test Sets 1-48-A and 1-48-B (FSN 6625-581-2466.)
TM 38-750	The Army Maintenance Management System (TAMMS).
TM 740-90-1	Administrative Storage of Equipment.
TM 750-244-2	Procedures for Destruction of Electronics Materiel to Prevent Enemy Use (Electronics Command).

APPENDIX C

MAINTENANCE ALLOCATION

Section I. INTRODUCTION

C-1. General

This appendix provides a summary of the maintenance operations for ZM-21/U, ZM-21A/U, and ZM-21B/U. It authorizes categories of maintenance for specific maintenance functions on repairable items and components and the tools and equipment required to perform each function. This appendix may be used as an aid in planning maintenance operations.

C-2. Maintenance Function

Maintenance functions will be limited to and defined as follows:

a. Inspect. To determine the serviceability of an item by comparing its physical, mechanical, and/or electrical characteristics with established standards through examination.

b. Test. To verify serviceability and to detect incipient failure by measuring the mechanical or electrical characteristics of an item and comparing those characteristics with prescribed standards.

c. Service. Operations required periodically to keep an item in proper operating condition; i.e., to clean, preserve, drain, paint, or to replenish fuel/lubricants/hydraulic fluids or compressed air supplies.

d. Adjust. Maintain within prescribed limits by bringing into proper or exact position, or by setting the operating characteristics to the specified parameters.

e. Align. To adjust specified variable elements of an item to about optimum or desired performance.

f. Calibrate. To determine and cause corrections to be made or to be adjusted on instruments or test measuring and diagnostic equipment used in precision measurement. Consists of the comparison of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared.

g. *Install.* The act of emplacing, seating, or fixing into position an item, part, module (component or assembly) in a manner to allow the proper functioning of the equipment/system.

h. Replace. The act of substituting a serviceable like-type part, subassembly, model (component or assembly) for an unserviceable counterpart.

i. Repair. The application of maintenance services (inspect, test, service, adjust, align, claibrate, replace) or other maintenance actions (welding, grinding, riveting, straightening, facing, remachining, or resurfacing) to restore serviceability to an item by correcting specific damage, fault malfunction, or failure in a part, subassembly, module/component/assembly, end item or system. This function does not include the trial and error replacement of running spare type items such as fuses, lamps, or electron tubes.

j. Overhaul. That periodic maintenance effort (service/action) necessary to restore an item to a completely serviceable/operational condition as prescribed by maintenance standards (e.g., DMR) in appropriate technical publications. Overhaul is normally the highest degree of maintenance performed by the Army. Overhaul does not normally return an item to like-new condition.

k. Rebuild. Consists of. those services/actions necessary for the restoration of unserviceable equipment to a like-new condition in accordance with original manufacturing standards. Rebuild is the highest degree of material maintenance applied to Army equipment. The rebuild operation includes the act of returning to zero those age measurements (hours, miles, etc.) considered in classifying Army equipment/components.

C-3. Column Entries

a. Column 1, Group Number. Column 1 lists group numbers, the purpose of which is to identify components, assemblies, subassemblies, and modules with the next higher assembly.

b. Column 2, Component/Assembly. Column 2 contains, the noun names of components, assemblies, subassemblies, and modules for which maintenance is authorized.

c. Column 3, Maintenance Functions. Column 3 lists the functions to be performed on the item listed in column 2. When items are listed without maintenance functions, it is solely for purpose of having the group numbers in the MAC and RP-STL coincide.

d. Column 4, Maintenance Category. Column 4

specifies, by the listing of a "worktime" figure in the appropriate subcolumn(s), the lowest level of maintenance authorized to perform the function listed in column 3. This figure represents the active time required to perform that maintenance function at the indicated category of maintenance. If the number or complexity of the tasks within the listed maintenance function vary at different maintenance categories, appropriate "worktime" figures will be shown for each category. The number of task-hours specified by the "worktime" figure represents the average time required to restore an item (assembly, subassembly, component, module, end item or system) to a serviceable condition under typical field operating conditions. This time includes preparation time, troubleshooting time and quality assurance/quality control time in addition to the time required to perform the specific tasks identified for the maintenance functions authorized in the maintenance allocation chart. Subcolumns of column 4 are as follows:

C–Operator/crew
O–Organizational
F–Direct support
H-General support
D–Depot

e. Column 5, *Tools and Equipment.* Column 5 specifies by code, those common tool sets (not individual tools) and special tools, test, and support equipment required to perform the designated function.

C-4. Tool and Test Equipment Requirements (Table 1)

a. Tool or Test Equipment Reference Code. The numbers in this column coincide with the numbers used in the tools and equipment column of the MAC. The number indicate the applicable tool or test equipment for the maintenance functions.

b. Maintenance Category. The codes in this column indicate the maintenance category allocated the tool or test equipment.

c. Nomenclature. This column lists the noun name and nomenclature of the tools and test equipment required to perform the maintenance functions.

d. National/NATO Stock Number. This column lists the National/NATO stock number of the specific tool or test equipment.

e. Tool Number. This column lists the manufactures part number of the tool followed by the Federal Supply Code for Manufacturers (5-digit) in parentheses.

(Next printed page is C-3)

SECTION II MAINTENANCE ALLOCATION CHART FOR

OHMMETER ZM-21/U, ZM-21A/U, AND ZM-21B/U

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY					(5) TOOLS AND EQUIPMENT
			C	O	F	H	D	
	OHMMETER ZM-21B/U							
01	CASE	Inspect		0.1				
		Service		0.2				
		Replace				0.4		1
02	CABLES	Inspect	0.1					
		Service	0.2					
		Replace	0.5					
		Repair				0.5		1
03	OHMMETER	Inspect	0.1					
		Service	0.2					
		Test				0.5		2,5,6,7,8
		Service				0.2		
		Adjust				0.2		1
		Calibrate				0.9		2,5,6,7,8
		Replace				1.5		1
		Overhaul					2.5	1-8

TABLE 1. TOOL AND TEST EQUIPMENT REQUIREMENTS FOR

OHMMETER ZM-21/U, ZM-21A/U, AND ZM-21B/U

TOOL OR TEST EQUIPMENT REF CODE	MAINTENANCE CATEGORY	NOMENCLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER
1	H,D	TOOL KIT, ELECTRONIC EQUIPMENT TK-101/G	180-00-064 -5178	
2	D	MULTIMETER ME-26/U	62 5-00-646-9409	
3	D	DC MICROMETER, 0-5 UA (WESTON MOD 622)		
4	D	RESISTANCE, DECADE ZM-16/U	62 5-00-669-0266	
5	H,D	RESISTOR, FIXED, FILM 0.1 MEGOHM ±1% (10 required)	905-00-683-6672	
6	H,D	RESISTOR, FIXED, FILM 1 MEGOHM ±1% (10 required)	905-00-433-9267	
7	H,D	RESISTOR, FIXED, FILM 10 MEGOHM ±1% (10 required)	905-00 -065 -0585	
8	H,D	RESISTOR, FIXED, FILM 100 MEGOHM ±1% (10 required)	905-00-049-8618	

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NG: State AG (3).
USAR: None.
***For explanation of abbreviations used, see AR* 310-60.**

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PAGE NO.	PARAGRAPH	FIGURE NO.	TABLE NO.	
2-25	2-28			Recommend that the installation antenna alignment procedure be changed throughout to specify a 2° IFF antenna lag rather than 1°. REASON: Experience has shown that with only a 1° lag, the antenna servo system is too sensitive to wind gusting in excess of [illegible] knots, and has a tendency to rapidly accelerate and decelerate as it hunts, causing strain to the drive train. Hunting is minimized by adjusting the lag to 2° without degradation of operation.
3-10	3-3		3-1	Item 5, Function column. Change "2 db" to "3db." REASON: The adjustment procedure for the TRANS POWER FAULT indicator calls for a 3 db (500 watts) adjustment to light the TRANS POWER FAULT indicator.
5-6	5-8			Add new step f.1 to read, "Replace cover plate removed in step e.1, above." REASON: To replace the cover plate.
		F03		Zone C 3. On J1-2, change "+24 VDC to "+5 VDC." REASON: This is the output line of the 5 VDC power supply. + 24 VDC is the input voltage.

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REVERSE OF DA FORM 2028-2 (TEST)

THE METRIC SYSTEM AND EQUIVALENTS

LINEAR MEASURE

. Centimeter = 10 Millimeters = 0.01 Meters = 0.3937 Inches
1 Meter = 100 Centimeters = 1000 Millimeters = 39.37 Inches
1 Kilometer = 1000 Meters = 0.621 Miles

WEIGHTS

Gram = 0.001 Kilograms = 1000 Milligrams = 0.035 Ounces
1 Kilogram = 1000 Grams = 2.2 lb.
1 Metric Ton = 1000 Kilograms = 1 Megagram = 1.1 Short Tons

LIQUID MEASURE

1 Milliliter = 0.001 Liters = 0.0338 Fluid Ounces
1 Liter = 1000 Milliliters = 33.82 Fluid Ounces

SQUARE MEASURE

1 Sq. Centimeter = 100 Sq. Millimeters = 0.155 Sq. Inches
1 Sq. Meter = 10,000 Sq. Centimeters = 10.76 Sq. Feet
1 Sq. Kilometer = 1,000,000 Sq. Meters = 0.386 Sq. Miles

CUBIC MEASURE

1 Cu. Centimeter = 1000 Cu. Millimeters = 0.06 Cu. Inches
1 Cu. Meter = 1,000,000 Cu. Centimeters = 35.31 Cu. Feet

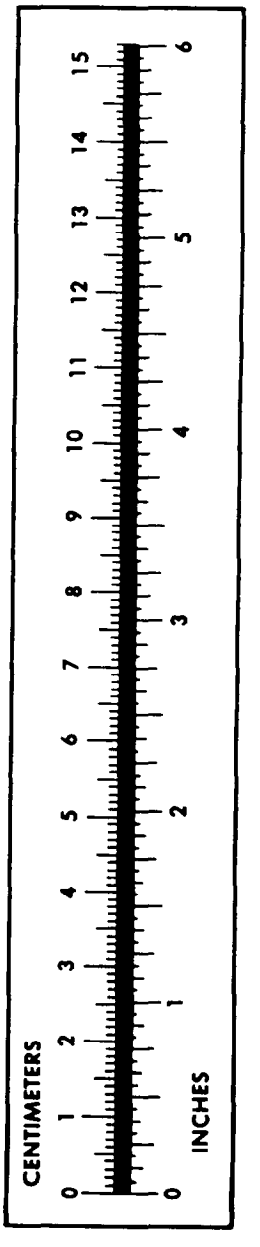
TEMPERATURE

5/9(°F - 32) = °C
212° Fahrenheit is evuivalent to 100° Celsius
90° Fahrenheit is equivalent to 32.2° Celsius
32° Fahrenheit is equivalent to 0° Celsius
9/5C° + 32 =°F

APPROXIMATE CONVERSION FACTORS

TO CHANGE	TO	MULTIPLY BY
Inches	Centimeters	2.540
Feet	Meters	0.305
Yards	Meters	0.914
Miles	Kilometers	1.609
Square Inches	Square Centimeters	6.451
Square Feet	Square Meters	0.093
Square Yards	Square Meters	0.836
Square Miles	Square Kilometers	2.590
Acres	Square Hectometers	0.405
Cubic Feet	Cubic Meters	0.028
Cubic Yards	Cubic Meters	0.765
Fluid Ounces	Milliliters	29.573
ıts	Liters	0.473
arts	Liters	0.946
allons	Liters	3.785
Ounces	Grams	28.349
Pounds	Kilograms	0.454
Short Tons	Metric Tons	0.907
Pound-Feet	Newton-Meters	1.356
Pounds per Square Inch	Kilopascals	6.895
Miles per Gallon	Kilometers per Liter	0.425
Miles per Hour	Kilometers per Hour	1.609

TO CHANGE	TO	MULTIPLY BY
Centimeters	Inches	0.394
Meters	Feet	3.280
Meters	Yards	1.094
Kilometers	Miles	0.621
Square Centimeters	Square Inches	0.155
Square Meters	Square Feet	10.764
Square Meters	Square Yards	1.196
Square Kilometers	Square Miles	0.386
Square Hectometers	Acres	2.471
Cubic Meters	Cubic Feet	35.315
Cubic Meters	Cubic Yards	1.308
Milliliters	Fluid Ounces	0.034
Liters	Pints	2.113
Liters	Quarts	1.057
ers	Gallons	0.264
ms	Ounces	0.035
ograms	Pounds	2.205
Metric Tons	Short Tons	1.102
Newton-Meters	Pounds-Feet	0.738
Kilopascals	Pounds per Square Inch	0.145
lometers per Liter	Miles per Gallon	2.354
meters per Hour	Miles per Hour	0.621



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