DEPARTMENT OF THE ARMY TECHNICAL MANUAL TM 11-2019

DEPARTMENT OF THE AIR FORCE TECHNICAL ORDER TO 33A1-12-15-1

TEST SETS I-49, I-49A AND I-49B AND RESISTANCE BRIDGES ZM-4A/U AND ZM-4B/U

This copy is a reprint which includes current pages from Changes 1 and 3.

DEPARTMENTS OF THE ARMY AND THE AIR FORCE

17 OCTOBER 1957

WARNING

Dangerous voltages are present in the test set when arranged for operation with an external power source above 25 volts. Disconnect the external power before replacing any parts inside the test set.

Changes now in force: C1 and C3

TECHNICAL MANUAL

TEST SETS I-49, I-49-A, AND I-49-B AND RESISTANCE BRIDGES ZM-4A/U AND ZM-4B/U

TM 11-2019

CHANGE NO. 3

HEADQUARTERS,
DEPARTMENT OF THE ARMY
WASHINGTON, D. C., 19 September 1963

TM 11-2019, 17 October 1957, is changed as follows:

Note: The parenthetical reference to previous changes (example: C2, 14 Oct 58) indicates that pertinent material was published in that change.

Page 5. Add paragraph 1.1 after paragraph 1.

1.1. Index of Publications

Refer to the latest issue of DA Pam 310-4 to determine whether there are new editions, changes, or additional publications pertaining to your equipment. DA Pam 310-4 is an index of current technical manuals, technical bulletins, supply bulletins, lubrication orders, and modification work orders which are available through publications supply channels. The index lists the individual parts (-10, -20, -35P, etc.) and the latest Changes to and revisions of each equipment publication.

Delete paragraph 2 (as changed by C2, 14 Oct 62) and substitute:

2. Forms and Records

a .Reports of Maintenance and Unsatisfactory Equipment. Use equipment forms and records in accordance with instructions in TM 38-750.

b. Report of Damaged or Improper Shipment. Fill out and forward DD Form 6 (Report of Damaged or Improper Shipment) as prescribed in AR 700-58 (Army), NAVSANDA Publication 378 (Navy), and AFR 71-4 (Air Force).

c .Reporting of Equipment Manual Improvements. The direct reporting by the individual user of errors, omissions, and recommendations for improving this manual is authorized and encouraged. DA Form 2028 (Recommended changes to DA technical manual parts lists or supply manual 7, 8, or 9) will be used for reporting these improvements. This form will be completed in triplicate using pencil, pen, or typewriter. The original and one copy will be forwarded direct to: Commanding Officer, U.S. Army Electronics Materiel Support Agency, ATTN: SELMS-MP, Fort Monmouth, N.J., 07703. One information copy will be furnished to the individual's immediate supervisor (e.g., officer, noncommissioned officer, supervisor, etc.).

Page 15, paragraph 15h (as changed by C2, 14 Oct 58). Delete the first two sentences and substitute:

It has been determined (par. 13b) that a cable pair in a length of spiral-four cable is shorted. The cable temperature is 68°F. and the resistance per loop mile of loaded spiral-four cable at 68°F. is 92.6 ohms.

•'This change supersedes C2, 14 October 1958.

Page 18, paragraph 18g(2) (as changed by C2. 14 Oct 58). In the equation, change "-Bg" to: -BRg.

Page 19, paragraph 18j(5) (as changed by C2. 14 Oct 58). In the equation. change:

$$"\frac{A(R + Rb - BRg"}{A + B} \text{ to: } \frac{A(R + Rb) - BRg}{A + B}$$

Page 33, figure 17, caption (as changed by C2. 14 Oct 1958). Change "Figure 17" to: Figure 11.

Paragraph 29c(2). Change to:

(2) Distance from test point to ground , 61.6 x 89,9, 5,538 feet

Paragraph 29c(3) (as changed by C2, 14 Oct 62). Change to:

(3) Distance from far end to ground , 61.6 x 22,5 , 1.386 feet

Page 36, paragraph 33a, chart (as changed by C2. 14 Oct 58). In the right-hand column, second item. change "17.4 per 100 ft)" to: (17.4 per 1,000 ft).

In footnote b. line 3 change "6-milliheavies" to: 6-millihenries. Paragraph 33b chart (as changed by C2, 14 Oct 58). Right-hand column. Change the heading to: Maximum dc res per loop mi at 68°F.(ohms)[a].

Add the following footnote below the table.

[a]Actual conductor resistance may be lower because of manufacturing variation. For exact resistance either refer to station records or use the test set to measure the resistance of a known length of the conductor and use the measurement to compute the resistance per loop mile.

Page 38. Delete section I and substitute:

SectionI. PREVENTATIVE MAINTENANCE

35. Scope of Maintenance

The maintenance duties assigned to the operator and organizational repairman of the test set are listed below together with a reference to the paragraphs covering the specific maintenance function. The duties assigned require the use of tools and test equipment listed in TM 11-6625-249-12P.

a. Daily preventive maintenance checks and services (par. 38).
b. Weekly preventive maintenance checks and services (par. 38.1).
c. Cleaning (par. 38.2).
d. Monthly preventive maintenance checks and services (par. 38.4).
e. Touchup painting (par. 38.5).

36. Preventive Maintenance

Preventive maintenance is the systematic care, servicing, and inspection of equipment to prevent the occurrence of trouble, to reduce downtime, and to assure that the equipment is serviceable.

a. Systematic Care. The procedures given in paragraphs 37 through 38.5 cover routine systematic care and cleaning essential to proper upkeep and operation of the equipment.

b. Preventive Maintenance Checks and Services. The preventive maintenance checks and services chart (pars. 38, 38.1 and 38.4) outline functions to be performed at specific intervals. These checks and services are to maintain Army electronic equipment in a combat serviceable condition; that is, in good general (physical) condition and in good operating condition. To assist operators in maintaining combat serviceability, the charts indicate what to check, how to check, and what the normal conditions are the

References column lists the illustrations paragraphs, or manuals that contain detailed repair or replacement procedures. If the defect cannot be remedied by performing the corrective actions listed, higher echelon maintenance or repair is required. Records and reports of these checks and services must be made in accordance with the requirements set forth in TM 38-750.

Delete section II heading.

Delete paragraphs 37 and 38, (as changed by C2, 14 Oct 58) and substitute:

37. Preventive Maintenance Checks and Services Periods

Preventive maintenance checks and services of the test set are required daily, weekly, and monthly. Paragraphs 38, 38.1 and 38.4 specify the items to be checked and serviced. In addition to the routine daily, weekly and monthly checks and services, the equipment should be rechecked and serviced immediately. before going on a mission and as soon after completion of the mission as possible.

38. Daily Preventive Maintenance Checks and Services Chart

Sequence No.	Item	Procedure	References
1	Completeness ----------	Se sure the equipment is complete.	TM 11-6625-249-12P.
2	Cleanliness ------------	Clean dirt and moisture from exposed surfaces of housing cabinet, control panel, and the meter window.	Par. 38.2
3	Knobs, dials, and switches --------------	During operation (items 5 below), observe that the mechanical action of each knob, dial, and switch is smooth and free of external or internal binding.	
4	Meter movement ----	During operation (item 5 below), check for sticking galvanometers movement.	
5	Operation ---------------	Operate the equipment according to paragraph 40.	Par. 40.

38.1. Weekly Preventive Maintenance Checks and Services Chart

Sequence No.	Item	Procedure	References
1	Handle, hinges, and latch ------------	Hand check for looseness of the handle, latch, and hinges.	
2	Batteries -----------	Inspect dry batteries for leakage.	
3	Preservation -----------	Inspect exposed metal surfaces for rust and corrosion If present, touchup paint the bare spots.	Par. 38.5.

38.2. Cleaning

Inspect the exterior of the test set. The exterior surfaces should be clean, and free of dust, dirt, grease, and fungus.

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

Cleaning compound is flammable and its fumes are toxic. Provide adequate ventilation. Do not use near a flame.

b. Remove grease, fungus, and ground-in dirt from the case; use a cloth dampened (not wet) with Cleaning Compound, (Federal stock No. 7930-395-9542).

c. Remove dust or dirt from binding posts with a brush.

Caution: Do not press on the meter face (glass) when cleaning. The meter may become damaged.

d. Clean the panel, meter, and control knobs; use a soft clean cloth. If necessary dampen the cloth with water; mild soap may be used.

38.3. Monthly Maintenance

Perform the maintenance functions indicated in the monthly preventive maintenance checks and services chart (par. 38.4) once each month. A month is defined as approximately 30 calendar days of 8-hour-per-day operation. If the equipment is operated 16 hours a day, the monthly preventive maintenance checks and services should be performed at 15-day intervals. Adjustment of the maintenance interval must be made to compensate for any unusual operating conditions. Equipment maintained in a standby (ready for immediate operation) condition must have monthly preventive maintenance checks and services Performed on it. Equipment in limited storage (requires service before operation) does not require monthly preventive maintenance.

38.4. Monthly Preventive Maintenance Checks and Services Chart

Sequence No.	Item	Procedure	References
1	Resistors -----------	Inspect resistors for cracks, blistering, or other detrimental defect.	
2	Connectors ---------	Inspect connectors for sung fit and good contact.	
3	Publications --------	See that all publication are complete, serviceable, and current.	DA Pam 310-4.
4	Modifications ----------	Check DA Pam 310-4 to determine if new applicable MWO's have been published. All urgent MWO's must be applied immediately. All normal MWO's must be scheduled.	TM 38-750 and DA 310-4.
5	Spare parts ---------	Check all spare parts (operator and organizational) for general condition and method of storage. There should be no evidence of overstock, and all shortages should be on valid requisitions.	TM 11-6625-305-12P.

38.5. Touchup Painting Instructions

Clean rust and corrosion from metal surfaces by lightly sanding them with fine sandpaper. Brush two thin coats of paint on the bare metal to protect if from further corrosion. Refer to the applicable cleaning and refinishing practices specified in TM 9-213.

Page 39. Delete figure 13(as changed by C2, 14 Oct 58).

Page 40. Delete figure 14 (as changed by C2, 14 Oct 58).

Page 55. Add the appendix after chapter 6.

APPENDIX

REFERENCES

Following is a list of applicable publications available to the operator and repairmen of Test Sets I-49, I-49-A, I-49-B, and Resistance Bridges ZM-4A/U and ZM-4B/U.

DA Pam 310-4	Index of Technical Manuals, Technical Bulletins, Supply Bulletins, Lubrication Orders, and Modification Work Orders.
TM 9-213	Painting Instructions for Field Use.
TM 11-6625-203-12	Operator and Organizational Maintenance Multimeter AN/URM-105, including Multimeter ME-77/U.
TM 11-6625-249-12P	Operator's and Organizational Maintenance Repair Parts and Special Tools List and Maintenance Allocation Chart for Resistance Bridges, ZM-4A/U and ZM-4B/U.
TM 11-6625-249-35P	Field and depot Maintenance Repair Parts and Special Tools List for Resistance Bridges ZM-4A/U and ZM-4B/U.
TM 38-750	The Army Equipment Record System and Procedures.

By Order of the Secretary of the Army:

EARLE G. WHEELER,
General, United States Army,
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Sig Dep (OS) (12)
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  Sacramento (28)
  Tobyhannd (12)
  Louisville (5)
  Granite City (5)
USA Elct RD Actv, White Sands (13)
USA Elct RD Actv, Ft Huachuca (2)
USA Trans Tml Comd (1)
Army Tml (1)
POE (1)
USAOSA (1)
AMS (1)
WRAMC (1)
AFIP (1)
Army Pic Cen (2)
USA Mbl Spt Cen (1)
USA Elct Mat Agcy (12)
Chicago Proc Dist (1)
USARCARIB Sig Agcy (1)
Sig Fld Maint Shop (3)
William Beaumont Gen Hosp (5)
Fitzsimmons Gen Hosp (5)
Arsenals: Benicia, Frankford,
  Raritan (5)
USAWECOM (5)
SIPRE (5)
Dugway PG (5)
USA Int Corps Agcy (5)
USMA (5)
USA Engr Cen (5)
USASATSA (5)
USA Mid East Sig Agcy (5)
Units org under fol TOE: (2 each UNOINDC)

6-125	11-36	11-237
6-126	11-39	11-500 AA-AE (4)
6-200	11-45	11-557
6-225	11-46	11-587
2-226	11-56	11-592
6-575	11-57	11-597
6-577	11-97	29-56
11-7	11-98	32-500
11-16	11-117	39-51
11-25	11-155	55-225
11-27	11-157	55-227
11-35	11-158	57

NG: State AG (3) units same as active Army except allowance is one copy to each unit.
USAR: None.
For explanation of abbreviations used see AR 320-50.

TEST SETS I-49, I-49-A, AND I-49-B AND RESISTANCE BRIDGES ZM-4A/U AND ZM-4B/U

TM 11-2019
TO 33A1-12-15-1
CHANGES No. 1

DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON 25, D. C., *24 February 1958*

TM 11-2019/TO 33A1-12-15-1, 17 October 1957, is changed as indicated so that the manual also applies to the following equipment:

Nomenclature	*Order No.*	*Serial No.*
Resistance Bridge ZM-4B/U	42796-Phila-57	1 through 854

Front cover. Add dash between 49A and 49B as shown in title above.

Page 5, chapter 1. Add the following note below the title of chapter 1:

Note. Resistance Bridge ZM-4B/U procured on Order No. 42796-Phila-57 is similar to Resistance Bridges ZM-4B/U procured on Orders No. 25738-Phila-53 and 3358-Phila-52.

Page 41, paragraph 40, chart, step 9. Make the following changes:

In "normal indication" column delete "Pointer does not move".

In "corrective action" column, line 3, after "power" add: If pointer does not deflect in either direction make checks listed below.

Page 48, paragraph 48, chart. Transpose the headings of the first two columns.

Page 48, paragraph 49. Make the following changes:

Subparagraph *a*(1)(*b*). Add the following note after subparagraph (*b*):

Note. If a complete rotary switch and resistor assembly is available, replace the complete assembly. If individual replacement resistors only are available, replace defective resistors as described below.

Subparagraph *a*(2)(*a*). Add the following note after subparagraph (*a*):

Note. In the ZM-4B/U purchased on Order No. 42796-Phila-57, a screw and washer are used to fasten the wipers to the rotary switch.

Page 52, figure 25. Change "NOTE" to: NOTES.

Number the existing note 1 and add the following:

2. WIRING OF ZM-4B/U ON ORDER NO. 42796-PHILA-57 DIFFERS AS FOLLOWS:

Interconnections	Color
R3 TO S7, TERM 1	BRN
R2 TO S8, TERM 1	RED
R1 TO S9, TERM 1	ORN
R1 TO M1	YEL

Page 53, paragraphs 53 and 54, charts. Change footnote ([b]) in each chart to read:

[b]Tolerances for Resistance Bridge ZM-4B/U purchased on Orders No. 3358-Phila-52, 25738-Phila-53, and 42796-Phila-57.

[AG 413.6 (12 Feb 58)]

BY ORDER OF THE SECRETARIES OF THE ARMY AND THE AIR FORCE:

MAXWELL D. TAYLOR,
General, United States Army,
Chief of Staff.

OFFICIAL:
HERBERT M. JONES,
Major General, United States Army,
The Adjutant General.

THOMAS D. WHITE,
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USA Comm Agcy
TASSA
USA Sig Eqp Spt Agcy
USA White Sands Sig Agcy
Yuma Test Sta
Dugway PG
USA Elct PG
Benicia Arsenal
Frankford Arsenal
Raritan Arsenal
Red River Arsenal
Redstone Arsenal
Sig Fld Maint Shops
Sig Lab
Mil Dist
JBUSMC
Units organized under following TOE's:
5-278
6-100
6-125
6-126
6-200
6-225
6-226
6-300
6-315
6-316
6-575
6-577
11-7
11-15
11-16
11-25
11-27
11-57
11-95
11-98
11-127
11-128
11-500 (AA-AE)
11-537
11-557
11-587
11-592
11-597
20-300
32-55
32-56
32-500
39-51
55-56
55-225
55-227

NG: State AG; units—same as Active Army.
USAR: None.
For explanation of abbreviations used, see AR 320-50.

TECHNICAL MANUAL No. 11-2019
TECHNICAL ORDER No. 33A1-12-15-1

DEPARTMENTS OF THE ARMY AND THE AIR FORCE

WASHINGTON 25, D. C., *17 October 1957*

TEST SETS I-49, I-49-A, AND I-49-B AND RESISTANCE BRIDGES ZM-4A/U AND ZM-4B/U

*** This manual supersedes TM 11-2019/TO 33A1-12-15-1, 12 August 1944, including C 1, 18 January 1954, and C 2, 17 October 1955.**

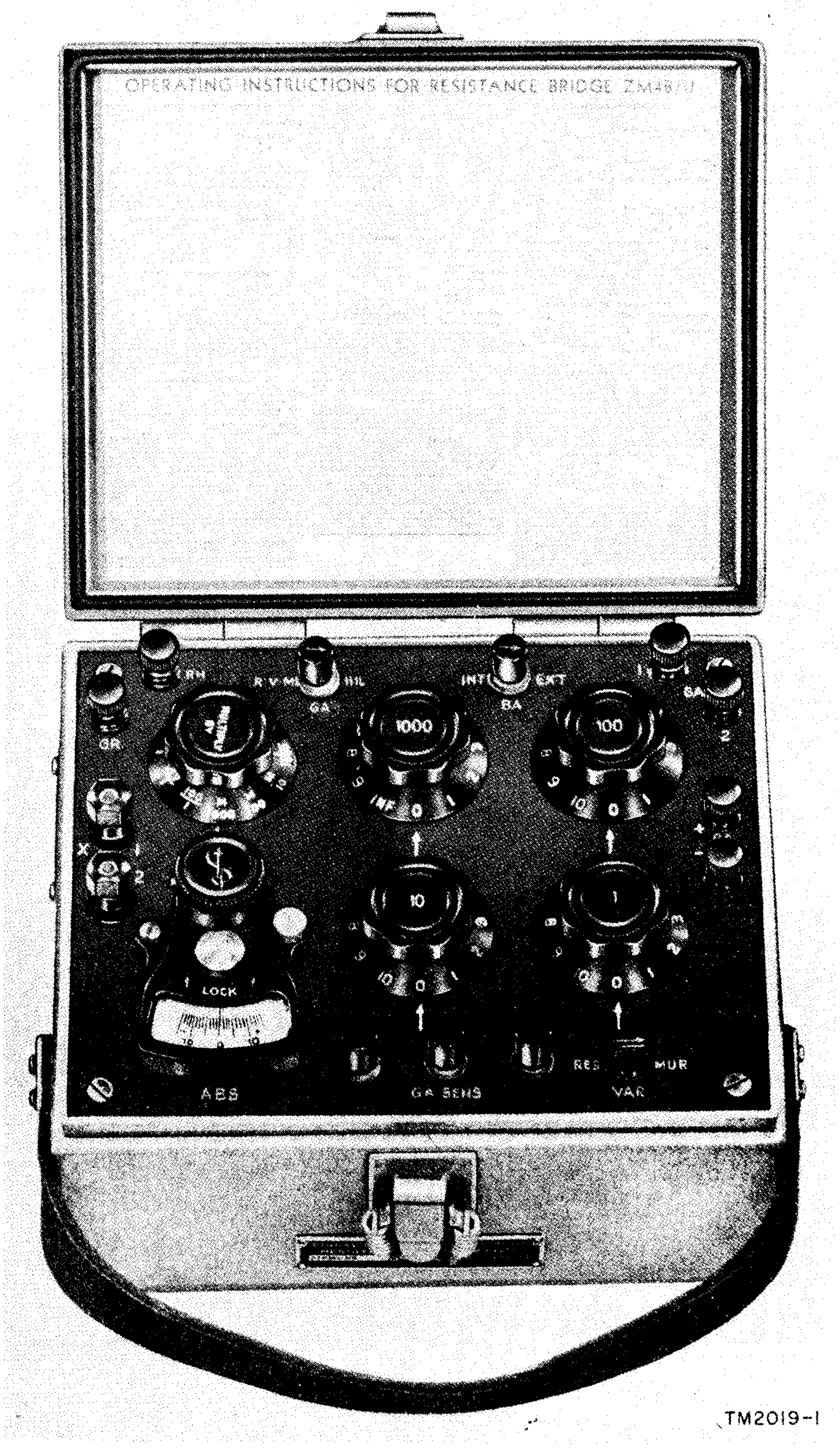

Figure 1. Resistance Bridge ZM–4B/U.

CHAPTER 1
INTRODUCTION

Section I. GENERAL

1. Scope

a. This manual covers the installation, operation, and maintenance of Test Sets I-49, I-49-A, and I-49-B, and Resistance Bridges ZM-4A/U and ZM-4B/U (fig. 1).

b. The term *test set* is used in this manual to refer to any of the above models. Official nomenclature followed by (*) is used to indicate all models of the nomenclature equipments. Thus, Test Set I-49-(*) represents Test Sets I-49, I-49-A, and I-49-B; Resistance Bridge ZM-4(*)/U represents Resistance Bridges ZM-4A/U and ZM-4B/U.

c. Forward comments on this publication direct to Commanding Officer, United States Army Signal Publications Agency, Fort Monmouth, N. J.

2. Forms and Records

a. Unsatisfactory Equipment Reports.

(1) Fill out and forward DA Form 468 (Unsatisfactory Equipment Report) to Commanding Officer, United States Army Signal Equipment Support Agency, Fort Monmouth, N. J., as prescribed in AR 700-38.

(2) Fill out and forward AFTO Form 29 (Unsatisfactory Report) to Commander, Air Materiel Command, Wright-Patterson Air Force Base, Ohio, as prescribed in AF TO 00-35D-54.

b. Damaged or Improper Shipment. Fill out and forward DD Form 6 (Report of Damaged or Improper Shipment) as prescribed in AR 700-58 (Army); Navy Shipping Guide, Article 1850-4 (Navy); and AFR 71-4 (Air Force).

c. Preventive Maintenance Forms (figs. 13 and 14).

(1) Prepare DA Form 11-238 (Operator First Echelon Maintenance Check List for Signal Corps Equipment (Radio Communication, Direction Finding, Carrier, Radar)) in accordance with instructions on the back of the form.

(2) Prepare DA Form 11-239 (Second and Third Echelon Maintenance Check List for Signal Corps Equipment (Radio Communication, Direction Finding, Carrier, Radar)) in accordance with instructions on the back of the form.

Section II. DESCRIPTION AND DATA

3. Purpose and Use

a. Test Set I-49-(*) and Resistance Bridge ZM-4(*)/U are portable Wheatstone bridges used to measure the direct current (dc) resistance of communication and power lines. The resistance measurements are used to determine if a line or cable is faulty and the type and approximate location of the fault. The test sets are used also to measure the dc resistance of electrical components and as auxiliary resistance boxes.

b. The test sets are used by maintenance personnel at central office testing stations and at field test points. All models are functionally interchangeable.

4. Technical Characteristics

Voltage source .... Either internal or external.
Voltage requirement:
Internal .... 4.5 volts dc (8 Batteries BA-30).
External .... 22.5 volts to 200 volts dc (par. 12)

Resistance measurement:
- Range .... 1 ohm to 1.011 megohms (1,011,000 Ohms).
- Accuracy .... ±.15 percent

Resistance box:
- Range .... 0 to 10,110 ohms
- Current limitations .... 016 to .5 amperes (par. 34)

5. Description
(fig. 1)

a. Each Teat Set I-49-(*) and Resistance Bridge ZM-4(*)/U is housed in either a wooden or metal carrying case (par. 6) about 5¾ inches high, 7¼ inches wide, and 8¾ inches deep. Each test set weighs about 8 pounds.

b. All operating controls and a galvanometers are mounted on the top panel and are accessible when the cover is raised Binding posts for all external connections are mounted on the top panel also. A plate on one side of the case covers the battery compartment.

6. Differences in Models

Item	Test Set			
	I-49	I-49-A and ZM-4B/U	I-49-B	ZM-4A/U
Case.	Wooden, nonwaterproof.	Metal, waterproof.	Same as I-49-A.	Same as I-49-A.
RES-VAR-MUR switch.	Cam-type, double bank, located at rear of control panel (fig. 3).	Turn-type, single bank, located at front edge of panel (fig. 1).	Same as I-49.	Same as I-49.
Line binding posts.	Round, knurled, do not accommodate banana-type plug (fig. 3).	Hexagonal, with center connector for banana-type plug (fig. 1).	Same as I-49.	Same as I-49.
GA switch and BA switch.	Mounted in center of panel (fig. 3).	Mounted along rear edge of panel (fig. 1).	Same as I-49.	

CHAPTER 2
OPERATING INSTRUCTIONS

Section I. SERVICE UPON RECEIPT OF TEST SET

7. Unpacking and Checking
(fig. 2)

a. Packaging Data. Each test set is packaged in a water-resistant 7- by 9- by 11-inch corrugated fiberboard carton and packed with a quantity of similarly packaged test sets in a nailed wooden packing case reinforced with metal straps. The volume of the packaged test set is approximately .4 cubic foot.

b. Removing Contents.

(1) Cut the metal straps at a point below the wooden cover and fold them back carefully.

(2) Remove the nails from the wooden cover with a nail puller and remove the cover.

(3) Cut the moistureproof barrier carefully with a sharp knife and remove the packaged test sets.

(4) Cut open each corrugated fiberboard carton, open the moisture-vaporproof barrier, and remove the technical manuals and the test set.

Caution: **When cutting the corrugated fiberboard cartons, be careful not to damage the technical manuals or the case of the test set.**

c. Checking. Inspect the test set for damage. If damaged, refer to paragraph 2.

8. Additional Equipment Required

The items listed below are required for use with the ZM-4(*)/U and 1-49-(*). None is supplied as part of the test set.

a. Three Batteries BA-30 are required when the test set is to be operated with an internal voltage supply.

b. One Battery BA-53 (or equivalent source of 45-volts dc) is required as an external voltage source to obtain maximum accuracy when measuring resistance values above 10,000 ohms.

c. A Test Set TS–190/U or equivalent telephone test receiver is required for locating opens with the ZM-4(*)/U and I-49-(*).

d. A Cable Splicer's Test Set TS-420/U (TM 11-2069) or equivalent oscillator is required as a source of 500 cycle test tone for locating opens with the ZM-4(*)/U and I-49-(*).

e. A single-pole, double-throw switch and a 14-microfarad capacitor are required to compensate for induced foreign voltage.

f. A 1- or 2-microfarad capacitor is required for locating an open in a single pair of wires.

g. A 0- to 6,500-ohm, .5 watt variable resistor is required for operation of the test set with external voltages between 45 and 200 volts.

Section II. OPERATION

9. Controls, Binding Posts, and Galvanometer
(fig. 3)

The galvanometer, mounted on the test set panel, indicates the degree of balance of the test set circuit. Identification and function of the controls and binding posts are listed in *a* and *b* below.

a. Controls.

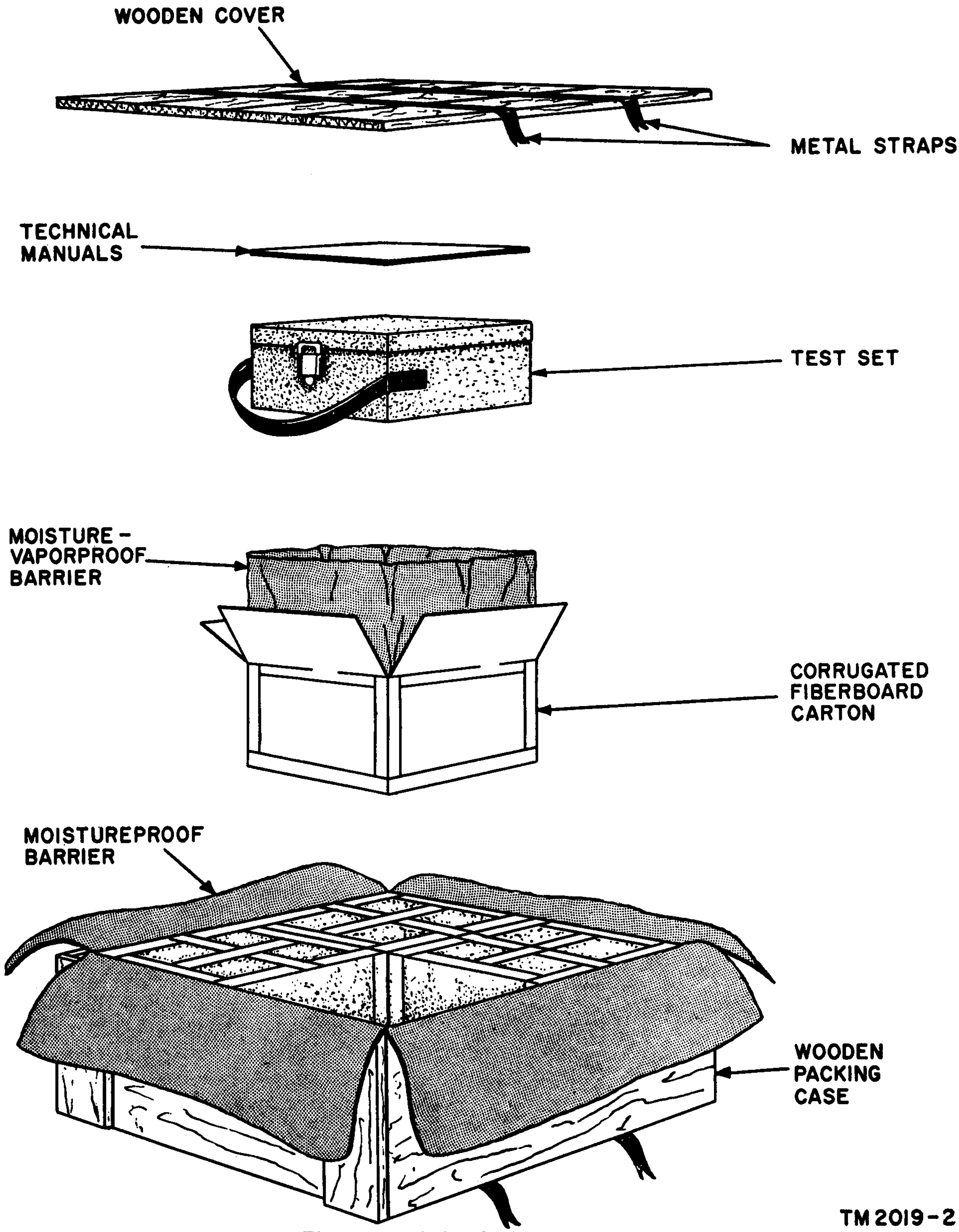

Figure 2. Typical packaging arrangement.

Control	Function
Units decade dial	Adjusts resistance from 0 to 10 ohms in 1-ohm steps.
Tens decade dial	Adjusts resistance from 0 to 100 ohms in 10-ohm steps.
Hundreds decade dial	Adjusts resistance from 0 to 1,000 ohms in 100-ohm steps.
Thousands decade dial	Adjusts resistance from 0 to 9,000 ohms in 1,000-ohm steps.
MULTIPLY BY dial	Positions $\frac{1}{1,000}$ through $\frac{100}{1}$ indicate ratio factors used to convert decade dial readings into resistance measurements. Positions M 1000, M 100, and M 10 indicate a significant value used in computations for Murray and Hilborn tests.
RES–VAR–MUR switch	Arranges test set circuitry for various tests.
BA switch	Arranges test set circuitry for test with either internal or external battery.
GA switch	Arranges galvanometer in test circuit as required for various tests.
GA SENS switches .01, .1, and 1.	Control sensitivity of galvanometer circuit.
Pointer lock	Locks galvanometer pointer during transportation of test set.
Zeroing knob	Adjusts galvanometer to zero.
Galvanometer screw	Locks galvanometer at zero setting.

b. Binding Posts.

Item	Function
Ground binding post	Connection point for ground lead.
Line binding post X1 and X2.	Connection points for line or unknown resistance.
BA- and BA+ binding posts	Connection points for external battery.
Galvanometer binding posts GA1 and GA2.	Connection points for external galvanometer.
Rh binding post	Connection point for use of test set as a resistance box (line binding post X2 used for other connection point).

10. Preparation for Use

(fig. 3)

Place the test set on a level surface as near as practicable to the test point and prepare the test set as follows:

a. Galvanometer Adjustment.

(1) If the test set galvanometers is to be used, slide the pointer lock toward the meter scale as far as it will go. If the pointer does not balance at the center of the scale, loosen the galvanometer screw, adjust the zeroing knob until the pointer balances at the center of the scale, and tighten the galvanometers screw.

(2) If an external galvanometers is to be used, loosen the galvanometers screw to disconnect the test set galvanometer. Connect the external galvanometer to GA binding posts land 2 (negative to 2), and adjust the external galvanometer to zero.

b. Power Source.

(1) *Internal.* If power for the test circuit is to be supplied by the test set, turn the BA switch to INT and install three Batteries BA-30 (par. 11).

(2) *External.* If external power is to be used, turn the BA switch to EXT and connect the external power to the BA binding posts (par. 12). Be sure to observe the correct polarity as marked on the test set panel near the BA binding posts.

c. Preoperational Test.

(1) Position the following controls as indicated:

(a) GA switch to RVM.

(b) RES-VAR-MUR switch to RES.

(c) MULTIPLY BY dial to 1/1.

(d) Units, hundreds, and thousands decade dials to 0.

(e) Tens decade dial to 5.

(2) Connect a jumper across line binding posts X1 and X2.

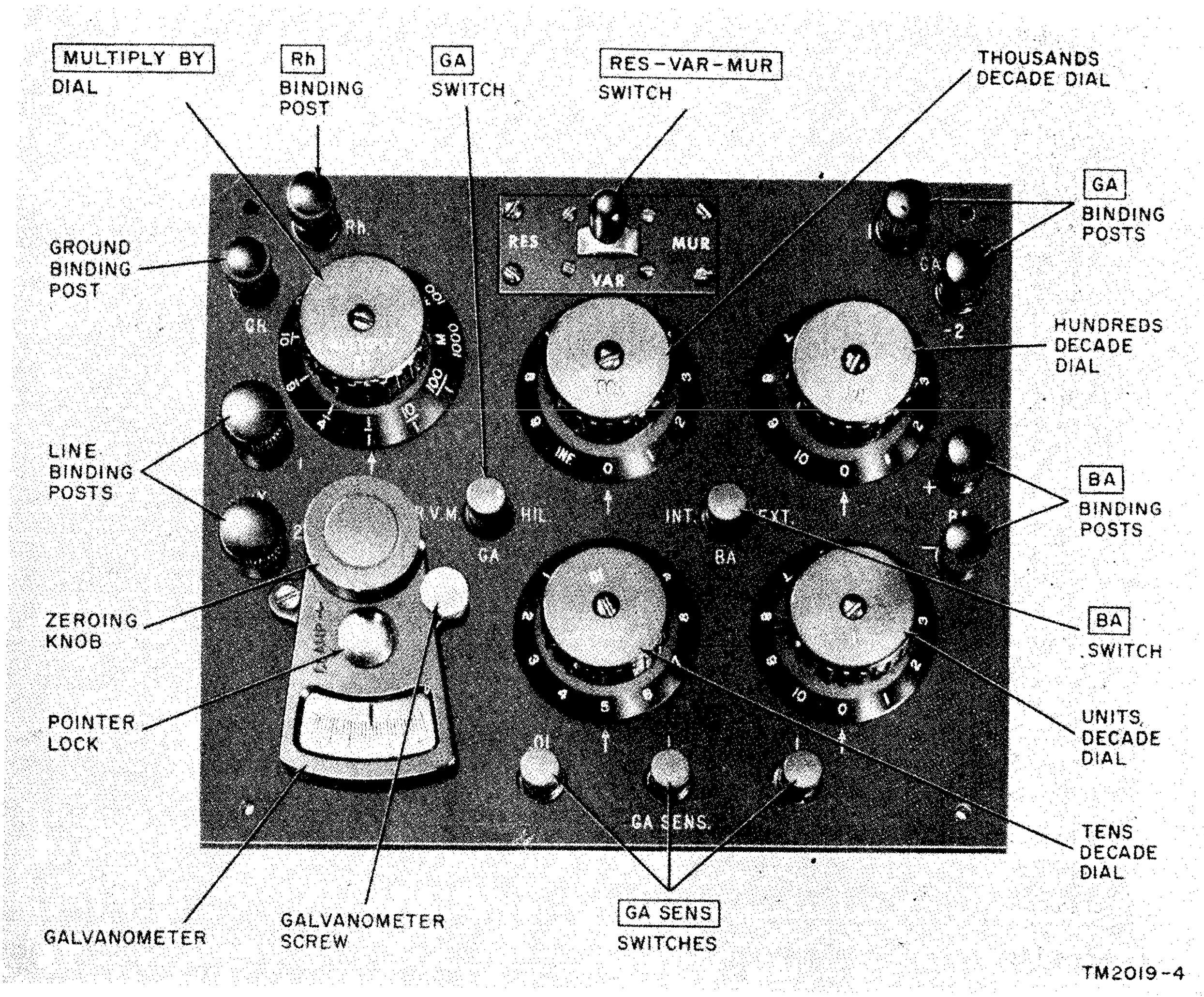

Figure 3. Operating controls, I–49, I–49–B, and ZM–4A/U.

(3) Press the GA SENS .01 switch and release it immediately. If the pointer of the galvanometers deflects to the left (-) and returns to zero, the test set is ready for use. If the pointer deflects to the right (+), reverse the polarity of the power source. If the pointer does not deflect in either direction, the test set is faulty and maintenance is required.

11. Battery Installation
(fig. 4)

a. Remove the plate screw from each corner of the plate on the side of the test set (all models except the ZM-4B/U on Order No. 15600-Phila-55). Use a wide-faced screwdriver to unscrew the large round bakelite plug from the left side of the ZM-4B/U (Order No. 15600-Phila-55).

b. Insert three Batteries BA-30 into the battery compartment. Be sure to insert the bottom of each battery first. When inserted properly, the batteries are in series and the center terminal of the last battery installed is exposed.

c. Replace the plate (or bakelite plug).

Note. Batteries are not furnished with the test sets. Always remove the batteries before storage.

12. External Power Connections
(fig. 3)

Use an external dc voltage when measuring resistances above 1,000 ohms to obtain more accurate results than are possible with use of the power supplied by the batteries

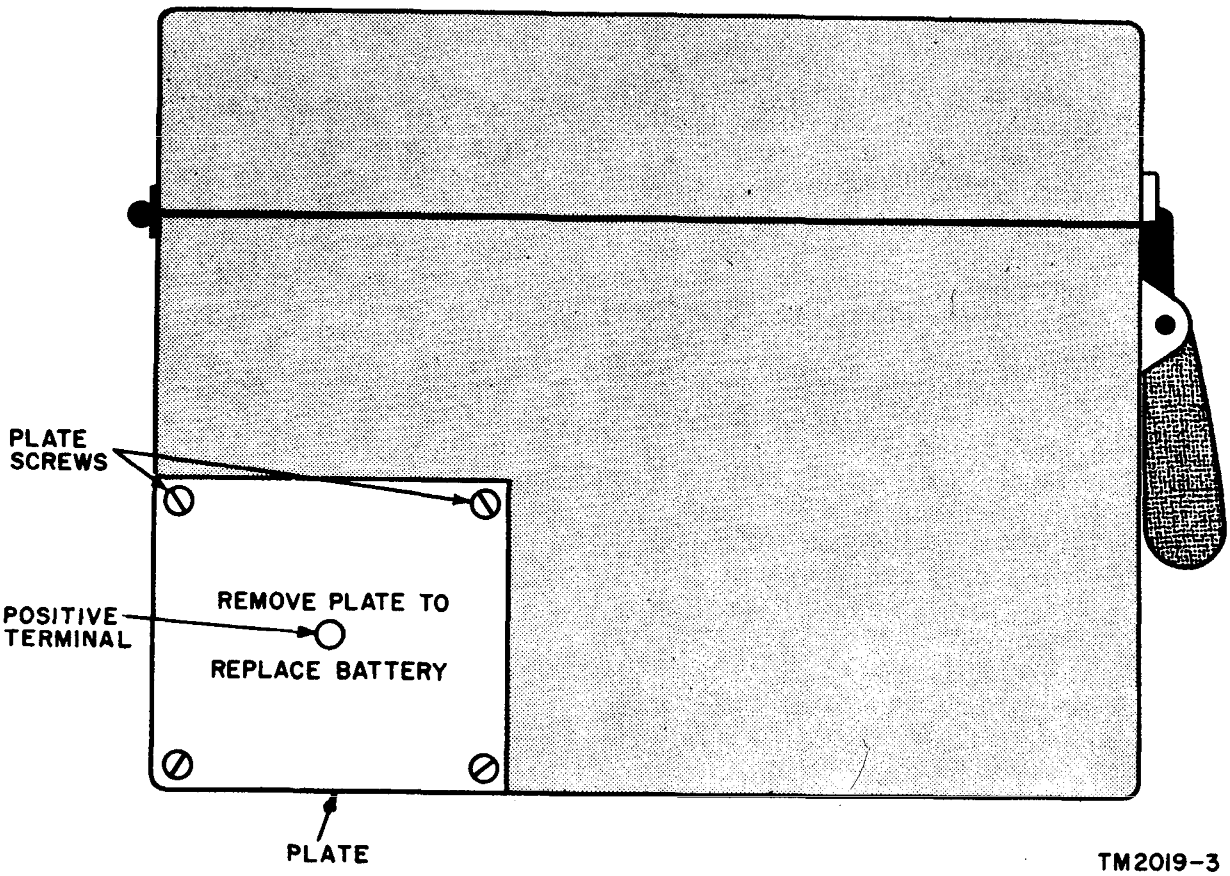

Figure 4. Test set, side view.

in the test set. Do not use an external voltage below 22.5 volts unless no other source of dc is available. Use of an external voltage below 22.5 volts results in decreased sensitivity of the test set. Connect the external voltage as follows:

a. If the external voltage is 45 volts or less, connect the voltage to the BA- and BA+ binding posts. When making the connections, observe the polarity as indicated on the test set panel.

b. If the external voltage is above 45 volts, connect a variable resistor (0 to 6,500 ohms, .5 watt) in series with the voltage before connecting power to the test set. Adjust the resistor to add a resistance of 40 ohms for each volt in excess of 45 volts. The external voltage must not exceed 200 volts.

13. Identification of Faults

a. Grounded Wire.

(1) Adjust the galvanometers (par. 10a).

(2) Set the GA switch to RVM (fig. 3).

(3) Set the RES-VAR–MUR switch to VAR.

(4) Set the MULTIPLY BY dial to M 1000.

(5) Connect the ground binding post to the cable sheath or steel braid (spiral-four). If the cable is rubber-covered, connect the binding post to a good ground.

(6) Press the GA SENS 1 switch and touch each of the wires in the cable (one at a time) to line binding post X1. The galvanometers pointer will deflect strongly when the grounded wire contacts line binding post X1 and will show no deflection with ungrounded wires. High resistance grounds up to 1 megohm can be detected. The pointer of the galvanometer deflects one scale division for

1 volt through 1 megohm. When using the 4½-volt internal battery, one megohm of resistance will cause the pointer to deflect 4½ scale divisions.

b. Shorts and Crosses. Wires in cable are commonly arranged in pairs (A, fig. 5). An electrical path between two wires of the same pair is commonly called a short. An electrical path between two wires of adjacent pairs is commonly called a cross (C, fig. 5). Test for a short or a cross as follows:

(1) Prepare the test set (a(1)-(4) above).

(2) Disconnect all equipment from the far end of the cable.

(3) Connect one of the wires to be tested to the ground binding post and press the GA SENS 1 switch. Touch each of the other wires in the cable to line binding post X1. The galvanometer will deflect strongly when the other faulty wire contacts line binding post and will show no deflection with wires not shorted or crossed.

c. Open Conductor.

(1) Perform a(1) through (5) above.

(2) If the wires to be tested are in lead-covered cable, connect the far end of the wires in the cable to the cable sheath. If the cable is not lead-covered, connect the far end of the wires to a good ground.

(3) Press GA SENS 1 switch and touch each of the wires at the near end (one at a time) to line binding post X1. The galvanometers will deflect for all wires except any that are open.

14. Measurement of Loop or Unknown Resistance

Measure the resistance of a loop (two lengths of wire joined at the distant end) or of any electrical component (resistors, transformers, etc.) as follows:

a. Preparation for Test.

(1) Adjust the galvanometers (par. 10a).

(2) Position the test set controls (fig. 3) as follows:

(a) GA switch to RVM.

(b) RES-VAR-MUR switch to RES.

(c) Make as close an estimate as possible of the resistance to be measured and set the MULTIPLY BY dial as indicated in the following chart:

Estimated resistance (ohms)	MULTIPLY BY dial setting
Below 10	1/1000
10 to 100	1/100
100 to 1000	1/10
1000 to 10,000	1/1
10,000 to 100,000	10[a]/1
100,000 to 1,011,000	100[a]/1

[a] To obtain more sensitive measurements (greater pointer deflections) when measuring resistances above 10,000 ohms, use an external 22½- or 45-volt battery (Battery BA-58) or equal.

(3) Make the following connections:

(a) If the resistance of a loop is to be measured, disconnect all equipment from the near end of the loop and connect one wire of the loop to line binding post X1 and the other wire to line binding post X2 (A, fig. 5). Be sure that the wires connected to the test set are clean and are firmly secured to the binding posts. Have all equipment disconnected from the far end of the loop and a short placed across the circuit at that end.

(b) If the resistance of an electrical component is to be measured, connect the component across line binding posts X1 and X2.

b. Balancing the Bridge.

(1) Position the thousands, hundreds, tens, and units decade dials (fig. 3) to settings that total the estimated

resistance to be measured divided by the setting of the MULTIPLY BY dial.

Example: If the estimated resistance to be measured is 500 ohms, the setting of the MULTIPLY BY dial must be 1/10 (chart in *a* above) ; therefore the positions of the decade dials must total 5,000.

$$\frac{\text{Estimated resistance to be measured}}{\text{Setting of MULTIPLY BY dial}} = \frac{500}{\frac{1}{10}} = 5{,}000$$

(2) Press the GA SENS .01 switch and note the direction of movement of the galvanometer pointer. If it moves to the right, increase the resistance total of the decade dials until it does not move from zero when the GA SENS .01 switch is pressed. If the pointer moves to the left, decrease the resistance total of the decade dials. Repeat the above procedure, using the GA SENS .1 and then the GA SENS 1 Switches. The test procedure is complete when the GA SENS 1 switch is pressed and the pointer does not move in either direction. Under these conditions, the bridge circuit in the test set is said to be balanced.

c. Resistance Determination. The unknown resistance is equal to the sum of the decade dial settings multiplied by the setting of the MULTIPLY BY dial.

Example: If the bridge is balanced when the sum of the decade dial settings is 5,137 and the MULTIPLY BY dial is set at 1/10, the resistance connected across the line binding posts is 5,137 x 1/10 or 513.7 ohms (decimal point moved one place to left). If the MULTIPLY BY dial is set at 1/100, move the decimal point two places to the left (51.37 ohms) ; for 1/1000, move the decimal point three places to the left (5.137 ohms). For 10/1, add one zero to the reading (51,370 ohms) and for 100/1, add two zeros (513,700 ohms).

15. Simple Loop Test for Locating Short

A simple method of locating a short is to determine the resistance of the short, subtract the resistance of the short from resistance measurements from each end of the shorted circuit, and use the resulting resistance value and the known resistance per mile or feet per ohm of the type of wire in the faulty circuit to compute the resistance from each end to the fault. When a fault has been identified as a short, have all equipment disconnected from both ends of the circuit and proceed as follows:

a. Determination of Loop Length (Test 1, fig. 5). If the length (distance from test point to far end) of the faulty loop is not known, compute it as follows:

(1) Measure the loop resistance of a good pair in the cable (par. 14).

(2) Determine the loop length in miles by dividing the resistance per loop mile (par. 33) into the loop resistance. To compute the loop length in feet, multiply one-half the loop resistance by the number of feet per ohm of the wire.

b. Measurement from Test Point to Short (Test *2,* fig. 5). Connect the shorted pair to line binding posts X1 and X2 and balance the bridge. Record the resistance measurement.

Note. This resistance is equal to the resistance of the short plus the resistance of the shorted circuit from the test point to the fault.

c. Equivalent Measurement from Far End (Test 3, fig. 5). Have a good cable pair connected to the shorted pair at the far end. Disconnect the shorted pair from the test set, connect the good pair to line binding posts X1 and X2, and measure the resistance of this circuit arrangement. Subtract the loop resistance *(a* (1) above) from the test 3 resistance measurement to obtain an equivalent resistance measurement from the far end of the shorted circuit.

Note. This resistance is equal to the resistance of the short Plus the resistance of the shorted circuit from the far end to the fault.

d. Resistance of Short. Subtract the loop resistance *(a* (1) above) from the sum of the resistance measurement from each end of the

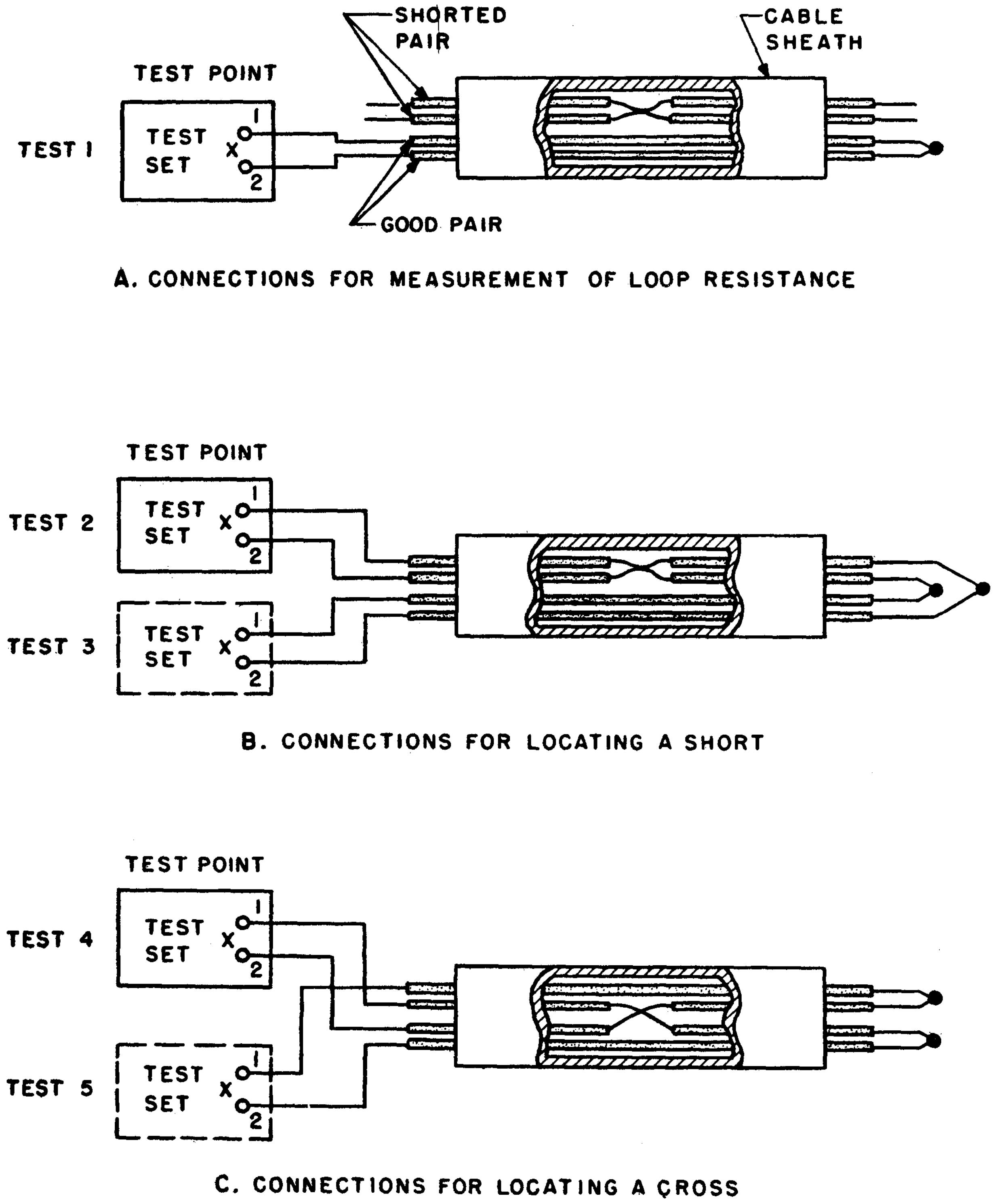

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Figure 5. Loop test connections.

faulty circuit (*b* and *c* above) and divide the result by 2 to obtain the resistance of the short.

e. Resistance of Wires from Each End to Fault.

(1) Subtract the resistance of the short from the test 2 measurement (*b* above) to obtain the combined resistance of both wires from the test point to the short.

(2) Subtract the resistance of the short from the computed equivalent resistance measurement (*c* above) to obtain the combined resistance of both wires from the far end to the short.

f. Distance from Each End to Fault.

(1) *Distance in miles.* Divide the computed resistances of the wire from each end to the short (*e* above) by the resistance per mile of the type of wire in the faulty circuit.

(2) *Distance in feet.* Multiply the computed resistances of the wire from each end to the short by twice the number of feet per ohm of the type wire in the faulty circuit.

g. Test Check. If all tests and computations are correct, the sum of the computed distances from each end of the short (*f* above) will be the same as the computed loop length (*a* above).

h. Example of Procedure. It has been determined (par. *13b*) that a cable pair is shorted. The resistance per loop mile of the wire in the cable is 92.6 ohms. Another good pair in the same cable is available for testing purposes. All equipment is removed from each end of both pairs and the short is located as follows:

(1) Loop resistance measurement of good pair = 463 ohms.

(2) Loop length $= \dfrac{\text{loop resistance}}{\text{resistance per loop mile}}$

$= \text{———} = 5$ miles

(3) Test point to short measurement (Test 2) = 324.1 ohms

(4) Test 3 measurement = 694.5 ohms

(5) Resistance equivalent to measurement from far end of shorted circuit = Test 3 measurement-loop resistance = 694.5 ohms - 463 ohms = 231.5 ohms

(6) Resistance of short =

$$\frac{\text{far end measurement} + \text{near end measurement} - \text{loop resistance}}{2}$$

$$= \frac{231.5 \text{ ohms} + 324.1 \text{ ohms} - 463 \text{ ohms}}{2}$$

=46.3 ohms

(7) Resistance of wires from test point to short
=324.1 ohms-46.3 ohms
=277.8 ohms

(8) Resistance of wires from far end to short
= 231.5 ohms-46.3 ohms
=185.2 ohms

(9) Distance in miles from test point to short

$$= \frac{\text{resistance of wires from test point to short}}{\text{wire resistance per loop mile}}$$

$$= \frac{277.8 \text{ ohms}}{92.6 \text{ ohms}}$$

=3 miles

(10) Distance in miles from far end to short

$$= \frac{\text{resistance of wires from far end to short}}{\text{wire resistance per loop mile}}$$

$$= \frac{185.2 \text{ ohms}}{92.6 \text{ ohms}}$$

=2 miles

(11) Test check:
Computed loop length
= Sum of computed distances from each end of faulty circuit to fault
5 miles = 3 miles+2 miles

16. Simple Loop Test for Locating Cross

A cross between two cable pairs may be located with the same procedure used to locate a short (par. 15). Consider the two good wires as a separate good pair (C, fig. 5), and the two crossed wires as a separate shorted pair. When testing, consider test 4 (fig. 5) as the equivalent of test 2, and test 5 as the equivalent of test 3.

17. Simplified Varley Loop Test for Locating Ground

A simple method of determining the location of a ground when both wires of a pair are of equal resistance is as follows:

a. Remove all equipment from the faulty circuit and join the grounded wire to the good wire at the far end' of the circuit.

b. Prepare the test set for test (par. *10a* and *b).*

c. Position the test set controls as follows:

(1) GA switch to RVM.

(2) RES-VAR-MUR switch to VAR.

(3) MULTIPLY BY dial to 1/1.

d. Make the following connections (A, fig. 6):

(1) Ground binding post to a good ground connection (cable sheath if the fault is in lead-covered cable).

(2) Grounded conductor of the faulty pair to line binding post X2.

(3) Ungrounded conductor of the faulty pair to line binding post X1.

e. Adjust the decade dials until the bridge is balanced (par. *14b).*

f. The distance in miles from the ground to the far end of the circuit is equal to the decade dial reading *(e* above) divided by the loop resistance per mile of the type conductors under test (par. 33). To obtain the distance in feet, multiply one-half the decade dial reading by the number of feet per ohm of the type of wire used.

18. Regular Varley Loop Test for Locating Ground, Short, or Cross

Use the regular Varley loop test to locate a fault in a high-resistance loop when the unbalance (difference in resistance between the faulty and good wires) does not exceed 1 ohm. If the unbalance is greater than 1 ohm, use the three-Varley method (par. 19). The regular Varley method requires the use of one good wire between the test point and the far end of the circuit. Locate the fault as follows:

a. Adjust the galvanometers (par. *10a).*

b. Remove all equipment from both ends of the faulty circuit.

c. If the fault is a ground or cross, measure and record the loop resistance (par. 14). If the fault is a short, connect the good wire to one of the shorted wires at the far end and measure the resistance of the loop.

d. Position the test set controls as follows:

(1) GA switch to RVM.

(2) RES-VAR-MUR switch to VAR.

(3) MULTIPLY BY dial to 1/9.

Note. The 1/9 and 1/4 positions of the MULTIPLY BY dial are provided for locating faults with Varley tests. If the resistance of the circuit under test is so great that it is not possible to balance the bridge with the dial set at 1/9 when performing step *f* below, set it at 1/4. If balance is still not possible, set it at 1/1.

e. Make the following connections:

(1) If the fault is a ground:

(a) Connect the ground binding post to a good ground connection (A, fig. 6) (cable sheath if the fault is in lead-covered cable).

(b) Connect the grounded wire to line binding post X2.

(c) Connect the ungrounded wire to line binding post X1.

(d) Have a short placed across the far end of the grounded circuit.

(2) If the fault is a short or cross:

(a) Connect one of the shorted or crossed wires to the ground binding post (B and C, fig. 6).

(b) Connect the other shorted or crossed wire to line binding post X2.

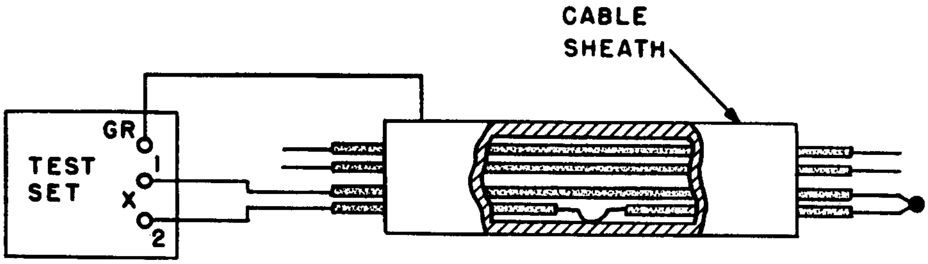
(c) Connect a good wire to line binding post X1.

(d) Have a short placed across the far ends of the wires connected to line binding posts X1 and X2.

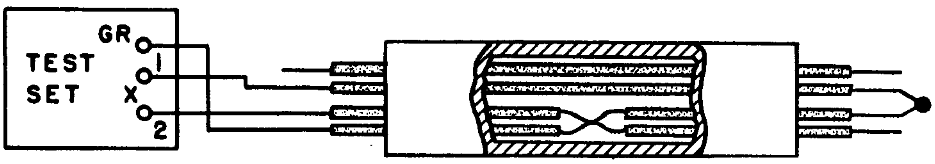
f. Adjust the decade dials to balance the bridge and record the sum of the decade dials.

g. Compute the resistance from the test point to the fault and from the far end to the fault. Use the following formulas:

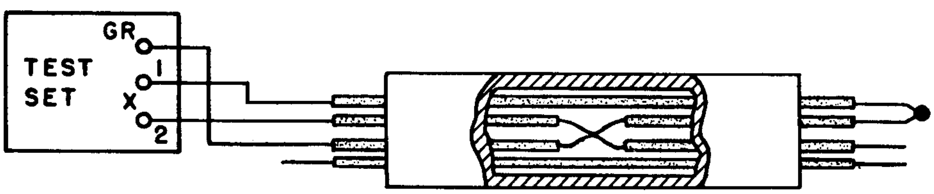
(1) Resistance from test point to fault $= \dfrac{rB - AR}{A + B}$



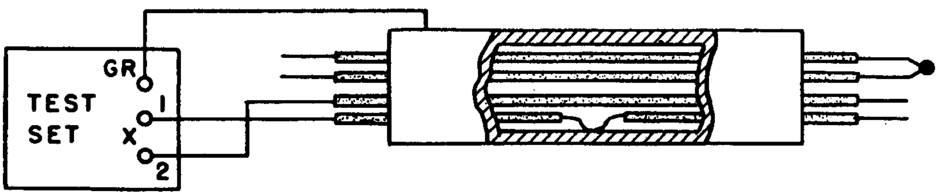
A. CONNECTIONS FOR GROUND LOCATION
(SIMPLIFIED VARLEY, REGULAR VARLEY
AND MURRAY LOOP TESTS)



B. CONNECTIONS FOR SHORT LOCATION
(REGULAR VARLEY AND MURRAY LOOP TESTS)



C. CONNECTIONS FOR CROSS LOCATION
(REGULAR VARLEY AND MURRAY LOOP TESTS)



D. CONNECTIONS FOR CHECK OF REGULAR VARLEY
TEST FOR GROUND

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Figure 6. Simplified and regular Varley and Murray loop test connections.

(2) Resistance from far end to fault $= \frac{A\ (R+R_b) - B_g}{A + B}$

where :

A = numerator of position of MULTIPLY BY dial,

B = denominator of position of MULTIPLY BY dial,

r = loop resistance (*c* above),

R = decade dial reading (*f* above),

R_g = resistance of good wire from test point to far end,

R_b = resistance of faulty wire from test point to far end.

h. Compute the location of the faults as follows :

(1) If the circuit under test consists of the same size wire throughout and includes no loading coils or other resistive elements, use the following formula to locate the fault:

$$\text{Distance from test point to fault} = \frac{\text{Resistance from test point to fault}}{\text{Resistance of full length of faulty conductor}} \times \text{length of faulty conductor}$$

(2) If either the resistance per unit length (feet per ohm) or the number of ohms per mile of the wire in the circuit is known, proceed as follows:

(a) Multiply each of the computed resistances (*g* (1) and (2) above) by the number of feet per ohm of the type of wire in the faulty circuit to obtain the distances in feet from each end of the circuit to the fault.

(b) Divide each of the computed resistances (*g* (1) and (2) above) by one-half the resistance per loop mile of the type of wire in the faulty circuit to obtain the distances in miles from each end of the circuit to the fault.

(3) If the fault is in a composite circuit (a circuit consisting of several lengths of wires of different gage connected in series), locate the fault as instructed in paragraph 30.

(4) If the fault is in a circuit that ineludes loading coils, locate the fault as instructed in paragraph 31.

i. Make a check test as follows:

(1) Reverse the wires connected to line binding posts X1 and X2 of the test set (D, fig. 6).

(2) Adjust the decade dials to balance the bridge and record the sum of the decade dials.

(3) Use the formula below to compute the resistance of the faulty wire from the test point to the fault. If all tests and computations are correct, the computed resistance will be the same as computed in *g* (1) above.

Resistance from test point of fault $= \frac{A\ (R_2 + r)}{A + B}$

Where:

R_2 = decade dial reading of check test

A, B, and *r* areas in *g* above

j. For example: It has been determined (par. 13) that a wire in a cable is grounded. The resistance per loop mile of wire in the cable is 85 ohms. After all equipment is removed from each end of the faulty circuit, the fault is located as follows:

(1) The loop resistance is measured and found to be 5,525 ohms.

(2) The loop length is computed as follows :

$$\text{Loop length} = \frac{\text{loop resistance}}{\text{resistance per loop mile}} = \frac{5{,}525}{85} = 65 \text{ miles}$$

(3) The faulty circuit and a ground are connected to the test set and the test set controls are set for a Varley test (*d* and *e* above). The bridge is balanced with the MULTIPLY BY dial set at 1/4. The decade dial settings total 9,560 ohms.

(4) Resistance from test point to fault

$$= \frac{rB - AR}{A + B}$$

$$= \frac{(5,525 \times 4) - (1 \times 9,560)}{1 + 4}$$

$$= 2,508 \text{ ohms}$$

where:

A = numerator of position of MULTIPLY BY dial

B = denominator of position of MULTIPLY BY dial

r = loop resistance ((1) above)

R = Decade dial reading

(5) Resistance from far end to fault

$$= \frac{A (R + R_b - BR_g}{A + B}$$

$$= \frac{1 (9,560 + 2762.5) - (4 \times 2,762.5)}{1 + 4}$$

$$= 254.5 \text{ ohms}$$

where:

R_b = resistance of faulty wire from test point to far end (1/2 loop resistance (r)).

R_g = resistance of good wire from test point to far end (1/2 loop resistance (r)).

A, B, r, and R are as in (4) above.

(6) Distance in miles from test point to fault

$$= \frac{\text{resistance from test point to faut}}{\frac{1}{2} \times \text{resistance per loop mile}}$$

$$= \frac{2508}{\frac{1}{2} \times 85}$$

$$= 59.01 \text{ miles}$$

(7) Distance in miles from far end to fault

$$\frac{\text{resistance from far end to fault}}{\frac{1}{2} \times \text{resistance per loop mile}}$$

$$= \frac{254.5}{42.5}$$

$$= 5.99 \text{ miles}$$

k. A check of the above tests and computations is made as follows:

(1) The wires connected to Xl and X2 (B, fig. 6) are reversed,

(2) The decade dials are adjusted to balance the bridge and the sum of the decade dials is found to be 7,015 ohms.

(3) The resistance from the test point to the fault It is computed as follows:

Resistance from test point to fault

$$= \frac{A (R_2 + r')}{A + B}$$

$$= \frac{1 (7,015 + 5,525)}{1 + 4}$$

=2, 508 ohms (same as *j(4)* above)

where:

R_2 = check test decade dial reading

A, B, and r as in *j(4)* above

19. Three-Varley Method for Locating Ground, Short, or Cross

The three-Varley method is the most commonly used met hod of locating faults in high-resistance circuits. This method requires the use of two good conductors which may be of different gage and length than the faulty wire. The fault location procedure consists of three tests called Varley 1, Varley 2, and Varley 3, and of computations using the results of these tests. Use this method to locate a ground, short, or cross as follows:

a. Adjust the galvanometer (par. *10a).*

b. Remove all equipment from both ends of the faulty circuit and from both ends of a good spare pair of wires. If a good spare pair is not available, a good wire from each of two different pairs can be used.

c. Position the test set controls as follows:

(1) GA switch to RVM.

(2) RES-VAR-MUR switch to VAR.

(3) MULTIPLY BY dial to 1/9. (See note, par. *18d* (3).)

Note, The MULTIPLY BY dial and RES-VAR-MUR switch must remain at the same settings for each of the three Varley tests.

d. Perform the Varley 1 test as follows (A, fig. 7) :

(1) If the fault is a ground, connect the

near end (end closest to the test set) of the grounded wire to line binding post X2. If the fault is a short or cross, connect one of the shorted or crossed wires to line binding post X2.

(2) Have the other end of the faulty wire connected to two good wires at the far end of the circuit.

(3) Connect one of the good wires to line binding post X1 and the other good wire to the ground binding post.

(4) Balance the bridge and record the sum of the decade dial settings as reading R_1.

e. Perform the Varley 2 test; use the same equipment connections *(d* above) except as follows :

(1) Disconnect the good wire from the ground binding post.

(2) If fault is a ground, connect the ground binding post to a good ground (cable sheath, if the fault is in lead-covered cable (B, fig. 7)).

(3) If the fault is a short or cross, connect one of the two faulty wires to the ground binding post (C and D, fig. 7).

Note. The other faulty wire is connected to line binding post X2 *(d(1)* above).

(4) Balance the bridge and record the sum of the decade dial settings as reading R_2.

f. Perform the Varley 3 test; use the same equipment connections as for the Varley 2 test except as follows:

(1) Disconnect the wire (ground) from the ground binding post.

(2) Connect a strap from the ground binding post to line binding post X2 (E, fig. 7).

(3) Balance the bridge and record the sum of the decade dial settings as reading R_3.

g. If the faulty wire includes no loading coils and is of the same gage throughout, use either of the following two methods to locate the fault:

(1) Use the direct computation method as follows:

Distance from test point to fault

$$= \frac{R_3 - R_2}{R_3 - R_1} \times \text{length of faulty wire}$$

Distance from far end to fault

$$\frac{R_2 - R_1}{R_3 - R_1} \times \text{length of faulty wire}$$

where:

R_1 = Varley 1 test reading
R_2 = Varley 2 test reading
R_3 = Varley 3 test reading

(2) Use the resistance-distance method as follows:

(a) Resistance from test point to fault

$$= \frac{A}{A + B} \times (R_3 - R_2)$$

(b) Resistance from far end to fault

$$= \frac{A}{A + B} \times (R_2 - R_1)$$

(c) Resistance of full length of faulty wire

$$= \frac{A}{A + B} \times (R_3 - R_1)$$

where:

A = numerator (upper number) of position of MULTIPLY BY dial
B = denominator (lower number) of position of MULTIPLY BY dial
R_1, R_2 and R_3 areas in *g(1)* above

(d) To obtain the distance in feet from each end of the circuit to the fault, multiply each of the computed resistances (*(a)* and *(b)* above) by the number of feet per ohm of the type of wire in the faulty circuit.

(e) To obtain the distance in miles from each end of the circuit to the fault, divide each of the computer resistances by one-half the resistance per loop mile of the type of wire in the faulty circuit.

h. If the faulty conductor either is loaded, or is not of the same gage throughout:

(1) Compute the resistance from the fault

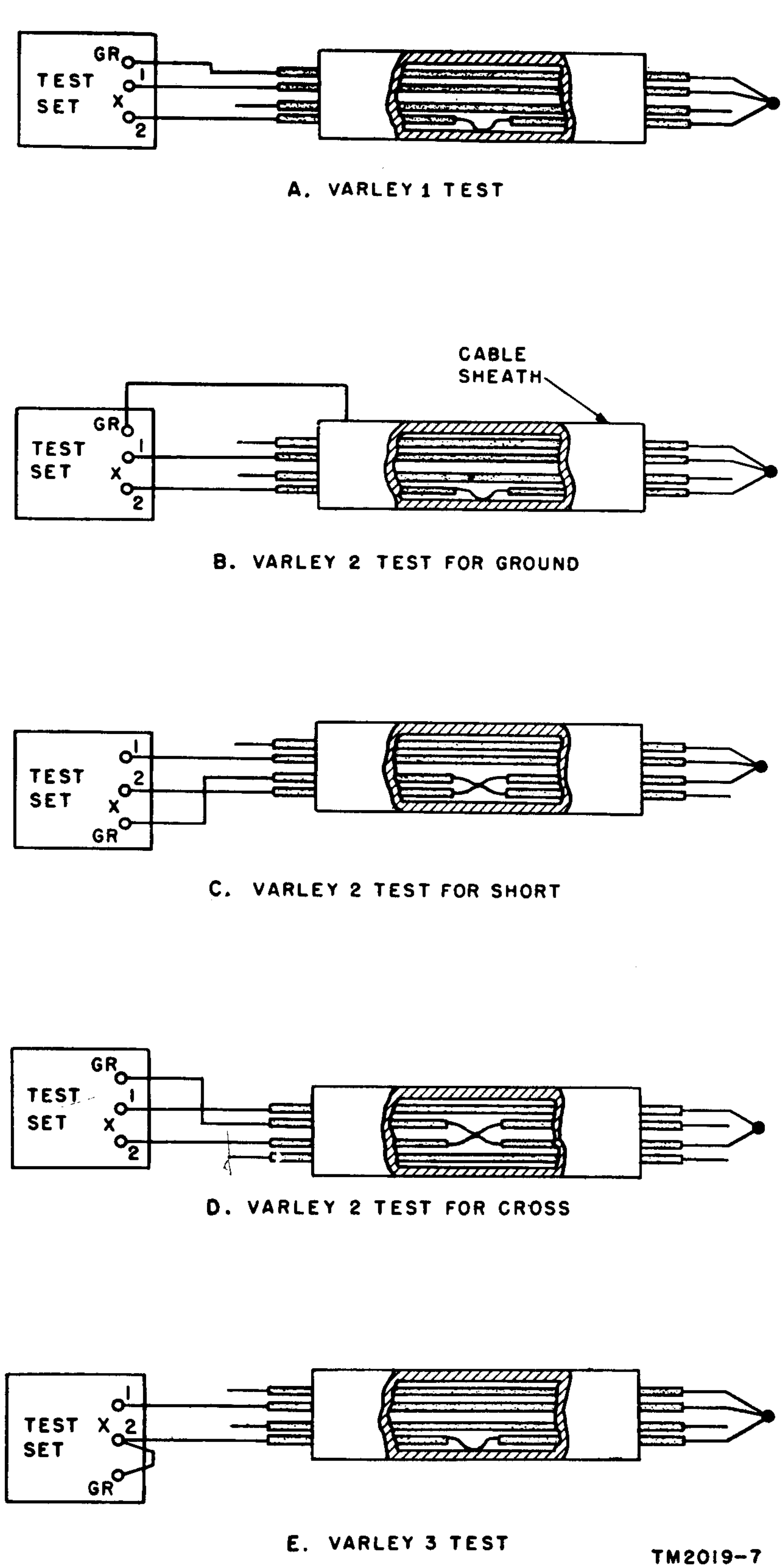


Figure 7. Three-Varley test connections.

to each end of the circuit (*g* (2) *(a)* and *(b)* above).

(2) Locate the fault as instructed in paragraphs 30 or 31.

i. For example: A wire in a rubber-covered cable is grounded. The only good wires available for use in locating the ground are the wires of a field-wire circuit terminating at the same points as the cable. The cable is 12 miles long and the resistance of each wire in the cable is 42.9 ohms per mile. All equipment is disconnected from each end of the grounded wire in the cable and from the good field-wire circuit.

(1) The Varley 1, Varley 2, and Varley 3 tests (*d, e,* and *f* above) are performed. The following readings are obtained with the MULTIPLY BY dial set at 1/4:

(a) Varley 1 test reading (R_1) is 1,544.4 ohms.

(b) Varley 2 test reading (R_2) is 2,402.4 ohms.

(c) Varley 3 test reading (R_3) is 4,118.4 ohms.

(2) The distance from the fault to each end of the circuit, determined by the direct computation method *(g(1)* above) is computed as follows:

(a) Distance from test point to fault

$$= \frac{R_3 - R_2}{R_3 - R_1} \times \text{length of faulty wire}$$

$$= \frac{4{,}118.4 - 2{,}402.4}{4{,}118.4 - 1{,}544.4} \times 12$$

$$= 8 \text{ miles}$$

(b) Distance from far end to fault

$$= \frac{R_2 - R_1}{R_3 - R_1} \times \text{length of faulty wire}$$

$$= \frac{2{,}402.4 - 1{,}544.4}{4{,}118.4 - 1{,}544.4} \times 12$$

$$= 4 \text{ miles}$$

(3) The distance from the fault to each end of the circuit, determined by the resistance-distance method *(g(2)* above) is computed as follows:

(a) Resistance from test point to fault

$$= \frac{A}{A + B} \times (R_3 - R_2)$$

$$= \frac{1}{1 + 4} \times 4{,}118.4 - 2{,}402.4$$

$$= 343.2 \text{ ohms}$$

(b) Resistance from far end to fault

$$= \frac{A}{A + B} \times (R_2 - R_1)$$

$$= \frac{1}{1 + 4} \times 2{,}402.4 - 1{,}544.4$$

$$= 171.6 \text{ ohms}$$

(c) Resistance of full length of faulty wire

$$= \frac{A}{A + B} \times (R_3 - R_1)$$

$$= \frac{1}{1 + 4} \times 4{,}118.4 - 1{,}544.4$$

$$= 514.8 \text{ ohms}$$

(d) Distance in miles from test point to fault

$$= \frac{\text{computed resistance from test point to fault}}{\text{wire resistance per mile}}$$

$$= \frac{343.2}{42.9}$$

$$= 8 \text{ miles}$$

(e) Distance in miles from far end to fault

$$= \frac{\text{computed resistance from far end to fault}}{\text{wire resistance per mile}}$$

$$= \frac{171.6}{42.9}$$

$$= 4 \text{ miles}$$

20. Murray Loop Test for Locating Ground, Short, or Cross

Use the Murray loop test to locate a ground, short, or cross in a low-resistance loop when the unbalance (resistance difference between the faulty and good wires) is less than 1 ohm. If the only good wire available is of a different size or length, use the modified Murray loop test (par. 21) to locate the fault. The Murray loop test requires the use of a good wire in addition to the grounded, shorted, or crossed wires. Remove all equipment from both ends of the faulty circuit and locate the fault as follows:

a. Adjust the galvanometer (par. *10a*).

b. Position the test set controls as follows:

(1) GA switch to RVM.

(2) RES-VAR-MUR switch to MUR.

(3) MULTIPLY BY dial to M 1000.

Note. MULTIPLY BY dial positions M 1000, M 100, and M 10 are provided for Murray loop tests. It it is not possible to balance the bridge with the dial set at M 1000 when performing a Murray loop test, set it at M 100. If balance is still not possible, set it at M 10.

c. Make the following connections:

(1) If the fault is a ground (A, fig. 6):

(a) Connect the grounded wire to line binding post X2.

(b) Connect the good wire to line binding post X1.

(c) Connect the ground binding post to a good ground connection (cable sheath, if fault is in lead-covered cable).

(2) If the fault is a short or cross.

(a) Connect one of the shorted or crossed wires to line binding post X2.

(b) Connect the other shorted or crossed wire to the ground binding post,

(c) Connect a good wire to line binding post X1.

(3) Have a short placed across the far ends of the wires connected to line binding posts X1 and X2.

d. Balance the bridge and record the decade dial reading.

e. If the faulty loop includes no loading coils and is of the same gage throughout, use either of the two methods below to locate the fault:

(1) Use the direct computation method as follows:

$$\text{Distance from test point to fault} = \frac{R \times L}{R + A}$$

where:

A = setting of MULTIPLY BY dial

L = length of loop

R = decade dial reading *(d)* above)

(2) Use the resistance-distance method as follows :

(a) Measure and record the loop resistance of the faulty circuit (par. 14).

(b) Use the following formula to compute the resistance from the test point to the fault:

$$\text{Resistance from test point to fault} = \frac{R \times r}{R + A}$$

where:

r = loop resistance of faulty circuit

A, L, and *R* are as in (1) above

(c) Use the following formula to compute the distance from the test point to the fault:

$$\text{Distance in miles from test point to fault} = \frac{\text{computed resistance from test point to fault}}{\frac{1}{2} \times \text{resistance per loop mile}}$$

(d) To make a check test, reverse the wires connected to line binding posts X1 and X2, balance the bridge, and use the formula below to compute the resistance from the test point to the fault. The computed resistance should be the same value as computed in *(b)* above.

$$\text{Resistance from test point to fault} = \frac{A \times r}{A + R_2}$$

where:

R_2 = decade dial reading for check test

r = loop resistance of faulty circuit

A = setting of MULTIPLY BY dial

f. If the faulty loop is either loaded or not of the same gage throughout:

(1) Compute the resistance from the test point to the fault *(e(2)* above).

(2) Locate the fault as instructed in paragraphs 30 or 31.

g. For example: A wire in a 4-mile length of spiral-four cable is grounded. The resistance of spiral-four cable is 92.6 ohms per loop mile. All equipment is disconnected from each end of the grounded circuit and the ground is located as follows:

(1) The test set controls are set for a Murray loop test *(b* above).

(2) The faulty circuit and a good ground are connected to the test set *(c* above).

(3) The bridge is balanced with the MULTIPLY BY dial set at M 1000. The decade dial settings total 600 ohms.

(4) The fault is located with the direct computation method *(e(1)* above) as follows:

Distance in miles from test point to fault

$$= \frac{R \times L}{R + A} = \frac{600 \times 8}{600 + 1000} = 3 \text{ miles}$$

where:

A = setting of MULTIPLY BY dial total length of loop

R = decade dial reading ((3) above)

(5) The fault is located with the resistance-distance method *(e(2)* above) as follows:

(a) The loop resistance is measured and found to be 370.4 ohms.

(b) Resistance from test point to fault

$$= \frac{R \times r}{R + A} = \frac{600 \times 370.4}{600 + 1000} = 138.9 \text{ ohms}$$

where:

A = setting of MULTIPLY BY dial

r = loop resistance of faulty circuit

R = decade dial reading ((3) above)

(c) Distance in miles from test point to fault

$$= \frac{\text{computed resistance from test point to fault}}{\frac{1}{2} \times \text{resistance per loop mile}}$$

$$= \frac{138.9}{46.3} = 3 \text{ miles}$$

(d) To make the check test, the wires connected to line binding posts X1 and X2 are reversed, and a decade dial reading of 1,666 ohms is obtained when the bridge is balanced. The resistance from the test point to the fault is computed as follows:

Resistance from test point to fault

$$= \frac{A \times r}{A + R_2} = \frac{1000 \times 370.4}{1000 + 1{,}666} = 138.9 \text{ ohms}$$

(same as *(b)* above)

where:

A = setting of MULTIPLY BY dial for check test

R_2= decade dial reading of check test

r = loop resistance

21. Modified Murray Loop Test for Locating Ground, Short, or Crass

Use the modified Murray loop test to locate a ground, short, or cross in low-resistance loops when the only good wire available is of a size or length different from the faulty wire. This test requires a test measurement from each end of the faulty circuit. Remove all equipment from both ends of the faulty circuit and locate the fault as follows:

a. If the resistance of the full length of the faulty wire is not known, compute it as follows:

(1) Determine the resistance per loop mile of the type wire at fault.

(2) Multiply the length of the faulty wire by one-half the resistance per loop mile.

b. Make the Murray loop test (par. *20a-c)* and record the result of this first test (Test 1) as R_1.

c. Repeat the Murray loop test from the far end of the circuit and record the result of this test (Test 2) as R_2. Be certain that the good wire is connected to line binding post X1, and that the MULTIPLY BY dial is at the same setting as in paragraph *20e*.

d. Compute the location of the fault as follows:

(1) Resistance from test 1 test point to fault

$$= \frac{R_1 (A + R_2) R_b}{R_2 (A + R_1) + R_1 (A + R_2)}$$

where:

A = setting of MULTIPLY BY dial
R_1 = test 1 decade dial reading
R_2 = test 2 decade dial reading
R_b = resistance of faulty conductor

(2) Distance in miles from test 1 test point to fault

$$= \frac{\text{resistance from test 1 test point to fault}}{\text{resistance per mile of faulty wire}}$$

e. For example: It has been determined that one pair in a 3-mile section of spiral-four cable is shorted. The only good wire available for test is a length of field wire terminating at the same terminal points as the spiral-four cable. The resistance of spiral-four cable is 92.6 ohms per loop mile. All equipment is disconnected from each end of the shorted circuit, and the short is located as follows:

(1) The test set controls are positioned for a Murray loop test (par. *20b*).
(2) The shorted and good wires are connected to the test set (par. *20c* (2) and (3)).
(3) The bridge is balanced with the MULTIPLY BY dial set at M 1000. The decade dial setting for this test (test 1) totals 145.6 ohms.
(4) Steps (1), (2), and (3) are repeated at the far end of the faulty circuit with the MULTIPLY BY dial setting unchanged and the far end of the good wire connected to line binding post X1. The decade dial setting for this test (test 2) totals 216.5 ohms.
(5) Resistance of faulty wire from test 1 test point to fault

$$= \frac{R_1 (A + R_2) R_b}{R_2 (A + R_1) + R_1 (A + R_2)}$$

$$= \frac{145.6\ (1{,}000 + 216.5)\ 138.9}{216.5\ (1{,}000 + 145.6) + 145.6\ (1{,}000 + 216.5)}$$

$$= 57.8 \text{ ohms}$$

where:

A = setting of MULTIPLY BY dial (both tests)
R_1 = test 1 decade dial reading
R_2 = test 2 decade dial reading
R_b = resistance of full length of faulty wire

(6) Distance in miles from test 1 test point to fault

$$= \frac{\text{resistance from test point to fault}}{\frac{1}{2} \times \text{resistance per loop mile of faulty wire}}$$

$$= \frac{57.8}{46.3}$$

$$= 1\text{-}1/4 \text{ miles}$$

22. Hilborn Loop Test for Locating Ground, Short, or Cross

This test is useful for locating faults in short sections of cable. It requires the use of two good wires in addition to the grounded, shorted, or crossed wires. The resistance of one of the two good wires must be known. Remove all equipment from both ends of the faulty circuit and locate the fault as follows:

a. Adjust the galvanometers (par. *10a*).

b. Position the test set controls as follows:

(1) GA switch to HIL.
(2) RES-VAR-MUR switch to MUR.
(3) MULTIPLY BY dial to M 1000.

Note. Use position M 100 if bridge balance is not possible when at M 1000.

c. Make the following connections:

(1) If the fault is a ground:
(a) Connect a good wire of known resistance to line binding post X1.
(b) Connect the second good wire to the GA1 binding post.
(c) Connect the grounded wire to line binding post X2.
(d) Connect the ground binding post to the cable sheath.
(e) Have someone at the far end of

the cable short the wires connected to binding posts X1, X2, and GA1.

(2) If the fault is a short or cross:

(a) Connect a good wire of known resistance to line binding post X1.

(b) Connect the second good wire to the GA1 binding post.

(c) Connect one of the shorted or crossed wires to line binding post X2.

(d) Connect the other shorted or grounded wire to the ground binding post.

(e) Have someone at the far end of the cable short the wires connected to binding posts X1, X2, and GA1.

d. Balance the bridge and record the decade dial reading.

e. Use the following formula to compute the resistance of the faulty wire from the fault to the far end of the cable:

$$\text{Resistance from fault to far end} = \frac{A + R_g}{A + R_g + R} \times R_b$$

where:

A = setting of MULTIPLY BY dial
R = decade dial reading
R_g = resistance of good wire
R_b = resistance of faulty wire

f. To determine the distance in feet from the fault to the far end of the cable, multiply the resistance from fault to far end by the number of feet per ohm of the faulty wire.

g. To make a check test, have steps *a* through *f* above performed at the far end of the circuit. Be sure the same wires are used and each wire is connected to the same binding post as in the first test. The sum of the computed resistances must equal the known resistance of the full length of the faulty wire, and the sum of the computed distances must equal the known full length of the faulty wire.

h. For example: It has been determined that a wire in a ¼-mile section of lead-covered cable is grounded. A good pair of wires in the same cable is available for use in locating the ground. The resistance of each wire in the cable is 22 ohms (60 feet per ohm). All equipment is removed from both ends of the faulty circuit and the ground is located as follows:

(1) The test set controls are set for the Hilborn test (*b* above).

(2) The test set is connected for a ground location test (*c(1)* above).

(3) The bridge is balanced with the MULTIPLY BY dial set at M 1000. The decade dial setting totals 477 ohms.

(4) The formula (*e* above) is used to compute the resistance of the faulty wire from the fault to the far end. The computed resistance is 15 ohms. The computed distance from the far end to the fault is 900 feet (15 ohms multiplied by 60 feet per ohm).

(5) A check test (*g* above) is made. The decade dial setting for the check test is 2,190 ohms. The formula (*e* above) is used to determine the resistance of the faulty wire from the first test point to the fault. The resistance is computed to be 7 ohms. The distance from the first test point to the fault is computed to be 420 feet (7 ohms multiplied by 60 feet per ohm).

23. Capacitance Tests for Locating Open in Single Pair

Two capacitance test methods may be used to locate an open in a wire when another good wire of the same length and gage (preferably the mate of the faulty wire) is available for testing purposes. The simplified method (*a* below) requires only one test reading, the use of a TS-190/U or similar telephone receiver, and a TS-140/U or similar source of 500 cycle test tone. The second method is more complex. It requires two readings and the use of an external capacitor in addition to a telephone receiver, and a source of test signals.

a. Simplified Method. This method makes a comparison of the capacitance between the good wire and ground and the capacitance between a portion of the faulty wire (test set to fault) and ground. Have all equipment disconnected from both ends of both wires and locate the open as follows:

(1) Position the test set controls as follows:

(a) GA switch to RVM.

(b) BA switch to EXT.

(c) RES-VAR-MUR switch to MUR.
(d) MULTIPLY BY dial to M 1000.

(2) Make the following connections:

(a) Near end of the faulty wire to line binding post X1.

(b) Near end of the good wire to line binding post X2.

(c) Ground binding post to the cable sheath if the faulty pair is in lead-covered cable. If the fault is in rubber-covered cable, bunch together all wires except those connected to line binding posts X1 and X2 and connect the bunch to the ground binding post.

(d) BA- and BA+ binding posts to output terminals of TS-420/U or equivalent test oscillator. Turn on the source of test oscillator.

(e) TS-190/U or equivalent telephone receiver to the GA1 and GA2 binding posts.

(3) Remove the galvanometers screw (fig. 3).

(4) Have a short placed across the far end of the wires connected to X1 and X2 (faulty and good wires).

(5) Depress the GA SENS 1 switch and adjust the decade dials while listening to the receiver until either silence, or a minimum tone is heard. Record the reading of the decade dials. If it is not possible to determine the exact setting at which the bridge is balanced, proceed as follows:

(a) Determine as nearly as possible the setting of the decade dials at which minimum tone is heard.

(b) If a movement of the units dial does not make any noticeable change in the tone, set it at 5 and move the tens dial first up one division and then down one division from the original setting. If a weaker tone is heard when the tens dial is moved to the lower position, move the units dial to 4 (if stronger, move it to 6) and repeat the above movement of the tens dial. Continue adjusting the units dial and checking with the tens dial until no change in tone is heard when the tens dial is moved up one division and then down one division from the original setting. Use the same procedure with the hundreds dial to position the tens dial if movement of the tens dial does not make any noticeable change in the tone.

(6) Use the following formula to compute the location of the fault:

$$\text{Distance in feet from test point to fault} = \frac{2RL}{A + R}$$

where:

A = MULTIPLY BY dial setting (M 1000)

L = length of wire from test point to strap

R = decade dial reading

Example: One wire of a pair in a 600-foot section of cable is open. The pair is tested ((1)-(5) above) and the decade dial reading is 500 ohms. The location of the open is computed to be 400 feet from the test set as follows:

$$\text{Distance in feet from test point to fault} = \frac{2RL}{A + R} = \frac{2 \times 500 \times 600}{1{,}000 + 500} = 400 \text{ ft}$$

b. External Capacitor Method. This method of locating an open requires two tests. The first test is a comparison of the capacitance of a known capacitor with the capacitance between the good wire and the length of the faulty wire from the test set to the fault. The second test is a comparison of the capacitance of the known capacitor with the capacitance between two wires of known length (usually the same pair as used for the first test). Have all equipment disconnected from both ends of the faulty pair and locate the fault as follows:

(1) Position the test set controls as follows:

(a) GA switch to RVM.
(b) BA switch to EXT.
(c) RES-VAR-MUR switch to MUR.
(d) MULTIPLY BY dial to M 1000.

(2) Make the following connections (A, fig. 8):

(a) Near end of the faulty wire to line binding post X1.

(b) Near end of the good wire to ground.

(c) One output terminal of the test oscillator to the BA- binding post and the other output terminal to ground. Turn on the test oscillator.

(d) One side of the 1- or 2-microfarad capacitor to line binding post X2 and the other side to ground.

(e) Telephone receiver (TS–190/U or equal) to GA1 and GA2 binding posts.

(3) Remove the galvanometer screw (fig. 3).

(4) Have the far end of the faulty wire grounded.

(5) Balance the bridge *(a(5)* above). Record the decade dial reading as R_1.

(6) Disconnect and ground the wires connected to line binding posts X1. Remove the near end of the good wire from ground and connect it to X1. Balance the bridge and record the decade dial reading as R2.

(7) Use the following formula to compute the location of the fault:

$$\text{Distance in feet from test point to fault} = \frac{R_1 \times L}{R_2}$$

where:

R_1 = first resistance reading (*e* above)
R_2 = second resistance reading (*f* above)
L = length of either conductor in feet)

(8) If the open is in a cable more than 2,000 feet long, have the above tests ((1)-(7) above) performed from the far end of the circuit and compute the distance between the far end and the fault. If the test results differ in location of the fault, recheck all tests and computations. If a difference still exists, the fault should be halfway between the two computed locations.

24. Capacitance Test for Locating Open in Quadded Cable

The capacitance test may be used to locate an open in one wire of a pair in quadded cable (including spiral-four) when the other pair of the quad is good and is available for testing purposes. A telephone receiver (TS-190/U or equal) and a source of test tone TS-140/U or equal) also are required. Have all equipment disconnected from both ends of both pair for this test.

a. Position the test set controls as follows:

(1) GA switch to RVM.
(2) BA switch to EXT.
(3) RES-VAR-MUR switch to MUR.
(4) MULTIPLY BY dial to M 1000.
(5) Remove the galvanometers screw (fig. 3).

b. Make the following connections (B, fig. 8).

(1) Near end of the faulty wire to line binding post X2.

(2) Near end of one of the good wires of the spare pair to line binding post X1.

(3) Near end of two remaining wires to one output terminal of the test oscillator, other output terminal to -BA binding post.

(4) Telephone receiver to GA1 and GA2 binding posts.

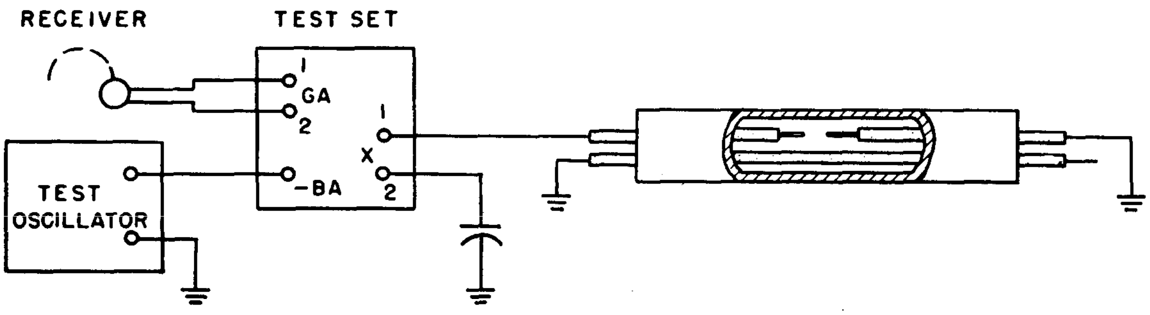
c. Have the distant ends of the wires shorted as follows:

(1) Short distant ends of the wires connected to line binding posts X1 and X2.

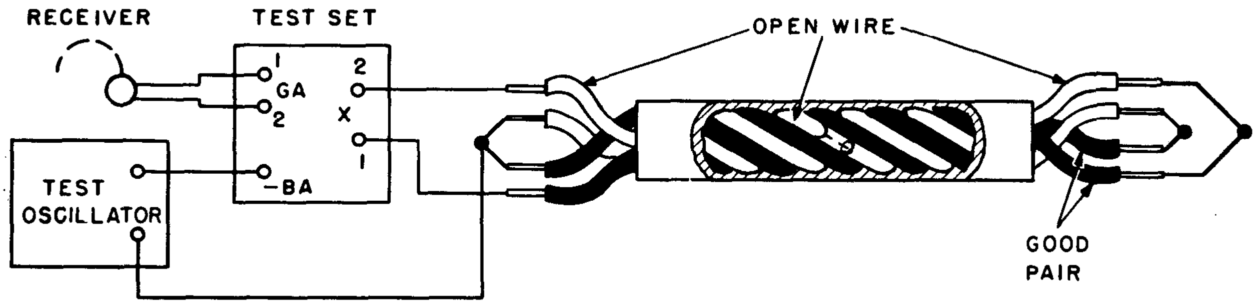
(2) Short distant ends of the wires connected to one side of test tone.

d. Depress GA SENS 1 switch, listen to the receiver, and adjust the decade dials until silence or a minimum tone is heard. Record the reading of the decade dials.

e. Use the following formula to compute the location of the fault:



A. CONNECTIONS FOR LOCATION OF OPEN IN SINGLE PAIR



B. CONNECTIONS FOR LOCATION OF OPEN IN SPIRAL-FOUR CABLE

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Figure 8. Connections for location of opens.

Distance in feet from test point to fault $= \dfrac{2AL}{A + R_1}$

where:

A = position of MULTIPLY BY dial
L = length of cable in feet
R_1 = decade dial reading (*d* above)

f. Make a check test as follows:

(1) Reverse the wires connected to line binding posts X1 and X2.

(2) Depress the GA SENS 1 switch and adjust the decade dials until silence or minimum tone is heard. Record the reading of the decade dials as R_2.

(3) Use the following formula to compute the location of the fault:

Distance in feet from test point to fault $= \dfrac{L(A - R_2)}{A + R_2}$

where:

A = position of MULTIPLY BY dial
L = length of cable in feet
R_2 = decade dial reading ((2) above)

25. Locating Fault in Split Pairs

Split pairs (fig. 9) are normally the result of incorrect splicing. The fault is located by determining in which splice the pairs are split (transposition of one wire from each pair to the other pair). A telephone receiver and a source of test tone are required. Two measurements are taken for this test.

a. Disconnect all equipment from each end of both affected pairs.

b. Position the test set controls as follows:

(1) GA switch to RVM.
(2) BA switch to EXT.
(3) RES-VAR-MUR switch to MUR.
(4) MULTIPLY BY dial to M 1000.

(5) Galvanometer screw (fig. 3) removed.

c. Make the following connections (A, fig. 9):

(1) One output terminal of the test oscillator to -BA binding post; other output terminal to one of the wires not transposed. Turn on the test oscillator.

(2) One of the transposed wires to line binding post X1.

(3) Other wire not transposed to line binding post X2.

(4) Telephone receiver to GA1 and GA2 binding posts.

d. Depress GA SENS 1 switch, listen to the receiver, and adjust the decade dials until either silence or a minimum tone is heard. Record the reading of the decade dials as R_1.

e. Remove the wire connected to line binding post X1 and connect the other transposed wire to this post. Repeat *d* above and record the reading as R_2.

f. Compute the location of the fault as follows:

$$\text{Distance in feet from test point to fault} = \frac{(R_1 - A)\,L}{R_1 + R_2 - 2A}$$

where:

A = setting of MULTIPLY BY dial *(b(4)* above).

L = length of cable in feet (from cable records)

R_1 = decade dial reading (*d* above)

R_2 = decade dial reading (*e* above)

26. Locating Fault in Split Quads

The procedure for locating a split between two quads is the same as for locating a split between two pairs, except that each pair of the two quads is shorted at the testing end (B, fig. 9) and each pair is considered as one wire during the test. Have all equipment disconnected from both ends of all pairs in both quads and follow the procedure described in paragraph 25 to locate the split.

27. Locating Branch Circuit Faults

Location of branch circuit faults includes isolating the fault to a particular branch, and testing the faulty branch to determine the exact location of the fault. Locate a fault in a branch circuit as follows:

a. Have all equipment disconnected from all branches.

b. Determine the type of fault in the circuit (par. 13).

c. Determine the branch at fault as follows:

(1) Have a short placed across the terminals of the farthest branch.

(2) Use the appropriate loop test (par. 18-22) to obtain an approximate location of the fault. The branch at fault is normally the branch closest to the computed distance from either end of the loop under test.

d. Have the short removed from the terminals of the farthest branch and a short placed across the terminals of the faulty branch. Make another loop test to locate the fault in the faulty branch.

e. For example, one side of a field wire circuit (WD-1/TT) that includes four branches (fig. 10) is grounded. The resistance of WD-1/TT is 50 feet per ohm. All equipment is disconnected from all branches and the ground is located as follows:

(1) The branch at fault is determined as follows:

(a) The Murray loop test (par. 21) is selected for location of the fault in this low-resistance circuit. The far terminals of the farthest branch (D) are strapped and the loop is tested.

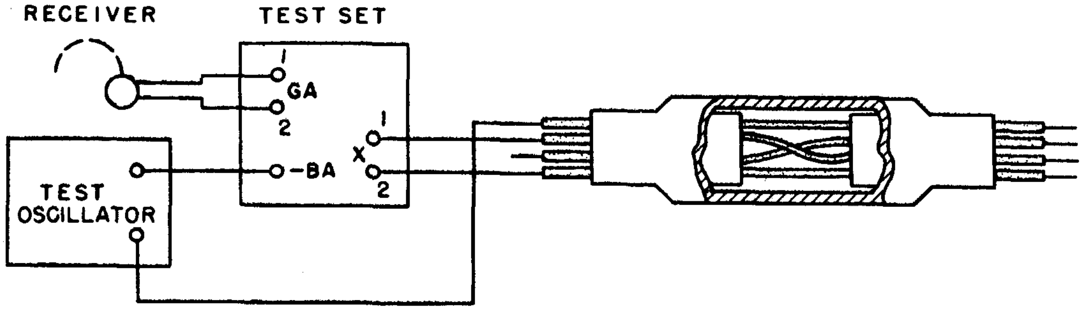
(b) The resistance of the circuit from the test point to the faulty branch is computed to be 20 ohms. A check test is made and the same resistance is computed.

(c) The distance from the test point to the faulty branch is determined to be 1,000 feet (20 ohms multiplied by 50 feet per ohm).

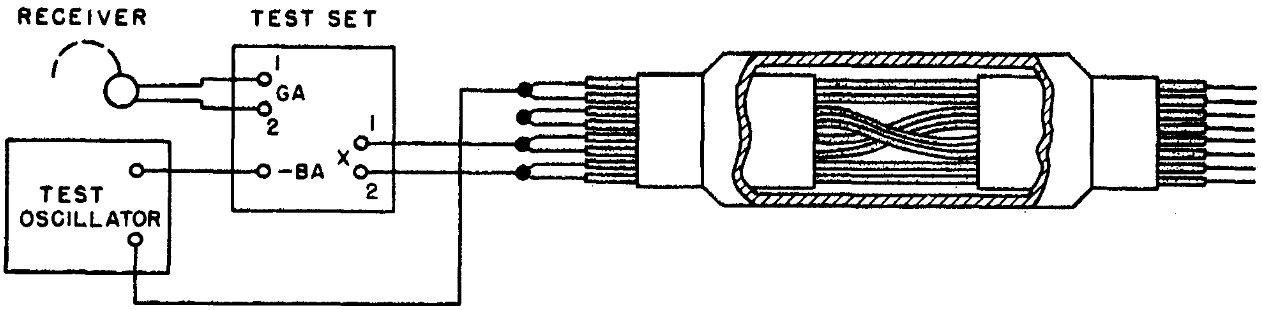
(d) Reference to the circuit diagram identifies branch A as the faulty branch.

(2) The fault in branch A is located as follows:

(a) The strap is removed from branch D and placed across the far terminals of branch A.



A. CONNECTIONS FOR FAULT LOCATION OF SPLIT PAIR



B. CONNECTIONS FOR FAULT LOCATION OF SPLIT QUADS

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Figure 9. Connections for location of fault in split pair and split quads.

The loop is tested with the Murray loop test and the resistance of the circuit from the test point to the fault is computed to be 21 ohms. A check test is made and the same resistance is computed.

(c) The distance from the test point to the fault is computed to be 1,050 feet (21 ohms multiplied by 50 feet per ohm).

(d) Reference to the circuit diagram reveals the fault is 50 feet from the point where branch A is bridged across the main feeder.

28. Compensating for Induced Foreign Voltage

The presence of an induced voltage from another source on communication and power lines may result in incorrect fault location readings or may make balancing the bridge extremely difficult. Two methods of overcoming this problem are the use of a higher test voltage and the use of an auxiliary capacitor and switch,

a. Use of Higher Test Voltage. Use a higher-than-normal test voltage (par. 12) to permit the most accurate measurements possible with this test set when an induced foreign voltage is present on *all* wires connected to the test set.

b. Use of Auxiliary Capacitor and Switch. Use an auxiliary capacitor and a switch to permit reasonably accurate fault location tests when a foreign voltage is present on some, but not all, of the wires connected to the test

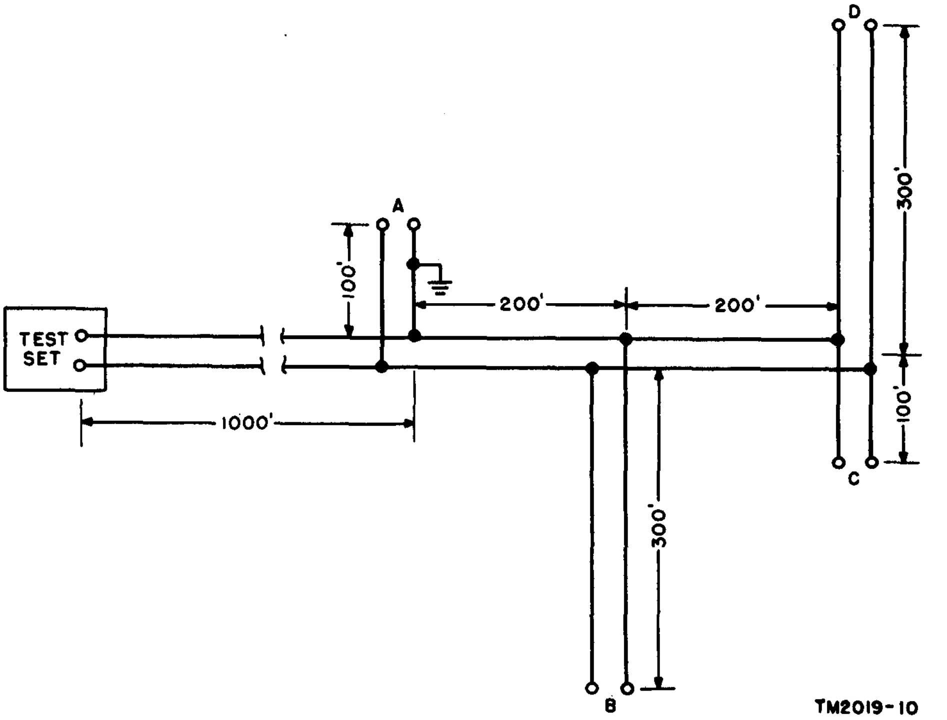

Figure 10. Branch circuit with grounded wire.

set. This condition occurs most frequently when all wires used for the test are not in the same cable. Use an auxiliary capacitor and a switch as follows:

(1) Prepare the test set and make the connections necessary for the desired test (par. 14-21).

(2) Connect a single-pole, double-throw switch and a 12- to 14-microfarad capacitor as shown in A, figure 11 for any of the Varley tests, and in B, figure 11 for any of the Murray tests.

(3) Set the decade dials to as accurate an approximation of the expected resistance reading as possible.

(4) Depress GA SENS .01 switch, move the single-pole, double-throw switch first to position B to charge the auxiliary capacitor, and then to position A to discharge the capacitor through the galvanometers. Adjust the decade dials until the galvanometers needle makes no movement when the switch is moved from position B to position A. Repeat this procedure with the GA SENS .1 switch depressed and then with the GA SENS 1 switch depressed.

(5) Use the decade dial readings to compute the location of the fault in accordance with the instructions for the type of test used.

29. Distance to Fault in Nonloaded Circuit of Uniform Gage Wire

When the resistance from the fault to either or both ends of the circuit has been determined (par. 15-20), and the circuit includes no loading coils and is of the same gage throughout, locate the fault as follows:

a. Distance in Feet. Obtain the distance in feet from one end of the circuit to the fault, in the following steps:

(1) If the average feet per ohm of the wire is not known, divide the total length in feet of the faulty wire by the total resistance of the wire to obtain the number of feet per ohm.

(2) Multiply the computed resistance of the applicable portion of the faulty wire by the number of feet per ohm

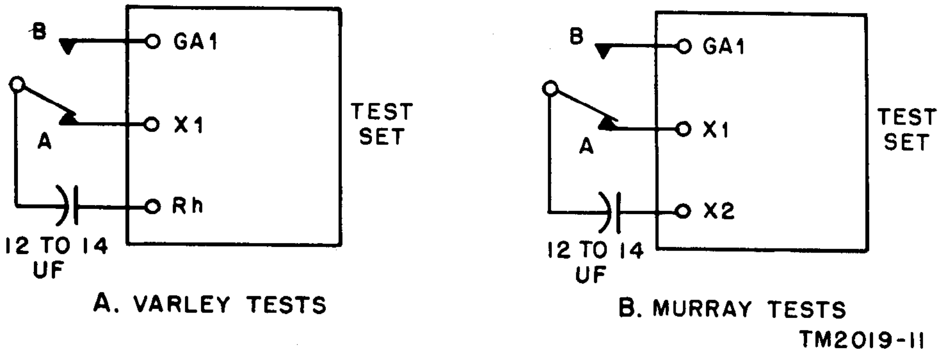

Figure* 11. *Connections for use of capacitor and switch to compensate for foreign voltage during test.

of the wire to obtain the distance in feet to the fault.

b. Distance in Miles. Obtain the distance in miles from one end of the circuit to the fault, in the following steps:

(1) If the average resistance per mile is not known, divide the total resistance of the wire into the total length in miles of the wire to obtain the average resistance per mile.

(2) Divide the average resistance per mile into the computed resistance of the applicable portion of the faulty circuit to obtain the distance to the fault in miles.

c. Example. A 22-gage wire in a cable 6,924 feet long is grounded. The three-Varley test is used and the resistances of the faulty wire are computed to be 89.9 ohms from the test point to the fault, 22.5 ohms from the far end to the fault, and 112.4 ohms total resistance (resistance from test point to far end). The location of the fault is determined as follows:

(1) $\text{Average feet per ohm} = \frac{6{,}924}{112.4} = 61.6 \text{ feet}$

(2) Distance from test point to ground = 61.6 X 22.5 = 1,386 feet

(3) Distance from far end to ground = 61.6 X 98.9 = 5,538 feet

30. Distance to Fault in Circuit with Nonuniform Gage Wire

When a fault is in a circuit consisting of composite conductors (more than one gage of wire connected in series), the resistance is not uniform throughout the circuit and the following procedure must be used to locate the fault:

a. Select one of the gages as a standard, preferably the gage of the longest section of the circuit. If all gage sections are approximately the same length, use the largest gage as the standard.

b. Convert the length of all other sections to equivalent section lengths of the standard gage. To accomplish this, multiply the length of each section by the appropriate conversion factor from the wire gage conversion table (*e(7)* below).

Note. If the conversion factor for the gage of a section length is not available, compute the equivalent length by multiplying the actual length of the section by the resistance per 1,000 feet of the gage wire in the section and dividing the result by the resistance per 1,000 feet of the standard gage.

c. Add all computed equivalent lengths to the length of the standard gage section to obtain the total length of the circuit if it were of standard gage wire throughout.

d. Convert the previously computed resistance of the faulty wire from one end of the circuit to the fault (par. 15-20) to an equivalent length of the standard gage wire by multiplying the resistance to the fault by the proper conversion factor from the conversion table (*e(7)* below). Compare the equivalent length of this portion of the circuit to the equivalent length of the complete circuit, subdivided into sections, and each converted to the equivalent length of standard gage wire. This comparison will indicate the section in which the fault is located and the length of standard gage wire between the fault and the last junction of two sections. To locate the fault, convert this length to an equivalent length of wire of the actual gage in the faulty section by multiplying the length in standard gage by the proper conversion factor from the conversion table.

e. For example, a wire in a 600-foot long cable is grounded (fig. 12). The Murray loop test is used to obtain the resistance of the grounded wire from the test point to the ground. The resistance is computed as 6.25 ohms. The cable is composed of three sections: section 1 is a 300-foot length of cable containing 19-gage wire; section 2 is a 200-foot length of cable containing 22-gage wire; and section 3 is a 100-foot length of cable containing 24-gage wire. The location of the fault is computed as follows:

(1) The 19-gage section is selected as the standard. The number of feet per ohm of 19-gage wire is 124.24 feet.

(2) Section 2 is converted to an equivalent length of 402 feet of 19-gage wire by multiplying the actual length (200 feet) by the proper conversion factor (2.01).

(3) Section 3 is converted to an equivalent length of 322 feet of 19-gage wire by multiplying the actual length (100 feet) by the proper conversion factor (3.22).

(4) The total equivalent length of the three sections is computed to be 1,024 feet (300 ft + 402 ft + 322 feet). The resistance of the full length of the faulty conductor is 8.24 ohms (1,024 feet divided by the number of feet per ohm of 19-gage wire (124.24)).

(5) The equivalent length in 19-gage wire of the wire from the test point to the fault is determined to be 776.5 feet, This length is obtained by multiplying the feet per ohm of 19-gage wire (124.24) by the computed resistance of the faulty wire from the test point to the fault (6.25 ohms). The equivalent distance from the test point to the fault (776.5 feet) exceeds the sum of the equivalent length of sections 1 and 2 (300 feet + 402 feet) by 74.5 feet.

(6) The actual distance from the junction of sections 2 and 3 to the fault in section 3 is determined by converting the equivalent length of 74.5 feet of 19-gage wire to the actual length of the 24-gage wire in the cable. A distance of 23.09 feet is obtained by multiplying 74.5 by a conversion factor of .31.

(7) An actual distance of 523.09 feet from the test point to the fault is obtained by adding the actual lengths of sections 1 and 2 (300 feet + 200 feet) to the distance between the fault and the junction of sections 2 and 3 (23.09 feet).

Wire gage conversion table

Actual gage	Factors to determine equivalent gage							
	10	13	16	19	22	24	26	28
10	1.0	.50	.255	.106	.062	.039	.024	.15
13	2.0	1.0	.510	.252	.125	.078	.049	.080
16	3.92	1.96	1.0	.496	.246	.153	.095	.060
19	7.94	3.97	2.02	1.0	.496	.31	.19	.12
22	16.0	7.99	4.07	2.01	1.0	.624	.389	.244
24	25.06	12.80	6.52	3.22	1.60	1.0	.623	.391
26	41.1	20.6	10.50	5.18	2.57	1.61	1.0	.628
28	65.4	32.7	16.7	8.24	4.09	2.56	1.59	1.0

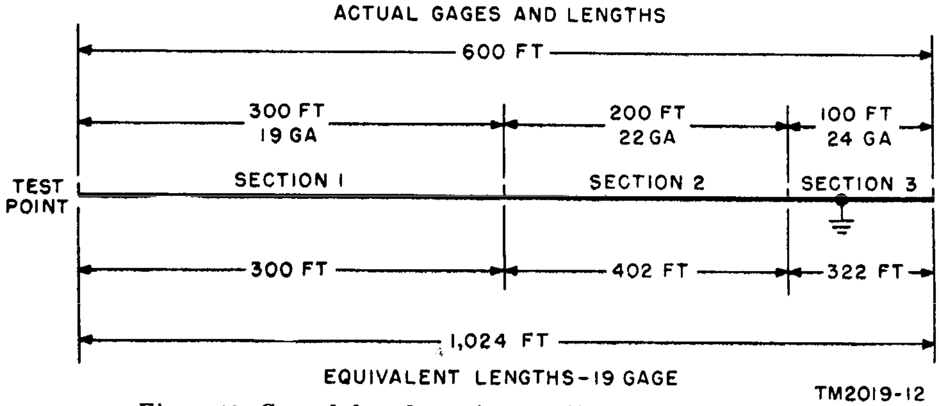

Figure 12. Grounded conductor in nonuniform gauge circuit.

31. Distance to Fault in Circuit with Loading Coils

If a faulty circuit includes loading coils, the location and resistance of the coils must be considered when computing the location of a fault. Determine the location of a fault in a loaded circuit as follows:

a. Computing Average Feet Per Ohm. Subtract the sum of the resistances of the coils and their cable stubs from the total resistance of a wire or circuit to obtain the resistance of the wire only. Divide the total length of the wire by this resistance value to obtain the average feet per ohm.

b. Computing Distance to Fault. Compare the computed resistances of the wire from the fault to the test point and from the fault to the far end to obtain an approximate location of the fault. Refer to the cable diagram to estimate the number of loading coils between one end of the circuit and the fault. Subtract the resistance of the coils and cable studs from the total resistance of this part of the circuit to obtain the resistance of the wire only. Multiply the result by the aver. age feet per ohm of the circuit to determine the location of the fault.

Note. If a fault is near a coil, two computations of the location may be necessary; one under the assumption that the fault is before the coil, and the other under the assumption the fault is beyond the coil. A comparison of the two computed distances with the actual distance to the coil will reveal the correct assumption.

32. Resistance Correction for Temperature Variations

When locating a fault, consideration must be given to the fact that the resistance of wire varies with temperature. The resistance increases as the temperature of the wire rises and decreases with a reduction in temperature. The temperature of underground conductors ranges from 35° F. (Fahrenheit) to 50° F. The temperature of aerial cable and open wire lines follow closely the temperature of the atmosphere, except where the cable or wire is exposed to the direct rays of the sun. Whenever possible, when locating a fault, use the mate of the faulty wire for the loop tests because the two are subject to the same temperatures for their full length. Wire resistance tables normally furnish the resistance of each type of wire at 68° F. Use the following formulas to determine the wire resistance at other temperatures:

a. For temperatures above 68° F.

$$\text{Feet per ohm of wire at higher temperature} = \frac{\text{feet per ohm of wire at 68° F.}}{\left(1-.00218\left[\text{actual temperature of wire}-68\right]\right)}$$

b. For temperatures below 68° F.:

$$\text{Feet per ohm of wire at lower temperature} = \frac{\text{feet per ohm of wire at 68° F.}}{\left(1+.00218\left[68-\text{actual temperature of wire}\right]\right)}$$

c. For example, a 2,000-foot cable of 19-gage wire is underground for the first 300 feet, aerial for the next 1,000 feet, and underground for the final 700 feet to the far end. The temperature of the cable is determined to be 45° F. for the underground sections and 85° for the aerial section. The resistance table indicates that the resistance of 19-gage wire at 68° is 124.24 feet per ohm. The resistance of the full length of a wire in this cable is computed as follows:

(1) Feet per ohm of underground sections (45°F.)

$$= 124.24\ (1+.00218[68-45])$$
$$= 130.34 \text{ feet per ohm}$$

(2) Feet per ohm of aerial section (85° F.)

$$= 124.24\ (1-.00218[85-68])$$
$$= 119.63 \text{ feet per ohm}$$

(3) Resistance of 300-foot underground section

$$= \frac{300}{130.34}$$
$$= 2.302 \text{ ohms}$$

(4) Resistance of 1,000-foot aerial section

$$= \frac{1{,}000}{119.63}$$
$$= 8.434 \text{ ohms}$$

(5) Resistance of 700-foot underground section

$$= \frac{700}{130.34}$$
$$= 5.370 \text{ ohms}$$

Note. A comparison of the resistance of the 1,000-foot aerial section (8.434 ohms) and the resistance of 1,000 feet of the same cable underground (2.302 ohms plus 5.370 ohms = 7.672 ohms) illustrates the effect of temperature on wire resistance.

33. Wire and Cable Resistance Tables

The tables in *a, b,* and *c* below list the resistance per loop mile at 68° F. of the various wire and cable used in military communication systems. Use the procedure described in paragraph 32 to determine the resistances at temperatures other than 68° F. The resistance of 1 mile of a single conductor in the wire and cable listed is equal to one-half the resistance per loop mile. To determine the number of feet per ohm, divide 5,280 ft by one-half the loop mile resistance.

a. Field Wire and Rubber-Covered and Spiral-Four Cable.

Wire or cable	No. of pairs	Dc res per loop mi at 68° F. (ohms)
Field Wire WD–1/TT	1	220
Rubber-covered cable:		
Telephone Cable CX–162/G	5	92 (17.4 per 100 ft)
Spiral-four cable:[a]		
Cable Assembly CX–1065/G (approx. ¼-mi (1280 to 1360-ft) lengths).	2	86.6[b] (21.65 per ¼ -mi.)
Telephone Cable Assembly CX–1606/G (100 ft lengths).	2	86.6 (1.64 per 100 ft)
Telephone Cable Assembly CX–1512/U (12 ft stub).	2	86.6 (.2 per 12 ft)

[a] Issued only as part of cable assemblies.

[b] Resistance without loading. Resistance per loop mile is 92.6 ohms when loaded at ¼-mile intervals with Telephone Loading Coil Assembly CU-260/G (1.5 ohms, 6-milliheavies each coil).

b. Lead-covered Cable.

Cable	No. of pairs	Dc res per loop mi at 88° F. (ohms)
19-gage conductors:		
Cable WC–401	11	92
Cable WC–404	26	92
Cable WC–407	51	92
Cable WC–409	101	92
Cable WC–462	202	92
Cable WC–453	303	92
Cable WC–454	404	92
22-gage conductors:		
Cable WC–411	11	184
Cable WC–414	26	184
Cable WC–417	51	184
Cable WC–419	101	184
Cable WC–421	202	184
Cable WC–425	404	184
Cable WC–429	606	184
Cable WM–12/U	909	184
24-gage conductors:		
Cable WC–447	11	290
Cable WC–449	26	290
Cable WC–450	51	290
Cable WM–13/U	101	290
Cable WM–14/U	202	290
Cable WM–91/U	404	290
Cable WM–92/U	606	290
Cable WM–93/U	909	290
Cable WM–34/U	1212	290

c. Open Wire.

Wire	Material	Gage (AWG)[a]	Dia (in.)	Dc res per loop mi at 68° F. (ohms)
Type numbered wire:				
Wire W-2	Soft copper	14	.080	17
Wire W-145	Galvanized steel	12 (BWG)[b]	.083	76
Wire W-153	Copper coated steel	12	.080	42
Wire WS-9/U	Copper coated steel	6	.162	10.6
Nontype numbered wire:				
Wire, #12 NBS[c]	Copper coated steel	....	.104	24.8
Wire, #10 NBS	Copper coated steel	8	.128	16.6
Wire, #10 NBS	Hard drawn copper	8	.128	6.9
Wire, #8 NBS	Hard drawn copper	6	.162	4.34

[a] American Wire Gage.
[b] Birmingham Wire Gage.
[c] New British Standard.

34. Use of Test Set as Resistance Box

The four resistance decades may be used as a resistance box, adjustable in 1-ohm steps from 0 to 10,110 ohms. Use binding posts Rh and X2 as connection points. When used as a resistance box, the current must be limited to prevent damage to the resistors. The maximum current is determined by the highest decade dial used. The maximum current values are:

a. Units dial used only (tens, hundreds, and thousands dials at zero) .... .5 ampere.

b. Tens dial used (hundreds, and thousands dials at zero)... .16 ampere.

c. Hundreds dial used (thousands dial at zero) .... .05 ampere.

d. Thousands dial used.......... .016 ampere.

CHAPTER 3

ORGANIZATIONAL MAINTENANCE

Section I. ORGANIZATIONAL TOOLS, MATERIALS AND TEST EQUIPMENT

35. Organizational Tools and Maintenance Materials

The following tools and maintenance materials are required for organizational maintenance:

a. Pliers TL-103 (diagonal cutting).

b. Pliers TL-126 (chain nose).

c. Screwdriver TL-459/U.

d. Soldering Iron TL-117.

e. Cleaning cloth.

f. Cleaning Compound (Federal Stock No. 7930-395-9542) .

g. Petrolatum, technical (Federal Stock No. 9150–250-0930, 4-oz. tube).

36. Organizational Test Equipment

The only test equipment required for organizational maintenance is Multimeter ME-77/U or equivalent, such as Multimeter TS-297/U (TM 11-5500) . This equipment is used for making continuity tests and dc voltage tests.

Section II. PREVENTIVE MAINTENANCE AND TROUBLESHOOTING

37. Daily and Weekly Preventive Maintenance

Use DA Form 11-238 (fig. 13) in accordance with the instructions on the back of the form when performing daily and weekly maintenance. Items not applicable to the test set are lined out.

38. Monthly Preventive Maintenance

Use DA Form 11-239 (fig. 14) when performing monthly maintenance. Items not applicable to the test set are lined out. Remove the screw in each corner of the panel and lift the panel from the carrying case to permit inspection and cleaning of the test set interior. Examine the contact surf aces of the five dial switches carefully. If dirty, wipe the surfaces clean with a cloth slightly moistened with cleaning compound and wipe dry. Apply a light coat of petrolatum on the switch contact surfaces, and wipe the surfaces slightly with a clean cloth to leave a very thin film of lubricant on the surfaces. Replace the panel in the carrying case and check for normal operation (item 6).

Warning: Cleaning compound is flammable and its fumes are toxic. Do not use near a flame and be sure adequate ventilation is provided.

Note. On the ZM-4A/U the brass screws in the upper left and upper right corners of the test set panel are used to connect the panel components the the batteries in the case. Never replace these brass screws with steel screws. The use of steel screws will result in inaccurate readings.

39. Organizational Troubleshooting

Troubleshooting at organizational level is limited to the location and correction of faulty wiring (loose connections, broken leads, etc.) and the replacement of only those parts authorized the using organization. Use the equipment performance checklist (par. 40) to check the test set.

OPERATOR FIRST ECHELON MAINTENANCE CHECK LIST FOR SIGNAL CORPS EQUIPMENT
RADIO COMMUNICATION, DIRECTION FINDING, CARRIER, RADAR

INSTRUCTIONS: See other side

EQUIPMENT NOMENCLATURE	EQUIPMENT SERIAL NO.
RESISTANCE Bridge ZM-4B/U	1286

LEGEND FOR MARKING CONDITIONS: ✓ Satisfactory; X Adjustment, repair or replacement required; Ⓧ Defect corrected.
NOTE: Strike out items not applicable.

DAILY

NO.	ITEM	S	M	T	W	T	F	S
1	COMPLETENESS AND GENERAL CONDITION OF EQUIPMENT ~~(receiver, transmitter,~~ *carrying cases,* ~~wire and cable, microphones, tubes, spare parts,~~ *technical manuals* ~~and accessories).~~		✓	✓	✓	✓	✓	
2	~~LOCATION AND INSTALLATION SUITABLE FOR NORMAL OPERATION.~~							
3	CLEAN DIRT AND MOISTURE FROM ~~ANTENNA, MICROPHONE, HEADSETS, CHESTSETS, KEYS, JACKS, PLUGS, TELEPHONES, CARRYING BAGS, COMPONENT~~ PANELS~~.~~		✓	✓	✓	✓	✓	
4	~~INSPECT SEATING OF READILY ACCESSIBLE "PLUCK-OUT" ITEMS: TUBES, LAMPS, CRYSTALS, FUSES, CONNECTORS, VIBRATORS, PLUG-IN COILS AND RESISTORS.~~							
5	INSPECT CONTROLS FOR BINDING, SCRAPING, EXCESSIVE LOOSENESS, ~~WORN OR CHIPPED GEARS,~~ MISALIGNMENT, POSITIVE ACTION.		✓	✓	✓	Ⓧ	✓	
6	CHECK FOR NORMAL OPERATION. PAR. 10 AND 14		✓	✓	✓	✓	✓	

WEEKLY

NO.	ITEM	CONDITION	NO.	ITEM	CONDITION
7	~~CLEAN AND TIGHTEN EXTERIOR OF COMPONENTS AND CASES, RACK MOUNTS, SHOCK MOUNTS, ANTENNA MOUNTS, COAXIAL TRANSMISSION LINES, WAVE GUIDES, AND CABLE CONNECTIONS.~~		13	~~INSPECT STORAGE BATTERIES FOR DIRT, LOOSE TERMINALS, ELECTROLYTE LEVEL AND SPECIFIC GRAVITY, AND DAMAGED CASES.~~	
8	~~INSPECT CASES, MOUNTINGS, ANTENNAS, TOWERS, AND EXPOSED METAL SURFACES, FOR RUST, CORROSION, AND MOISTURE.~~		14	CLEAN ~~AIR FILTERS, BRASS NAME PLATES, DIAL AND~~ METER WINDOWS~~, JEWEL ASSEMBLIES.~~	✓
9	~~INSPECT CORD, CABLE, WIRE, AND SHOCK MOUNTS FOR CUTS, BREAKS, FRAYING, DETERIORATION, KINKS, AND STRAIN.~~		15	INSPECT METERS FOR DAMAGED GLASS~~, AND CASES.~~	✓
10	~~INSPECT ANTENNA FOR ECCENTRICITIES, CORROSION, LOOSE FIT, DAMAGED INSULATORS AND REFLECTORS.~~		16	~~INSPECT SHELTERS AND COVERS FOR ADEQUACY OF WEATHER-PROOFING.~~	
11	~~INSPECT CANVAS ITEMS, LEATHER, AND CABLING FOR MILDEW, TEARS, AND FRAYING.~~		17	~~CHECK ANTENNA GUY WIRES FOR LOOSENESS AND PROPER TENSION.~~	
12	INSPECT FOR LOOSENESS OF ACCESSIBLE ITEMS: SWITCHES, KNOBS. ~~JACKS, CONNECTORS, ELECTRICAL TRANSFORMERS, POWERSTATS, RELAYS, SELSYNS, MOTORS, BLOWERS, CAPACITORS, GENERATORS, AND PILOT LIGHT ASSEMBLIES.~~	Ⓧ	18	~~CHECK TERMINAL BOX COVERS FOR CRACKS, LEAKS, DAMAGED GASKETS, DIRT AND GREASE.~~	

19 IF DEFICIENCIES NOTED ARE NOT CORRECTED DURING INSPECTION, INDICATE ACTION TAKEN FOR CORRECTION.

DA FORM 1 MAY 51 **11-238** REPLACES DA AGO FORM 419, 1 DEC 50, WHICH IS OBSOLETE.

TM2019-13

Figure 13. Daily and weekly maintenance recorded on DA Form 11-238.

SECOND AND THIRD ECHELON MAINTENANCE CHECK LIST FOR SIGNAL CORPS EQUIPMENT
RADIO COMMUNICATION, DIRECTION FINDING, CARRIER, RADAR

INSTRUCTIONS.—See other side

EQUIPMENT NOMENCLATURE	EQUIPMENT SERIAL NO.
Resistance Bridge ZM-4B/U	1286

LEGEND FOR MARKING CONDITIONS: ✓ *Satisfactory;* X *Adjustment, repair, or replacement required;* ⊗ *Defect corrected.*
NOTE: *Strike out items not applicable.*

NO.	ITEM	CONDITION	NO.	ITEM	CONDITION
1	COMPLETENESS AND GENERAL CONDITION OF EQUIPMENT (~~receiver, transmitter,~~ *carrying cases,* ~~wire and cable, microphones, tubes, spare parts,~~ *technical manuals,* ~~and accessories~~).	✓	19	~~ELECTRON TUBES—INSPECT FOR LOOSE ENVELOPES, CAP CONNECTORS, CRACKED SOCKETS, INSUFFICIENT SOCKET SPRING TENSION; CLEAN DUST AND DIRT CAREFULLY; CHECK EMISSION OF RECEIVER-TYPE TUBES.~~	
2	~~LOCATION AND INSTALLATION SUITABLE FOR NORMAL OPERATION.~~		20	~~INSPECT FILM CUTOUTS FOR LOOSE PARTS, DIRT, MISALINEMENT, AND CORROSION.~~	
3	CLEAN DIRT AND MOISTURE FROM ~~ANTENNA, MICROPHONE, HEADSETS, CHESTSETS, KEYS, JACKS, PLUGS, TELEPHONES, CARRYING BAGS, COMPONENT PANELS.~~	✓	21	~~INSPECT FIXED CAPACITORS FOR LEAKS, BULGES, AND DISCOLORATION.~~	
4	~~INSPECT SEATING OF READILY ACCESSIBLE "PLUCK-OUT" ITEMS: TUBES, LAMPS, CRYSTALS, FUSES, CONNECTORS, VIBRATORS, PLUG-IN COILS, AND RESISTORS.~~		22	~~INSPECT RELAY AND CIRCUIT BREAKER ASSEMBLIES FOR LOOSE MOUNTINGS, BURNED, PITTED, CORRODED CONTACTS, MISALINEMENT OF CONTACTS AND SPRINGS, INSUFFICIENT SPRING TENSION, BINDING OF PLUNGERS AND HINGE PARTS.~~	
5	INSPECT CONTROLS FOR BINDING, SCRAPING, EXCESSIVE LOOSENESS, ~~WORN OR CHIPPED GEARS,~~ MISALINEMENT, POSITIVE ACTION.	✓	23	~~INSPECT VARIABLE CAPACITORS FOR DIRT, MOISTURE, MISALINEMENT OF PLATES, AND LOOSE MOUNTINGS.~~	
6	CHECK FOR NORMAL OPERATION. PAR 10 AND 14	✓	24	~~INSPECT RESISTORS, BUSHINGS, AND INSULATORS, FOR CRACKS, CHIPPING, BLISTERING, DISCOLORATION, AND MOISTURE.~~	
7	~~CLEAN AND TIGHTEN EXTERIOR OF COMPONENTS AND CASES, RACK MOUNTS, SHOCK MOUNTS, ANTENNA MOUNTS, COAXIAL TRANSMISSION LINES, WAVE GUIDES, AND CABLE CONNECTIONS.~~		25	~~INSPECT TERMINALS OF LARGE FIXED CAPACITORS AND RESISTORS FOR CORROSION, DIRT, AND LOOSE CONTACTS.~~	
8	~~INSPECT CASES, MOUNTINGS, ANTENNAS, TOWERS, AND EXPOSED METAL SURFACES, FOR RUST, CORROSION, AND MOISTURE.~~		26	CLEAN AND TIGHTEN SWITCHES, ~~TERMINAL BLOCKS, BLOWERS, RELAY CASES,~~ AND INTERIORS OF CHASSIS ~~AND CABINETS~~ NOT READILY ACCESSIBLE.	✓
9	~~INSPECT CORD, CABLE, WIRE, AND SHOCK MOUNTS FOR CUTS, BREAKS, FRAYING, DETERIORATION, KINKS, AND STRAIN.~~		27	~~INSPECT TERMINAL BLOCKS FOR LOOSE CONNECTIONS, CRACKS, AND BREAKS.~~	
10	~~INSPECT ANTENNA FOR ECCENTRICITIES, CORROSION, LOOSE FIT, DAMAGED INSULATORS, AND REFLECTORS.~~		28	~~CHECK SETTINGS OF ADJUSTABLE RELAYS.~~	
11	~~INSPECT CANVAS ITEMS, LEATHER, AND CABLING FOR MILDEW, TEARS, AND FRAYING.~~		29	~~LUBRICATE EQUIPMENT IN ACCORDANCE WITH APPLICABLE DEPARTMENT OF THE ARMY LUBRICATION ORDER.~~	
12	INSPECT FOR LOOSENESS OF ACCESSIBLE ITEMS: SWITCHES, KNOBS, ~~JACKS, CONNECTORS, ELECTRICAL TRANSFORMERS, POWERSTATS, RELAYS, SELSYNS, MOTORS, BLOWERS, CAPACITORS, GENERATORS, AND PILOT LIGHT ASSEMBLIES.~~	✓	30	~~INSPECT GENERATORS, AMPLIDYNES, DYNAMOTORS, FOR BRUSH WEAR, SPRING TENSION, ARCING, AND FITTING OF COMMUTATOR.~~	
13	~~INSPECT STORAGE BATTERIES FOR DIRT, LOOSE TERMINALS, ELECTROLYTE LEVEL AND SPECIFIC GRAVITY, AND DAMAGED CASES.~~		31	~~CLEAN AND TIGHTEN CONNECTIONS AND MOUNTINGS FOR TRANSFORMERS, CHOKES, POTENTIOMETERS, AND RHEOSTATS.~~	
14	CLEAN ~~AIR FILTERS, BRASS NAMEPLATES, DIAL AND~~ METER WINDOWS, ~~JEWEL ASSEMBLIES.~~	✓	32	~~INSPECT TRANSFORMERS, CHOKES, POTENTIOMETERS, AND RHEOSTATS FOR OVERHEATING AND OIL LEAKAGE.~~	
15	INSPECT METER~~S~~ FOR DAMAGED GLASS ~~AND CASES.~~	✓	33	BEFORE SHIPPING OR STORING—REMOVE BATTERIES.	✓
16	~~INSPECT SHELTERS AND COVERS FOR ADEQUACY OF WEATHERPROOFING.~~		34	~~INSPECT CATHODE RAY TUBES FOR BURNT SCREEN SPOTS.~~	
17	~~CHECK ANTENNA GUY WIRES FOR LOOSENESS AND PROPER TENSION.~~		35	~~INSPECT BATTERIES FOR SHORTS AND DEAD CELLS.~~	
18	~~CHECK TERMINAL BOX COVERS FOR CRACKS, LEAKS, DAMAGED GASKETS, DIRT, AND GREASE.~~		36	~~INSPECT FOR LEAKING WATERPROOF GASKETS, WORN OR LOOSE PARTS.~~	
			37	~~MOISTURE AND FUNGIPROOF.~~	

38 IF DEFICIENCIES NOTED ARE NOT CORRECTED DURING INSPECTION, INDICATE ACTION TAKEN FOR CORRECTION.

DA FORM 1 MAY 51 11-239   Replaces DA AGO Form 419, 1 Dec 50, which is obsolete.

TM2019-14

Figure 14. Monthly maintenance recorded on DA Form 11–239.

40. Equipment Performance Check List

	Step	Item	Action	Normal indication	Corrective action
PREPARATORY	1	Galvanometer	Adjust (par. 10*a*).	Pointer balances at center of scale.	Field maintenance required.
	2	Power	Connect for desired type of power source (par. 11 and 12).		
	3	GA switch	Move to RVM.		
	4	RES–VAR–MUR switch	Move to RES.		
	5	MULTIPLY BY (	Move to $\frac{1}{1}$.		
	6	Units, hundreds, a thousands decade dials.	Move to 0.		
	7	Tens decade dial	Move to 5.		
	8	Line binding posts X1 and X2.	Connect jumper across X1 and X2.		
EQUIPMENT PERFORMANCE	9	GA SENS .01 swi	Press and release immediately.	Pointer deflects to left and returns to zero.	If pointer deflects to right, reverse polarity of power.
				Pointer does not move.	With internal power, check batteries and replace if necessary. With external power, check power source. If power source is correct, check for open circuit (caution, par. 11).
	10	Line binding posts X1 and X2.	Remove jumper (8 above). Connect known resistance across X1 and X2. Balance bridge (par. 14).	Sum of decade dial positions equal to value of resistance connected to X1 and X2.	Check for dirty contact surfaces on dial switches. Clean (par. 37) if dirty. Check for contact between wipers and contact surfaces of dial switches, if not in contact, field maintenance is required.

CHAPTER 4
THEORY

41. Basic Bridge Circuit

The basic circuit of the test set is a bridge network (fig. 15), commonly referred to as a Wheatstone bridge circuit. This circuit permits extremely accurate measurement of resistance. Resistors A and B are referred to as the ratio arms of the bridge. Their relationship to each other is variable in eight steps from 100/1 to 1/1,000 and is controlled by the positioning of a rotary switch. Resistor R represents a known resistance, adjustable in 1-ohm steps from 0 to 10,110 ohms. The resistance to be measured (X) is connected between points d and e. The resistance of the R arm is adjusted until the galvanometer pointer is at midscale. Under this condition, the voltage at points e and f are equal, no current flows through the galvanometer, and the ratio A/B is equal to X/R. The unknown resistance (X) is equal to A/B x R.

Example: An unknown resistance is connected to points d and e, the A/B ratio switch is set at 1/10, and the galvanometer reads zero when the R arm is adjusted to 4,327. The unknown resistance value is computed as follows:

$$X = \frac{A}{B} \times R$$

$$= \frac{1}{10} \times 4{,}327$$

$$= 432.7 \text{ ohms}$$

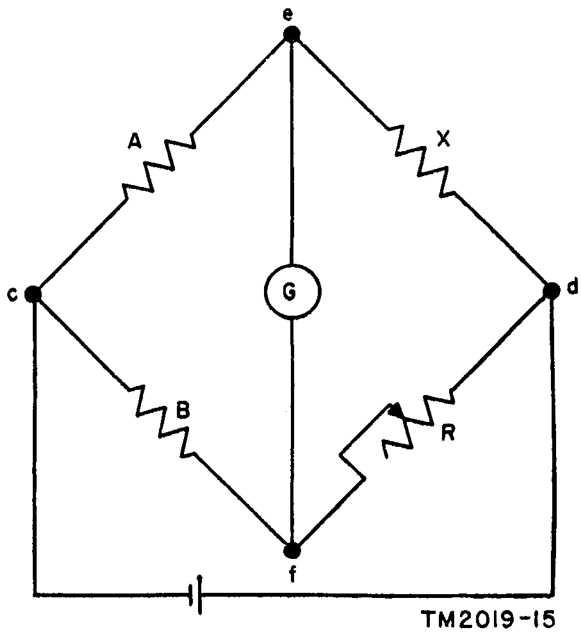

Figure 15. Basic bridge circuit.

42. Loop Test Circuits

Simplified schematic diagrams and circuit details of the regular Varley, three-Varley, Murray, and Hilborn loop tests are described in *a* through *d* below. Refer to the complete schematic diagram (fig. 21) for additional circuit switching information.

a. Regular Varley Loop Test Circuit (fig. 16).

(1) Basic equation:

$$\frac{A}{B} = \frac{R_g + R_b - X_a}{R + X_a}$$

(2) The equation used to determine the resistance from test point to fault (X_a equals:

$$X_a = \frac{rB - AR}{A + B}, \text{ where } r \text{ equals } R_g + R_b \text{ (loop resistance)}$$

(3) The equation used to determine resistance from far end to fault (X_b equals:

$$X_b = \frac{A\,(R + R_b) - BR_g}{A + B}$$

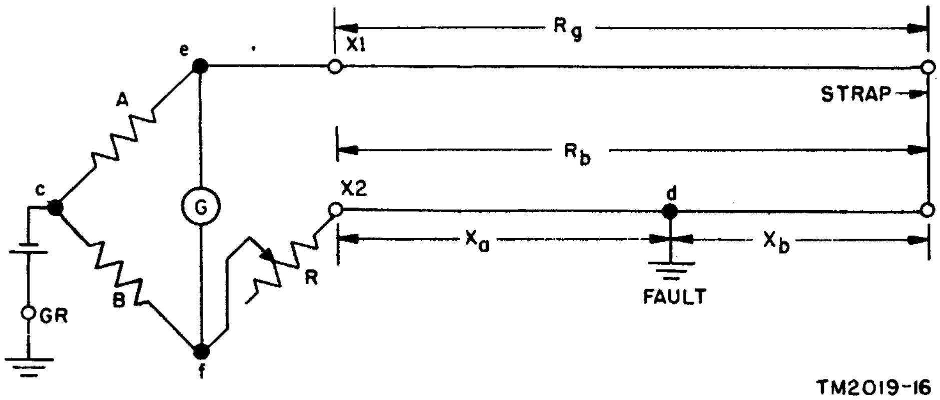

Figure 16. Regular Varley loop test circuit, simplified schematic diagram.

b. Three-Varley Loop Test Circuit.

(1) Varley 1 test (A, fig. 17), basic equation:

$$\frac{A}{B} = \frac{R_g}{R_g + R_1}$$

(2) Varley 2 test (B, fig. 17), basic equation:

$$\frac{A}{B} = \frac{R_g + X_b}{X_a + R_2}$$

(3) Varley 3 test (C, fig. 17), basic equation:

$$\frac{A}{B} = \frac{R_g + R_b}{R_3}$$

(4) The equation used to determine the resistance (X_a) between the test point and the fault is-

$$X_a = \frac{A}{A + B} \times (R_3 - R_2)$$

Note. This equation is derived from the basic equation of the Varley 2 test ((2) above), substituting R_b- X_a for X_b (B, (fig. 17), and using the basic equation of the Varley 3 test ((3) above) to obtain the substitute $\frac{AR_3}{B}$ for $R_g + R_b$.

(5) The equation used to determine the resistance (X_b) between the far end and the fault is-

$$X_b = \frac{A}{A + B} \times (R_2 - R_1)$$

Note. This equation is derived from the basic equation of the Varley 2 test ((2) above) substituting R_b-X_b for X_a (B, fig. 17), and using the basic equation of the Varley 1 test ((1) above) to obtain the substitute $\frac{BR_g - AR_1}{A}$ for R_b.

(6) The equation used to determine the resistance (R_b) of the full length of the faulty wire is-

$$\frac{A}{B} = \frac{A}{A + B} \times (R_3 - R_1)$$

Note. This equation is derived from the basic equation of the Varley 3 test ((3) above) and using the basic equation of the Varley 1 test ((1) above) to obtain the substitute, $\frac{AR_b + AR_1}{B}$, for R_g.

c. Murray Loop Test Circut (fig. 18).

(1) Basic equation:

$$\frac{A}{R} = \frac{r - X_a}{X_a} \text{ where } r = R_g + X_a + X_b.$$

(2) The equation used to determine the resistance (X_a) from the test point to the fault is-

$$X_a = \frac{Rr}{R + A}$$

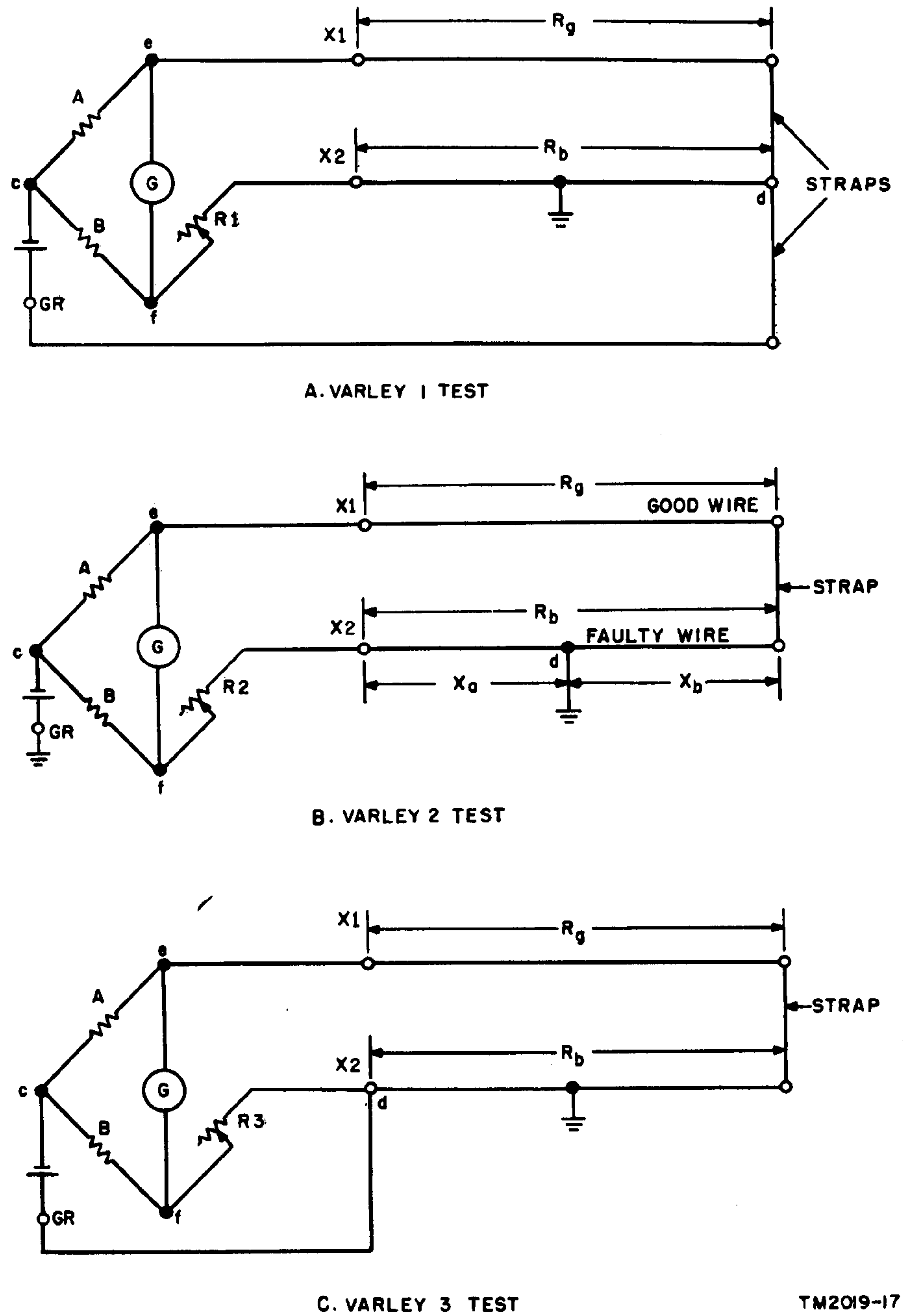

Figure 17. Three-Varley loop test circuits, simplified schematic diagram.

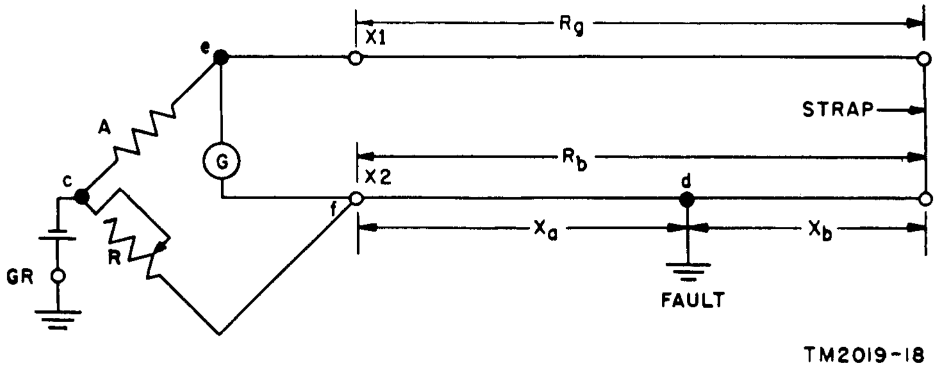

Figure 18. Murray loop test circuit, simplified schematic diagram.

d. Hilhorn Loop Test Circuit (fig. 19).

(1) Basic equation:

$$\frac{A + R_g}{R} = \frac{X_b}{X_a} \quad \text{where } X_a = R_b - X_b$$

(2) The equation used to determine the resistance (X_b) from the far end to the fault is-

$$X_b = \frac{A + R_g}{A + R_g + R} \times R_b$$

43. Test Circuit for Location of Opens

The capacitance tests for location of opens is based on the fact that any two parallel wires and the insulating material between them form a capacitor. Figure 20 is a simplified schematic diagram of the test arrangement. The galvanometer of the test set is disconnected and replaced by a telephone receiver. A source of test tone is used to power the test circuit. The B ratio arm of the preceding tests (fig. 15) is replaced by the decade dials (R). The A arm is set at either 1000, 100, or 10 as desired. Capacitors C1 and C2 form the remaining two arms of the bridge. These capacitors represent the capacitance between adjacent conductors, between a conductor and ground, or of an external capacitor, depending on the test connections (par. 23 and 24). The ratio of A to R is varied by adjustment of the decade dials until a minimum of tone is heard in the receiver, indicating the bridge is balanced. When the bridge is balanced, A divided by R is equal to C2 divided by C1. The formulas for computing the distance to an open vary with the type of capacitor test used (par. 23 and 24).

44. Galvanometer Sensitivity Circuit (fig. 21)

Resistors R1, R2, and R3 and switches S7, S8, and S9 permit the selection of three degrees of galvanometers sensitivity. For minimum sensitivity, S9 (GA SENS .01) is pressed. A parallel circuit is completed consisting of R1 (40 ohms) in parallel with the galvanometer, R2 (360 ohms), and R3 (3,600 ohms). For medium sensitivity, S8 (GA SENS .1) is pressed, increasing the shunt around the meter to 400 ohms (R1 plus R2) and including only R3 (3,600 ohms) in series with the galvanometer. For maximum sensitivity, S7 (GA SENS 1) is pressed. The shunt is increased to 4,000 ohms (R1, R2, and R3), and no resistor is in series with the galvanometer.

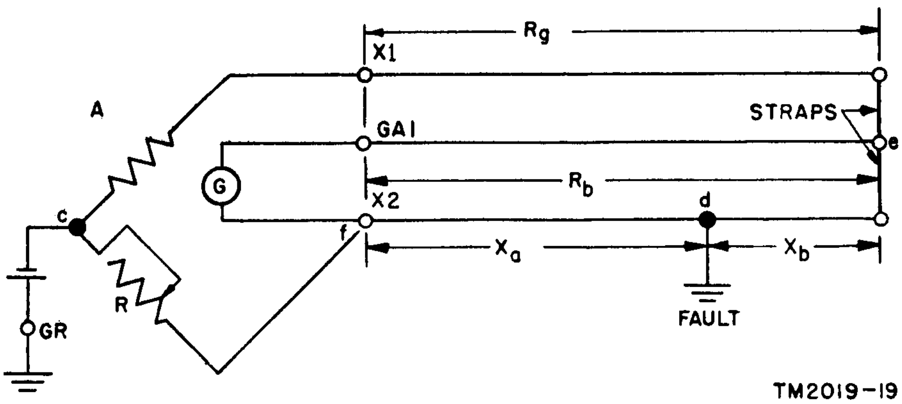

Figure 19. Hilborn loop test circuit, schematic diagram.

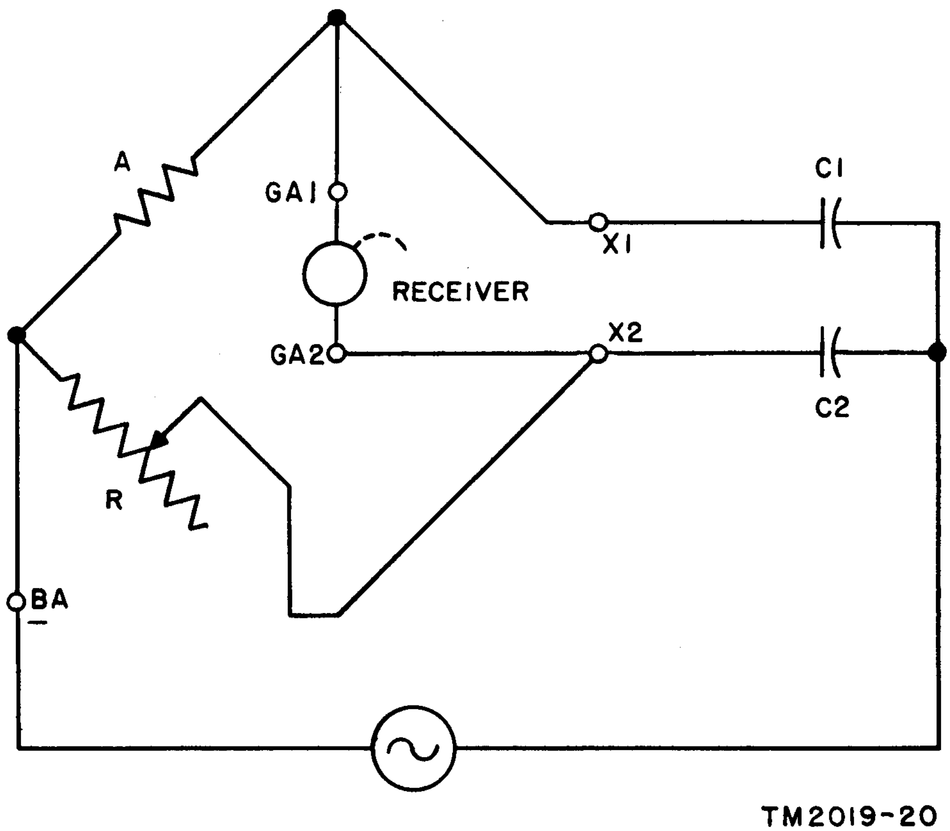

Figure 20. Capacitance test for open circuit, simplified schematic diagram.

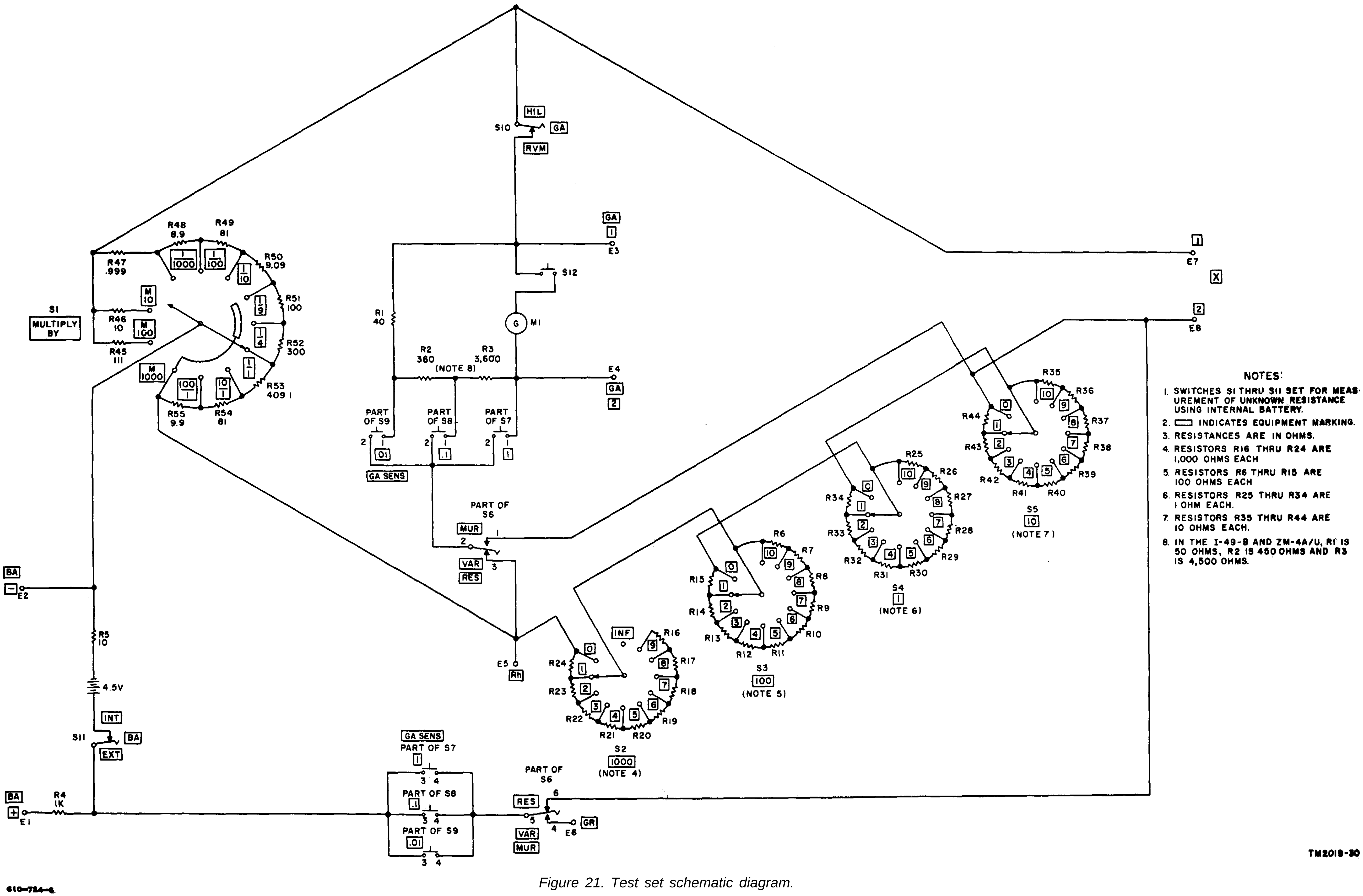

Figure 21. Test set schematic diagram.

CHAPTER 5

FIELD AND DEPOT MAINTENANCE

Section I. TOOLS AND TEST EQUIPMENT

45. Tools

The following tools are required for field and depot maintenance:

a. Pliers TL-13-A (6-inch side cutters).

b. Pliers TL-103 (5-inch diagonal cutting).

c. Pliers TL-126 (6-inch chain nose).

d. Screwdriver TL-459/U (3/8-by .050-inch tip).

e. Screwdriver TL-358/U (¼-by .037-inch tip).

f. Socket wrench, 5/16-inch hexagonal screw driver handle.

g. Socket wrench, 3/8-inch hexagonal screw driver handle.

h. Socket wrench, 7/16-inch hexagonal screw driver handle.

i. Soldering aid tool (CBS Hytron or equal).

j. Soldering Iron TL-117 (85 watts or less).

46. Test Equipment

a. Third Echelon. The only test equipment required for third echelon maintenance is Multimeter ME-77/U. It is used for testing the continuity of the circuits in the test set. If Multimeter ME-77/U is not available, use an equivalent substitute such as Multimeter TS-297/U (TM 11–5500) or Multimeter TS-352/U (TM 11-5527) .

b. Fourth Echelon and Depot.

(1) Laboratory Standards AN/URM-2 Fed stock No. 6625-188-5850).

(2) Resistor, 1,000 ohms, ±.1 percent Fed stock No. 5905–198-6305).

(3) Resistor, 1 megohm, ±.1 percent (Fed stock No. 5905-407-0856).

(4) Decade Resistor TS-679/U (TM 11-5520) .

Section II. TROUBLESHOOTING AND REPAIR

47. Troubleshooting Procedure

Prepare the test set for operation (par. 10). During preparation, if the position of the galvanometers is not adjustable to midpoint on the scale, replace the galvanometer. Connect a resistor of known value to line binding posts X1 and X2 and measure its resistance (par. 14). Use the troubleshooting chart (par. 48) to locate and correct faults.

48. Troubleshooting Chart

	Possible trouble	Remedy
Galvanometer does not move from midpoint of scale regardless of which GA SENS switch is depressed.	Galvanometer screw (S12) not screwed in tightly.	Tighten galvanometer screw (fig. 3).
	Defective RES–VAR–MUR switch (S6).	Clean, adjust, or replace S6 as necessary.
	Defective GA switch (S10).	Clean, adjust, or replace S10 as necessary.
	Open in galvanometer coil.	Replace galvanometer.
Galvanometer seems to operate properly when GA SENS .1 and 1 switches are pressed. Makes no	Defective GA SENS .01 switch S9.	Clean, adjust, or replace S9, as necessary.

Possible trouble		Remedy
movement when GA SENS .01 switch is pressed (bridge not in perfect balance).	Open in resistor R2.	Replace R2.
Galvanometer operates properly when GA SENS 1 switch is pressed. Makes no movement when either GA SENS .01 or .1 switch is pressed (bridge not in perfect balance).	Open in resistor R3.	Replace R3.
Erratic movement of galvanometer pointer.	Dirty contacts or weak contact springs in GA switch, GA SENS .01, .1, or 1 switch, or RES–VAR–MUR switch.	Tap each switch lightly to localize trouble. Clean and adjust switch contacts as necessary.
	Dirt on contact surfaces or rotary switches.	Clean and lubricate (par. 38). Replace switch if badly scored.
Bridge will not balance. As decade dials are rotated slowly, galvanometer remains motionless and deflects suddenly as a decade dial is moved to the next position.	Open resistor in decade.	Replace resistor.
High-resistance reading when measuring value of known resistance.	Shorted resistor in decade.	Remove short. Replace resistor if short is internal.

49. Removal and Replacement of Parts

Most components of the test set can be removed and replaced easily. When replacing components, refer to the wiring diagram (figs. 24 and 25) to check the wiring connections. Removal and replacement instructions for parts not easily replaced are as follows:

a. Rotary Switch and Resistor Assemblies.

(1) *ZM-4A/U, I-49, and I-49-B* (figs. 3 and 22).

(a) Unsolder the leads connected to the assembly. Remove the cotter pin and wiper from the shaft and pull the dial and shaft from the test set. Catch the ball detent and spring normally held captive beneath the dial.

Note. A solder connection bonds the wiper of some test sets to the ratio switch shaft. Unsolder this connection before removing the dial and shaft.

(b) Remove the two screws and lockwashers that fasten the complete assembly to the panel and remove the assembly.

(c) To replace any resistor in the assembly, remove the three flathead screws that attach the contact wafer to the center portion of the switch and lift the wafer and attached resistors from the switch. Replace the faulty resistor and reassemble the resistor group by reversing the disassembly procedure.

(d) Install the reassembled switch and resistor assembly on the test set by reversing the removal procedure.

(2) *ZM-4B/U and I-49-A* (figs. 1 and 23).

(a) Unsolder the leads connected to the switch and resistor assembly. Loosen the dial setscrew and pull the dial from the shaft. Unscrew the nut that holds the assembly to the test set panel and remove the assembly from the panel.

(b) To replace any resistor in the assembly, unsolder and lift it from the locating post. Install the new resistor on the post and solder it to the wafer contact.

(c) Install the switch and resistor assembly on the test set by reversing the removal procedure.

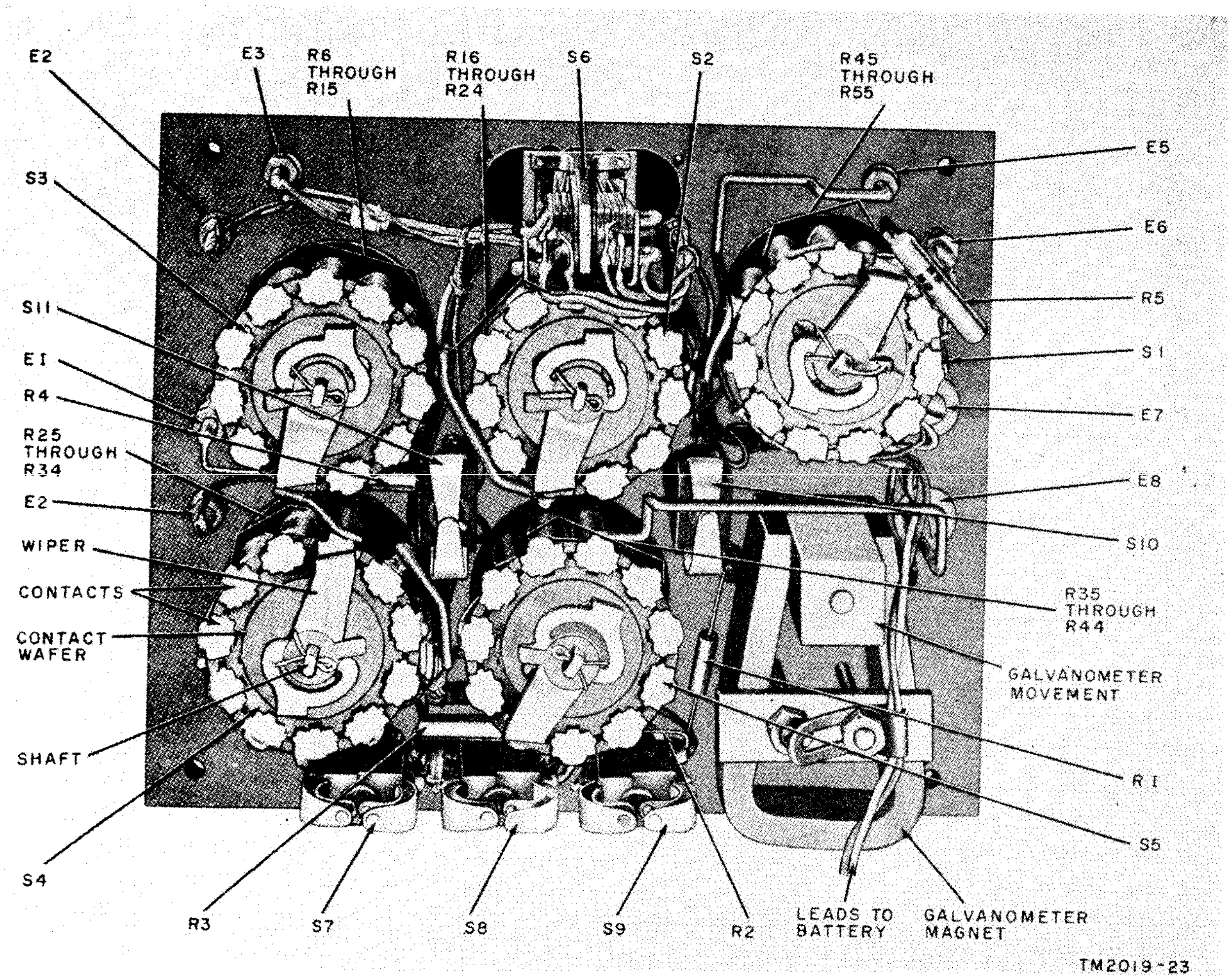

Figure 22. Resistance Bridge ZM–4A/U, bottom view.

b. Galvanometer (All Models).

(1) Remove the galvanometer screw and the slotted screw from the left side of the galvanometer (fig. 3).

(2) Lift the galvanometer straight up from the test set panel. No leads are attached to the galvanometer and it can be lifted free.

(3) Install the new galvanometer by reversing the removal procedure. No leads need be attached to the galvanometer as the two screws ((1) above) are used to connect the galvanometer coil to the circuitry of the test set.

50. Switch Adjustments

The spring switches in the test set must meet the requirements specified below. Use appropriate spring bending tools to bend the springs to meet the requirements.

a. GA SENS Switches. The switches used for GA SENS switches S7, S8, and S9 (figs. 22 and 23) vary from model to model, but all are the plunger type with spring contacts. The contacts of all must be open when the plunger is fully released. As the plunger is depressed slowly, the pair of contacts in the battery circuit must close first. Continued downward movement of the plunger must then close the pair of contacts in the galvanometers circuit. After the second pair of contacts is closed, spring follow must be perceptible as the plunger is moved to the fully depressed position.

b. BA and GA Switches. The type of switch

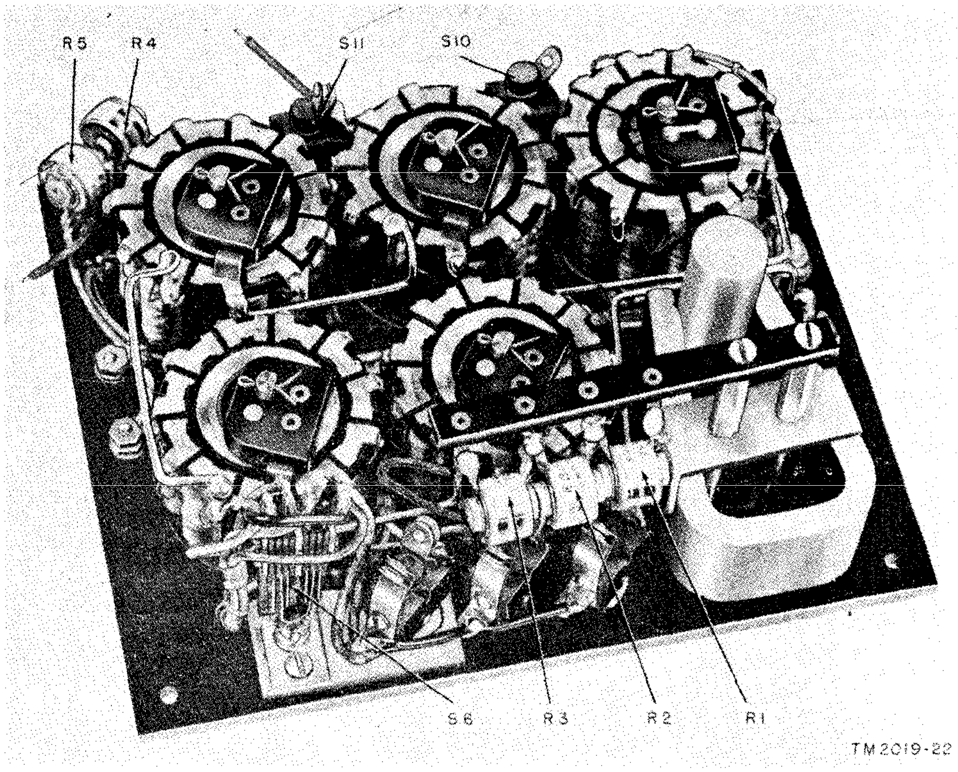

Figure 23. Resistance Bridge ZM–4B/U, bottom view.

used for BA switch S11 and GA switch S10 (figs. 22 and 23) varies from model to model but all are two-position rotary plunger type with spring contacts. As the plunger is rotated clockwise, a caroming surface moves the plunger downward until it is held latched in the fully downward position. The contacts must be open when the GA switch is in the HIL position (released) and the BA switch is in the EXT position. As the GA switch is moved toward the RVM position and the BA switch is moved toward the INT position, the contacts must close with perceptible spring follow until the switches are latched in the fully clockwise position.

c. Wipers of Rotary Switches. As the switch dial is rotated slowly, each of the wiper springs must come in firm contact with each contact surface on the switch. Remove the wiper from the shaft and bend the wiper springs to meet the requirements.

Section III. FINAL TESTING

51. Purpose of Final Testing

The repaired test set must be tested thoroughly to insure that it meets the performance standards required of new equipment. Use the tests described in this section to measure the performance of a repaired test set. The test data is applicable at 68° F.

52. Galvanometer Test

Test the galvanometer as follows:

a. Set the RES-VAR-MUR switch to MUR and the GA switch to RVM.

b. Connect a source of 4½ volts dc in series with the 1-megohm resistor and connect both across line binding posts X1 and X2.

c. Depress the GA SENS 1 switch. The galvanometer must deflect at least three divisions of the scale (3 millimeters).

53. Test of Decades and Multiplier Resistors

Test the operation of the test set at each

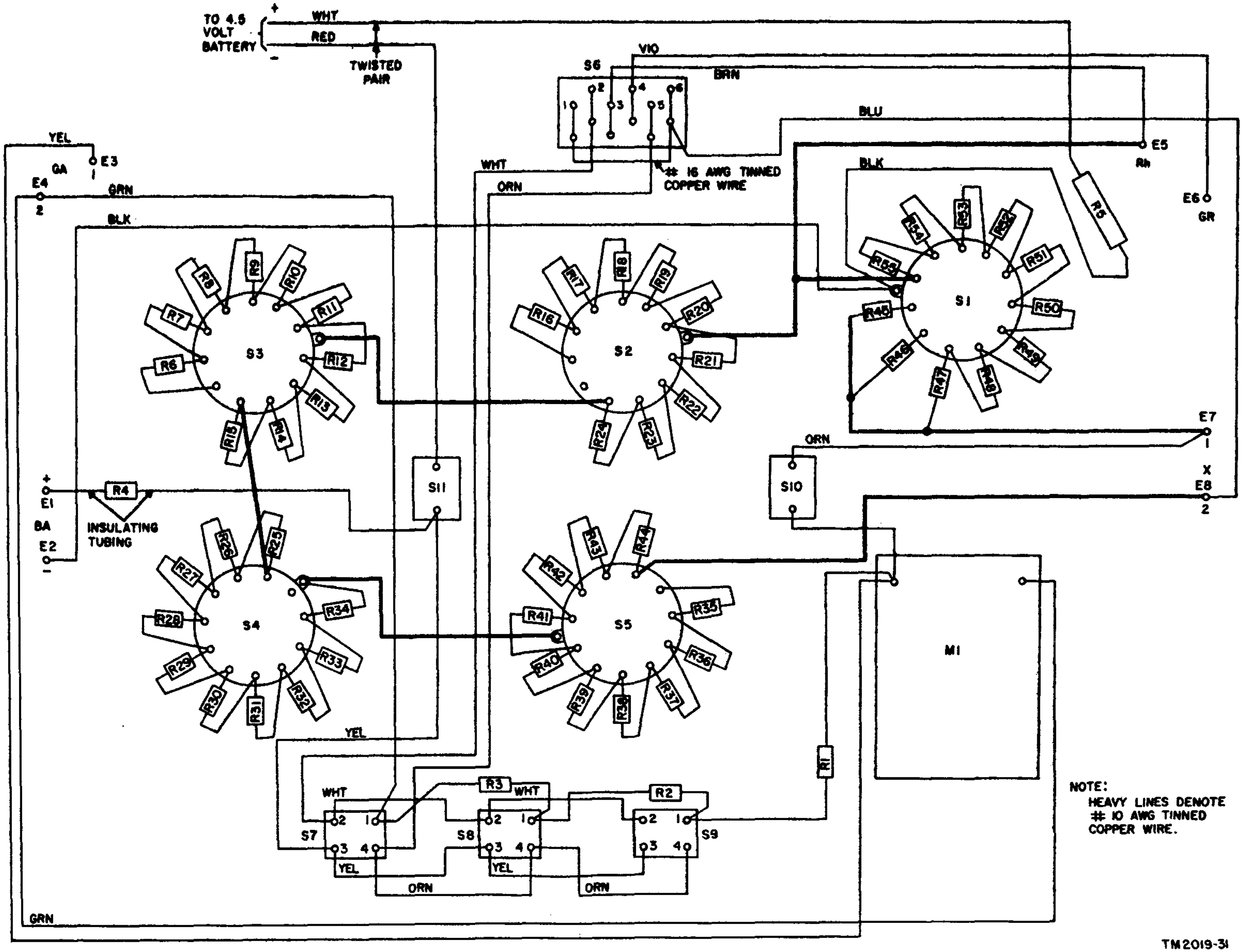

Figure 24. ZM-4A/U, I-49, and I-49B, wiring diagram.

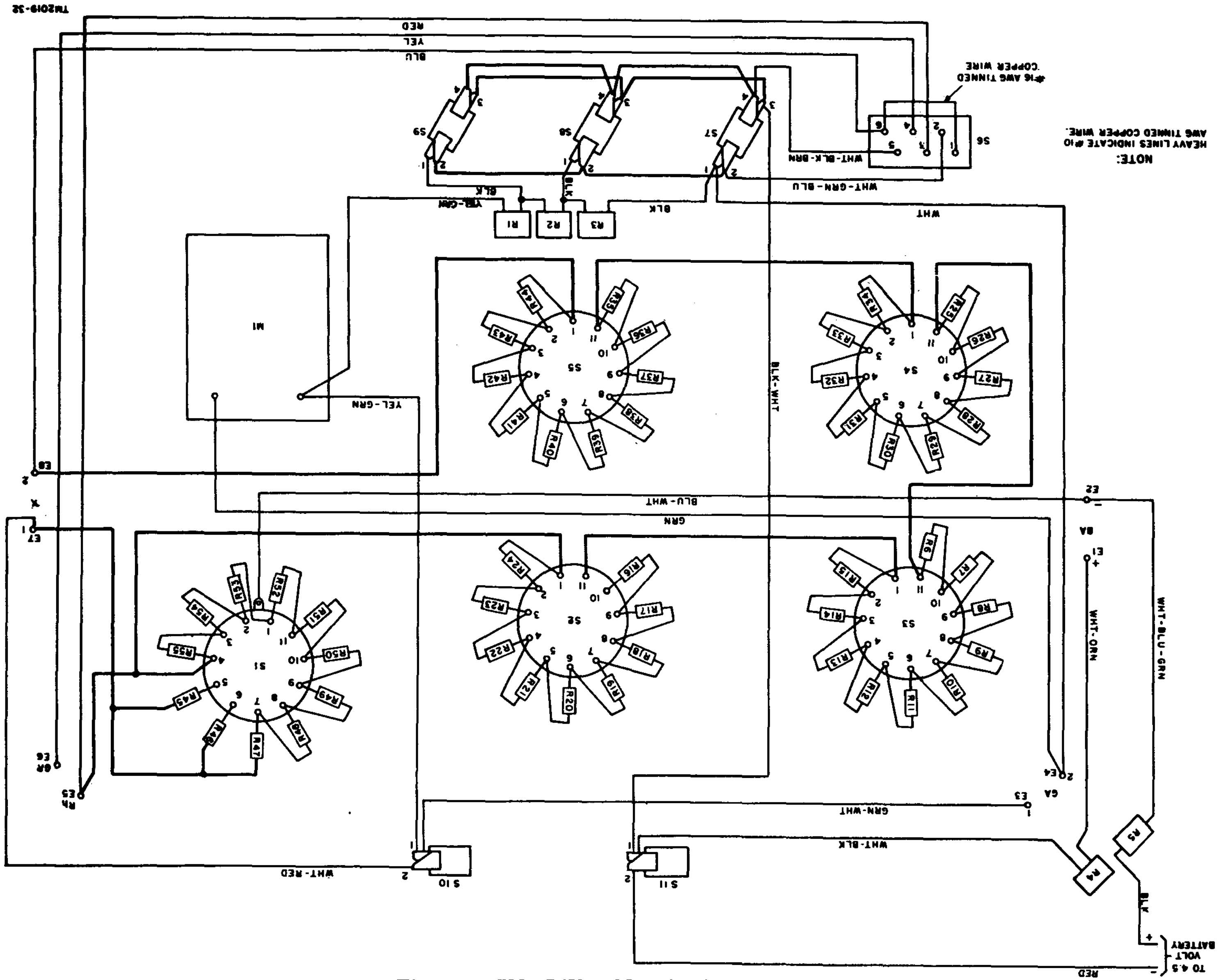

Figure 25. ZM-4B/U and I-49A, wiring diagram.

a. Set the RES-VAR-MUR switch to RES, the BA switch to EXT, and the GA switch to RVM. Connect a source of 45 volts dc to binding posts BA- and BA+.

b. Position the MULTIPLY BY dial as in- the AN/URM-2 across line binding posts X1 and X2.

d. Balance the bridge by using the decade positioning pattern indicated for the test. The resistance measurement for each test must not exceed the tolerance specified in the table.

Decades and multiplier resistor test table.

Setting of MULTIPLY BY dial	Standard resistor used (ohms)	Approx decade dial positions				Tolerance (ohms)	
		1,000	100	10	1	A[a]	B[b]
100/1	1,000	0	0	0	10	±2.5	±1.5
10/1	1,000	0	0	10	0	±2.5	±1.5
1/1	1,000	0	10	0	0	±2.5	±1.5
1/1	9,000	9	0	0	0	±22.5	±13.5
1/4	1,000	4	0	0	0	±10	±6
1/9	1,000	9	0	0	0	±22	±14
1/10	900	9	0	0	0	±22	±14
1/100	90	9	0	0	0	±22	±14

[a] Tolerances for all test sets except those purchased on Order No. 3358-P-52 and Order No. 25738-P-53.
[b] Tolerances for Resistance Bridge ZM-4B/U purchased on Orders No. 3358-Phila-52 and Order No. 27538-Phila-53.

54. Murray Circuit Test
(fig. 26)

Use the following procedure to test the operation of the test set arranged for Murray tests (MULTIPLY BY dial at M 1000, M 100, and M 10).

a. Set the RES-VAR-MUR switch to MUR, the BA switch to EXT, and the GA switch to RVM.

b. Connect a source of 45 volts dc to binding posts BA- and BA+.

c. Connect one side of Decade Resistor TS-679/U to line binding post X2 and the other side to a 1,000-ohm resistor. Connect the other side of the resistor to line binding post X1.

d. Connect the GR binding post to the junction of the 1,000-ohm resistor and the TS-679/U.

e. Position the MULTIPLY BY dial and the decade dials of the set under test as indicated in the table in *f* below.

f. Adjust the dials of the TS-679/U to balance the bridge. The resistance reading of the TS-679/U must equal 1,000 ohms within the tolerances specified in the table.

Murray circuit test table

Setting of MULTIPLY BY dial	Sum of test test decade dial settings (ohms)	Tolerance (ohms)	
		B[b]	A[a]
M 10	10	2.5	1.5
M 100	100	2.5	1.5
M 1000	1000	2.5	1.5

[a] Tolerance for all test sets except those purchased on Orders No. 3358-Phila-52 and Order No. 25738-Phila-53.
[b] Tolerances for Resistance Bridge ZM-4B/U purchased on Orders No. 3358-Phila-52 and Order No. 25738-Phila-53.

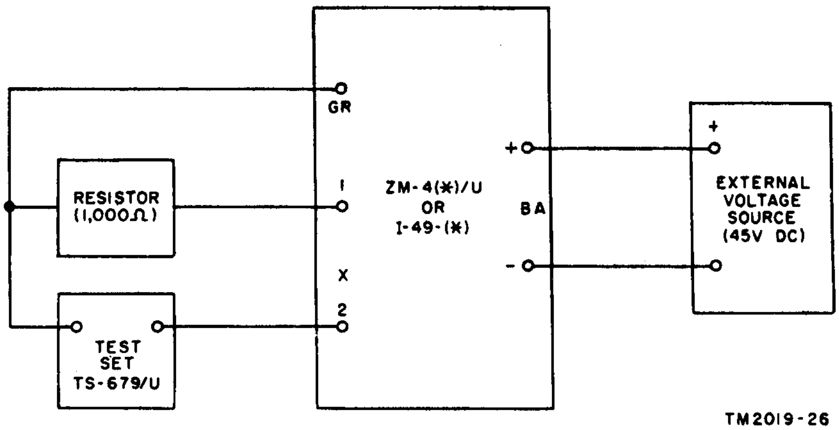

Figure 26. Test arrangement for Murray circuit test.

CHAPTER 6

SHIPMENT AND LIMITED STORAGE AND DEMOLITION TO PREVENT ENEMY USE

55. Repackaging for Shipment and Limited Storage

The exact procedure for repackaging depends on the material available and the conditions under which the equipment is to be shipped or stored. Repackaging should be as similar as possible to the original packaging (fig. 2).

a. Preparation. Prepare the test set for shipment or storage as follows:

(1) Move the pointer lock of the galvanometer to the LOCK or CLAMP position.

(2) Remove the batteries (par. 11).

(3) Set the RES-VAR-MUR switch to VAR, the BA switch to EXT, and the GA switch to HIL.

(4) Check to be sure the battery compartment screws and the mounting screw in each corner of the panel are tight.

b. Material Requirements. The following materials are required for repackaging the test set. For stock numbers of materials, refer to SB 38-100, Preservation, Packaging, and Packing Materials, Supplies, and Equipment Used in the Army.

Material	Quantity
Corrugated paper (flexible, single-face)	20 sq ft
Gummed paper tape	10 ft
Waterproof paper	20 sq ft
Waterproof tape (pressure-sensitive)	6 ft
Wooden packing case (inside dimensions 10 in. by 9 in. by 8 in.)	1

c. Packaging.

(1) Wrap each test set with corrugated paper and secure the wrap with gummed paper tape.

(2) Wrap the technical manuals in waterproof paper and seal the package with waterproof tape.

d. Packing.

(1) Use waterproof paper and waterproof tape to make a liner for the wooden packing case. Insert the liner in the case and place several layers of corrugated paper in the bottom of the liner.

(2) Place the packaged test set in the liner and cushion the test set firmly on all sides with pads of corrugated paper.

(3) Close the waterproof liner and seal it with waterproof tape.

(4) Use waterproof tape to fasten the technical manual package to the top of the sealed waterproof liner.

(5) Fill the space between the top of the technical manual package and the top of the wooden case with layers of corrugated paper. Nail the top to the wooden case.

(6) Mark the sealed case as described in Military Standard MIL-129, Marking for Shipment and Storage.

56. Demolition

Demolition of the test set will be accomplished only upon the order of the commander. Use the following methods to demolish the test set:

a. Smash. Use a sledge, pickaxe, or other heavy tool to smash the panel, galvanometer, resistors, switches, and binding posts.

b. Burn. Saturate the test set and technical manuals with any available flammable material such as gasoline or kerosene and ignite it.

c. Dispose. Throw the demolished test set into any nearby body of water. If time permits, and no body of water is available, bury the test set.

[AG 413.64 Oct 57)]

BY ORDER OF THE SECRETARIES OF THE ARMY AND THE AIR FORCE:

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Chief of Staff.

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Major General, United States Army,
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USA Air Def Bd	Army Terminals	6–577
USA Abn & Elct Bd	OS Sup Agcy	11–7
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Sig Depots	5–278	32–500
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NG: State AG; units—same as Active Army.
USAR: None.
For explanation of abbreviations used, see AR 320–50.

☆U.S. GOVERNMENT PRINTING OFFICE: 1990 - 262-912 (30221)

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS

SOMETHING WRONG WITH PUBLICATION

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PUBLICATION NUMBER	PUBLICATION DATE	PUBLICATION TITLE

BE EXACT PIN-POINT WHERE IT IS

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PRINTED NAME, GRADE OR TITLE AND TELEPHONE NUMBER	SIGN HERE

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PREVIOUS EDITIONS ARE OBSOLETE.

P.S.--IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS AND GIVE IT TO YOUR HEADQUARTERS.

THE METRIC SYSTEM AND EQUIVALENTS

'NEAR 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

'EIGHTS

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

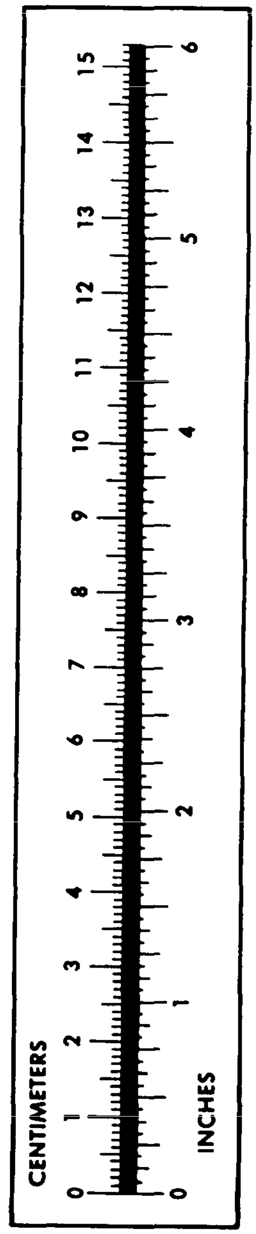
TEMPERATURE

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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