FAULT LOCATING
OUTSIDE PLANT

CONTENTS PAGE

FIGURES

FIGURES PAGE

FIGURES PAGE

1. GENERAL

1.01 This section describes the procedures in flowchart format used to locate conductor, wire, and cable troubles in outside plant. The procedures outlined are intended to permit fault locating in the least time-consuming manner and should be considered as guidelines rather than hard and fast rules. These procedures are established to:

- Reduce the number of double dispatches
- Eliminate unnecessary dispatches
- Provide for better coordination of tests performed by wire repair with those performed by cable repair.

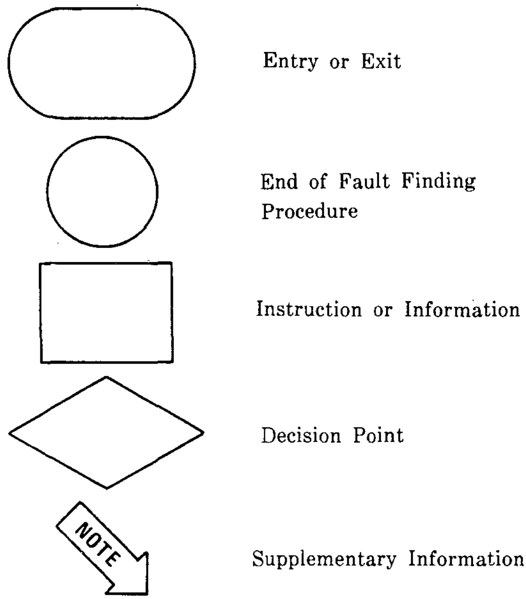
In addition to the above, these fault locating procedures can provide a basis for training the repair forces.

1.02 When this section is reissued, the reason for reissue will be listed in this paragraph.

1.03 The flowcharts cover two major areas; one for the wire repair group, and one for the cable repair group. Under cable repair, there is distribution plant and feeder plant. Each is divided into aerial, buried with pedestal access, buried out of sight, and under the feeder; an additional section covering underground. To use the flowcharts, go to the first chart in the section for the type of plant that is to be worked on. Follow the chart until you locate the trouble, or you come to a block that directs you to another section or directs you to take other action.

1.04 The flowcharts were developed for use with the test sets listed in Part 3, or their equivalents, and should be available to repair personnel.

1.05 The blocks in the flowcharts have four shapes whose meanings are explained below. In addition to the four blocks, an open arrow is used on the flowcharts to indicate a note on a given step in the fault-finding procedure.



1.06 Fault locating procedures are outlined as follows:

Fig. 1-8—Wire Repair (Aerial and Buried)

Fig. 9-19—Cable Repair (Aerial and Buried)

Fig. 20-27—Cable Repair (Aerial and Buried and Underground Feeder)

Fig. 28-38—Typical Faults

2. PRECAUTIONS

2.01 Although not listed in the flowcharts, safety procedures shall be observed. At all times observe the safety procedures and precautions outlined in the following sections:

SECTION	TITLE
620-060-510	Below Ground Protection
620-060-520	Joint Use Below Ground Protection
620-102-010	Outside Plant Precautions Underground and Buried Work
620-135-010	Guarding Work Areas
620-140-501	Testing and Ventilating Manholes
629-100-010	Buried Plant Precautions

2.02 Observation of safety procedures shall not be limited to the above mentioned sections. Precautions in applicable test set sections shall also be observed.

2.03 Always call the below ground plant protection center in your area to obtain permission to dig up underground plant.

3. TEST SETS

3.01 Test sets required by the outside plant repair forces for fault locating are listed below:

91A	(Section 106-300-100) An audio amplifier kit consisting of a 147C amplifier, 513A probe and a headset.
101B	(Sections 106-340-115 and 634-305-505) A hand held exploring coil intended for use with 147-type amplifier.
105D	(Sections 106-340-115 and 634-305-505) Exploring coil mounted on a pole used in fault locating in aerial plant.
139A	(Section 105-242-100) A tone generator used by station forces in troubleshooting individual conductors and pairs in cables, inside wiring and service drops.
145A	(Section 634-200-225) A general purpose test set that can be used to measure resistance, AC and DC voltages, line current, open faults to 20 KFT, circuit loss, noise, and provide tone for identification purposes.
146A	(Section 634-200-504) Used for wire identification, construction testing, and fault locating; replaces the 76C test set.
170A	(Section 634-315-502) Used to trace buried service wire and to pinpoint shield or conductor grounds in service wire (requires AT-8681 B ground probe).
173A	(Section 634-315-501) Used to pinpoint sheath damage in buried PIC cables. Requires an AT-8681 B ground probe when test set is in the fault locating mode.
188A	(Section 081-705-102) A voltage tester used to indicate the presence of hazardous voltages in the range from 50 to 20,000 volts, 60 Hz AC. Up to 2000 volts DC may be tested when using the B temporary bond.
1013B	(Section 106-020-113) This handset has dial capability for communication in outside plant.
1097A	(Sections 634-020-505 and 644-104-100) Narrowband filter designed for use with the 147C amplifier. Permits toning where noise or power influence is a problem.

AT-8629	(Section 105-241-100) Test probe used with 1013-type handset to detect an identification signal on a telephone line without damaging the insulation.
AT-8681	(Section 634-220-505) B ground probe used with 170A and 173A test sets for locating faults in the sheath of buried service wire and buried cable.
KS-14103L6	(Section 634-305-502) Used to break down high resistance faults in paper or pulp insulated copper conductors so they can be run down with an exploring coil.
Dynatel* 710 or equivalent	(Section 634-305-514) Used to locate faults in buried, underground or aerial PIC and pulp cables.
Delcon 4910F or equivalent	(Sections 106-340-110 and 634-305-510) Used for locating opens in conductors.
Metrotech 440 or equivalent	(Sections 106-350-113 and 634-220-501) Used to locate, trace, and determine the depth of underground conductors, pipes, and cable in conduit.
Time Domain (TDR) Reflectometer	A test set such as the TDR cable fault locator sends pulses of energy down a cable pair under test. When these pulses encounter the end of the cable pair or any impedance discontinuity (Fault), a portion of the energy is reflected. The elapsed time for the pulse return is a measure of distance to the fault and the shape of the returned pulse identifies the type of cable fault.

*Trademark of Dynatel Corporation

3.02 The test center (test desk) should have fault locating test sets such as the Delcon 4913A, Dynatel 720, or their equivalent. The test desk should have up-to-date copies of cable records and location maps. These maps will show location of terminals where a cable pair makes multiple appearances or other points of access along the cable route. This will permit the repair forces to make measurements closer to the actual fault location.

3.03 In case wire repair forces have a trouble that is beyond their ability to locate and/or repair, they should arrange for temporary service by making pair transfers before returning the trouble ticket to the dispatch center for subsequent repair. Pair transfers must be made in accordance with local practices. As a rule of thumb, however, the transfer is made after wire repair has made three climbs and/or investigated three terminals without locating the trouble. In the case of resistive type faults, wire repair should assist the test desk in making bridge measurements and should record the results on the trouble ticket. This information will help cable repair in their subsequent work.

3.04 In some instances, the cable repair following these flowcharts will need to replace service wire or drop wire. For this reason, it is important that supplies of this wire and accessories be available on their repair vehicle.

3.05 In the case of buried out-of-sight plant, the procedures were developed with the assumption that the following conditions exist:

(1) Service wires are waterproof.

(2) Cable is waterproof.

(3) Splices and enclosures are encapsulated.

(4) Two pairs are dedicated from a Feeder Distribution Interface (FDI) to the customer and are cut dead ahead.

(5) Any nonworking second pairs are grounded at the protectors.

(6) No access points exist between the FDI and the protector, or between the FDI and the central office.

Although the above assumptions were made in developing the procedures for buried out-of-sight plant, the methods described are applicable even if some of the conditions do not exist.

4. WIRE REPAIR

4.01 Fault locating procedures for wire repair are shown in Fig. 1 through 8. These procedures cover aerial plant, buried plant with pedestal closures, and buried out-of-sight plant.

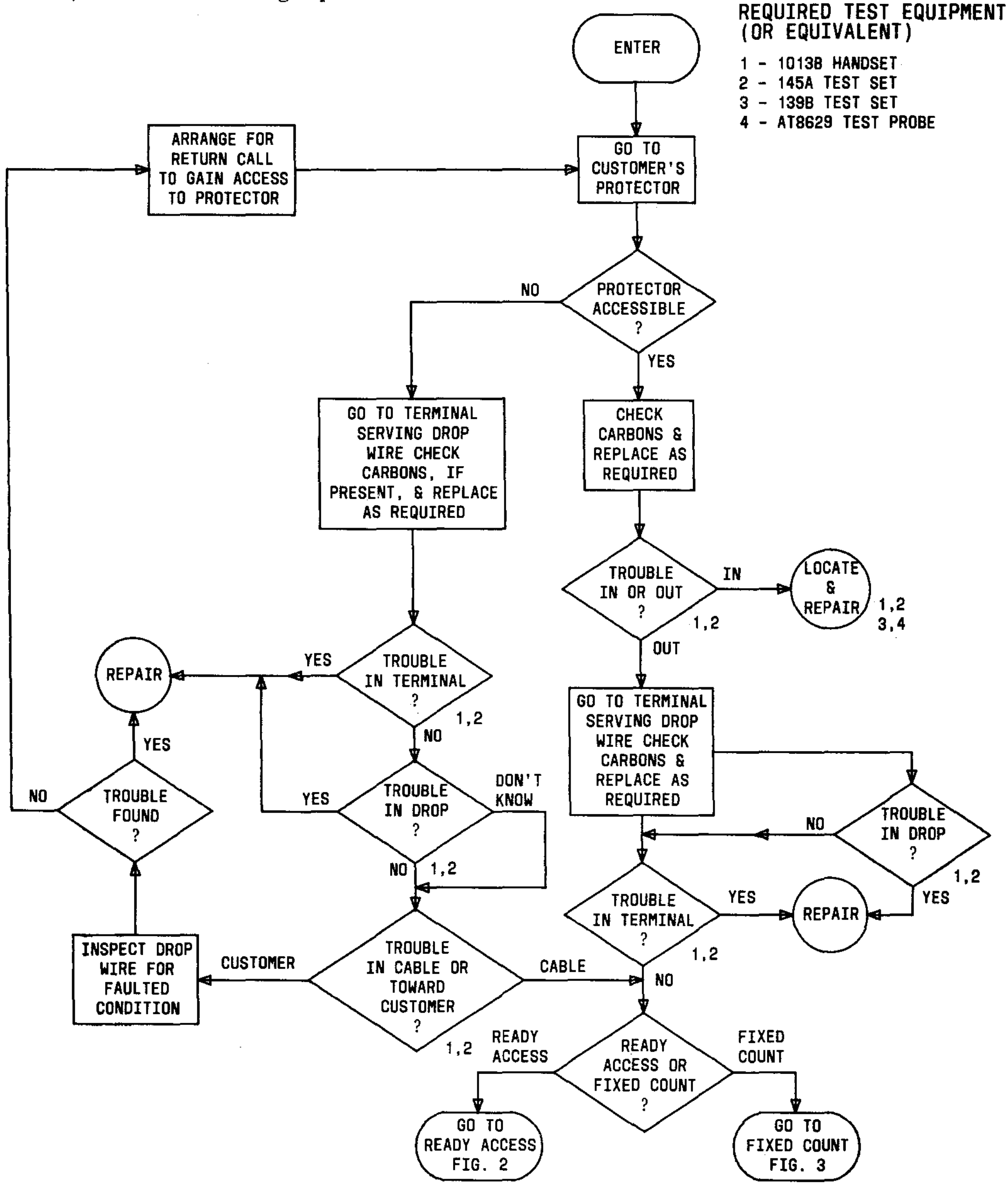


Fig. 1—Wire Repair—Aerial Plant

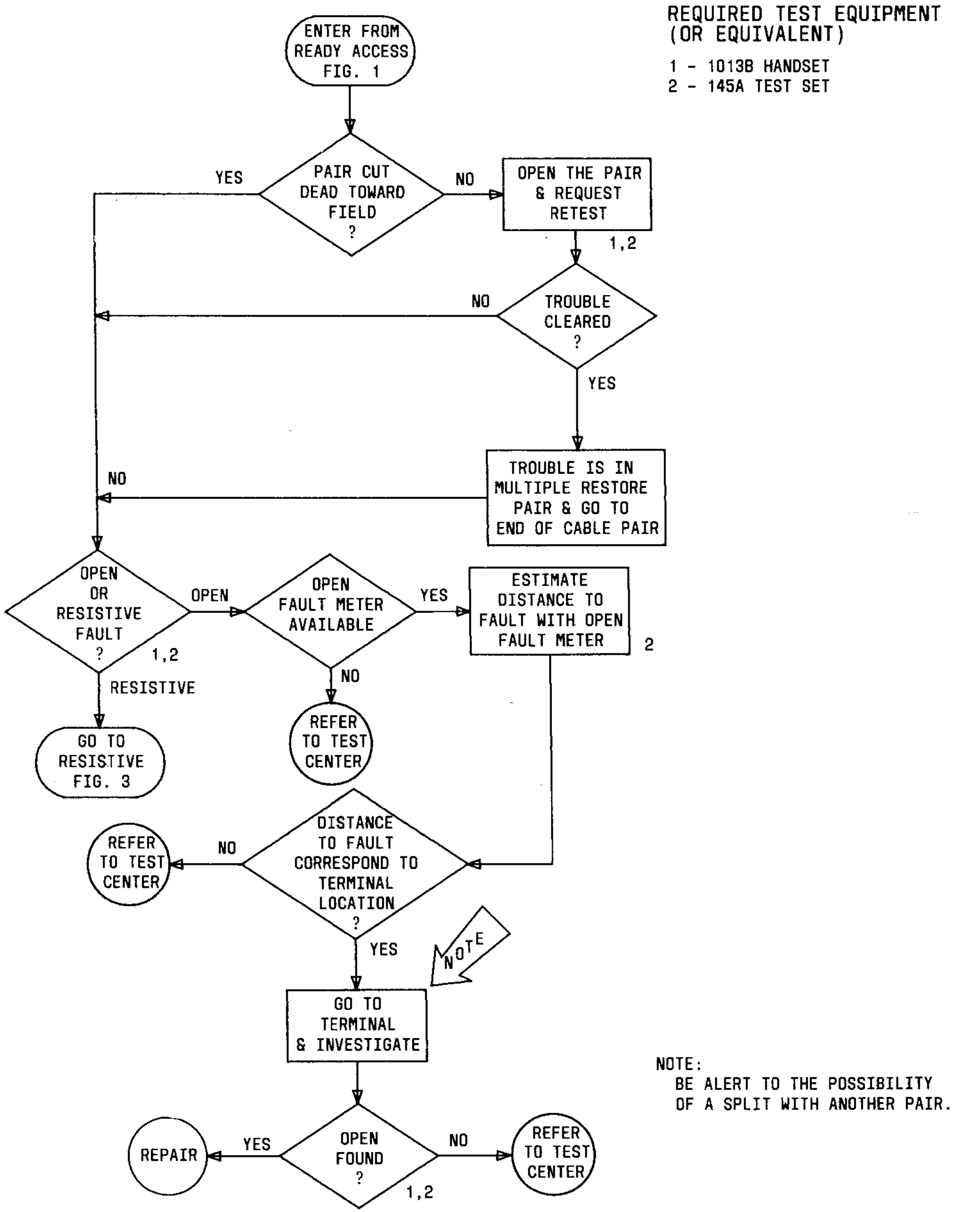


Fig. 2—Wire Repair—Aerial Plant (Ready Access)

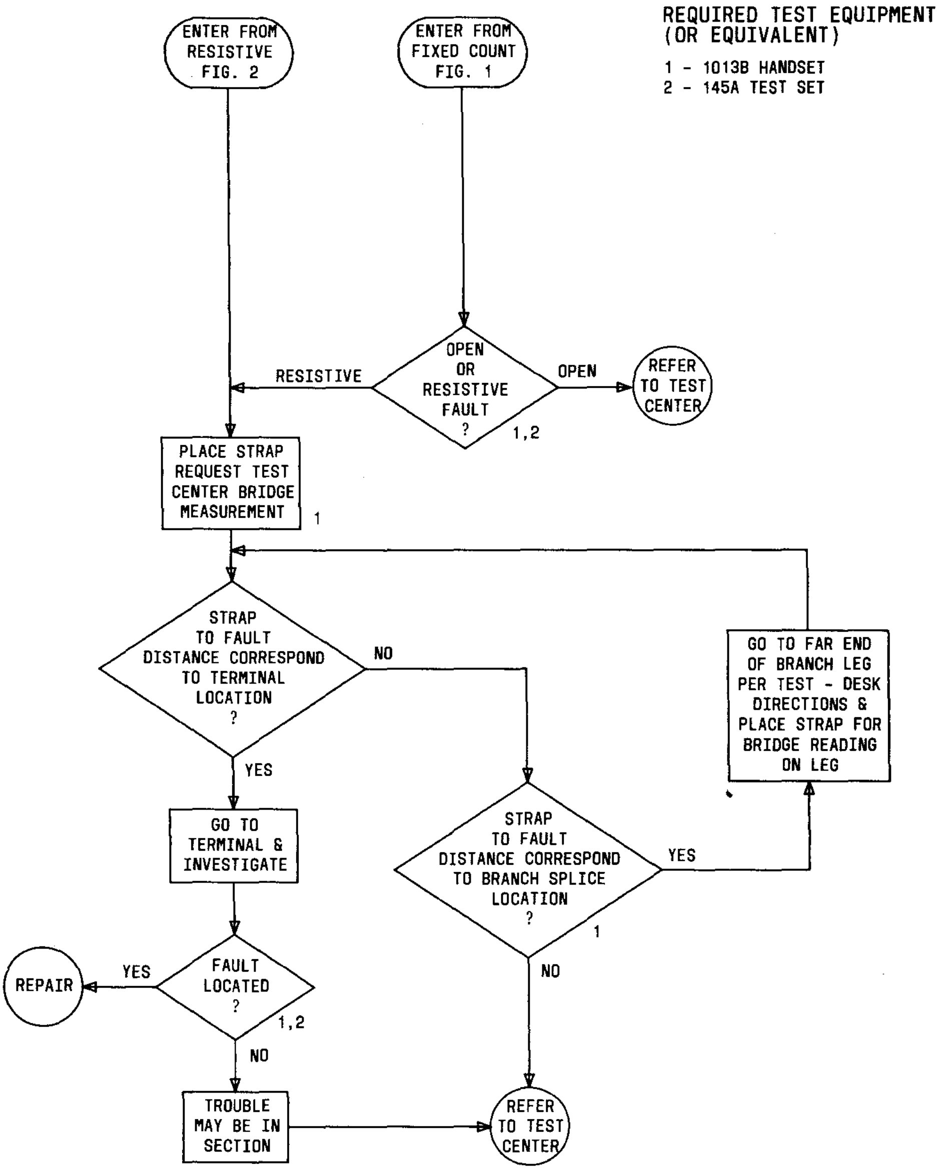


Fig. 3—Wire Repair—Aerial Plant (Fixed Count)

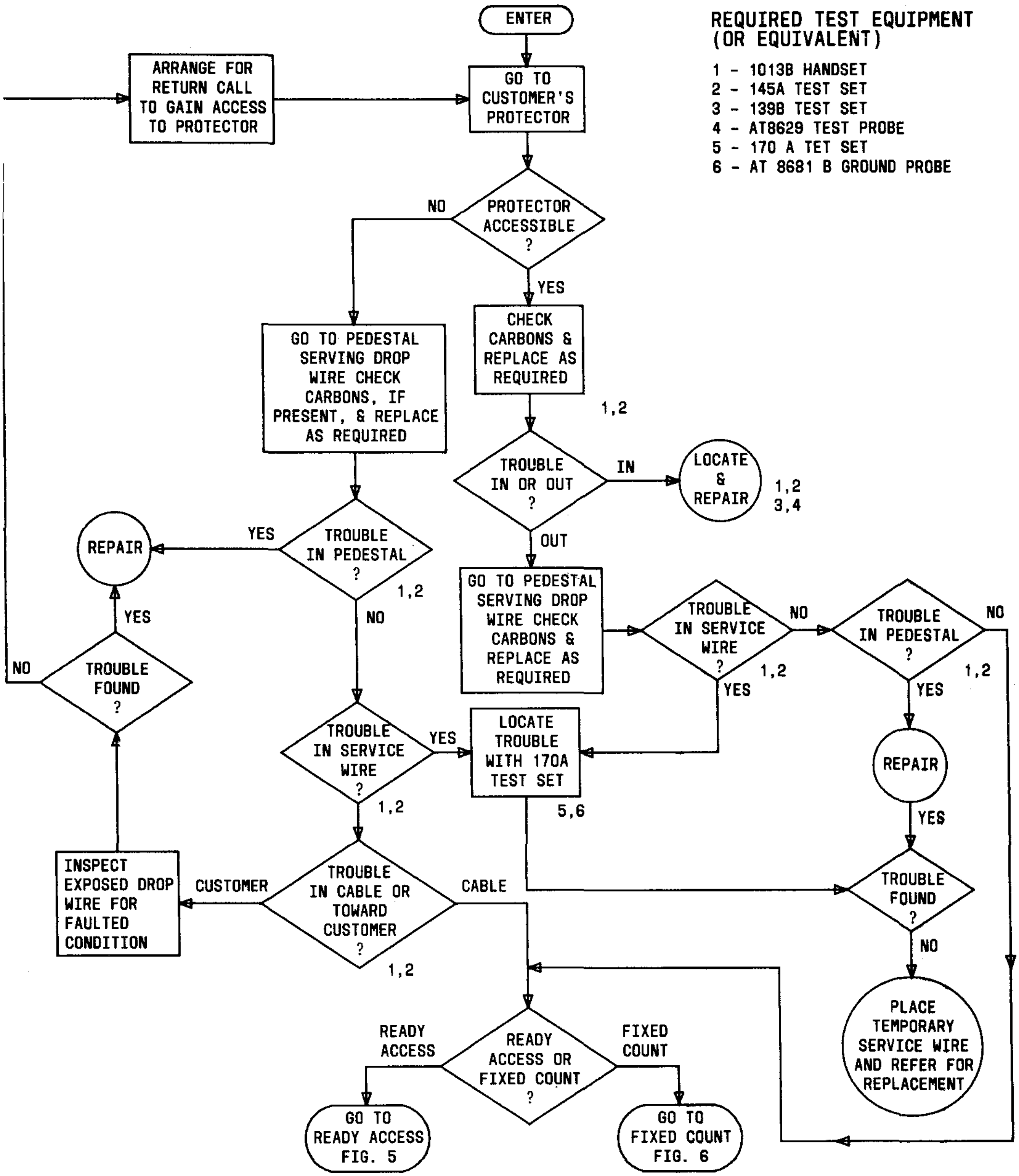
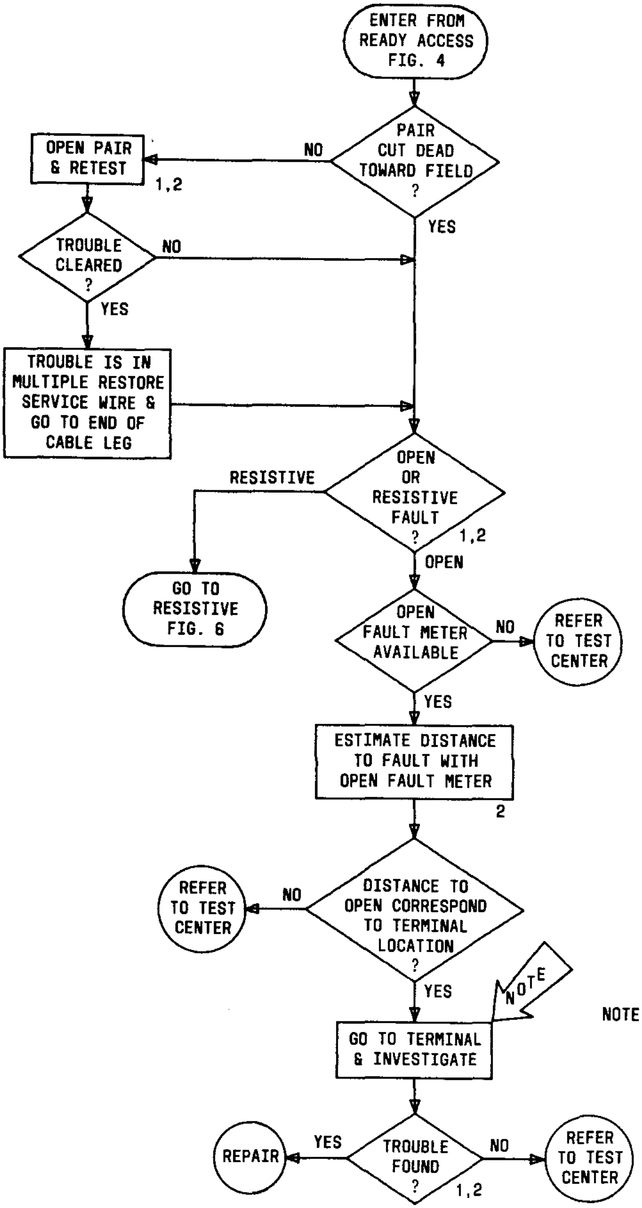


Fig. 4—Wire Repair—Buried Plant With Pedestal Closures



REQUIRED TEST EQUIVALENT (OR EQUIVALENT)

1 - 1013B HANDSET
2 - 145A TEST SET

NOTE: BE ALERT TO THE POSSIBILITY OF A SPLIT WITH ANOTHER PAIR.

Fig. 5—Wire Repair—Buried Plant With Pedestal Closures (Ready Access)

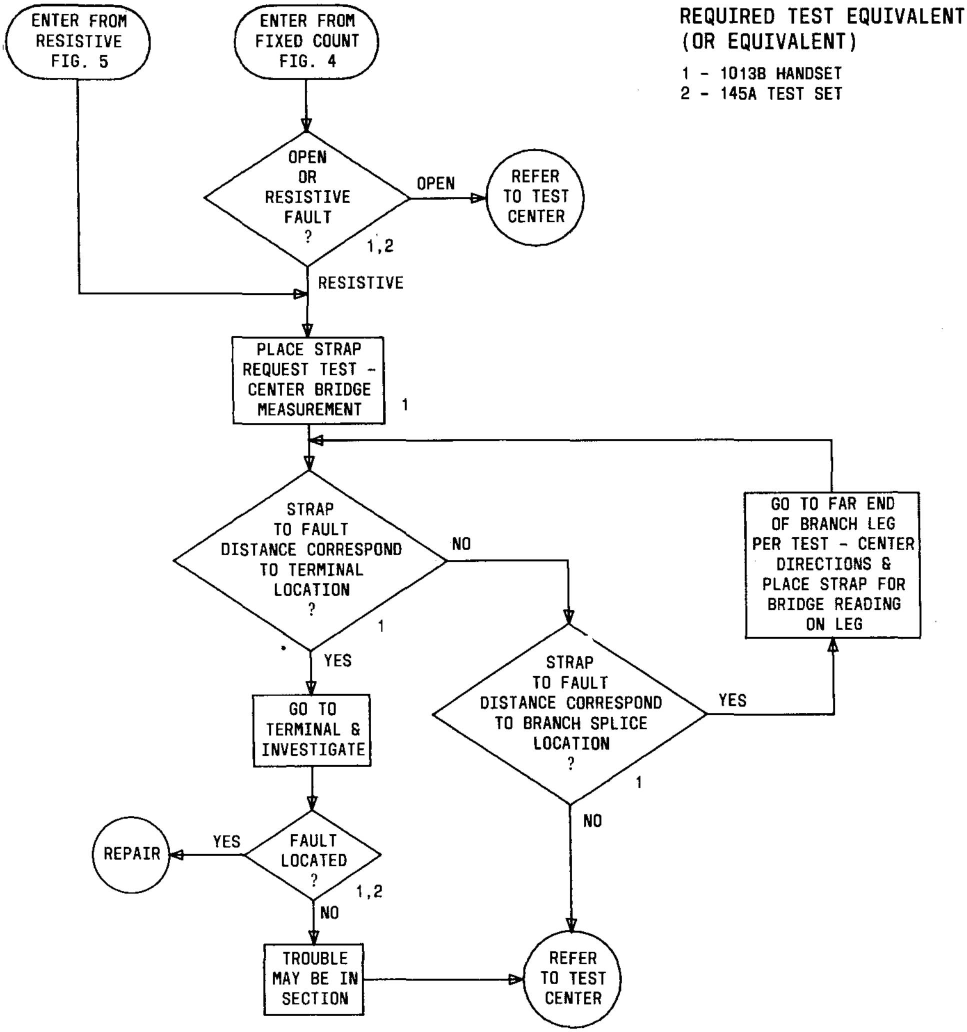


Fig. 6—Wire Repair—Buried Plant With Pedestal Closures (Fixed Count)

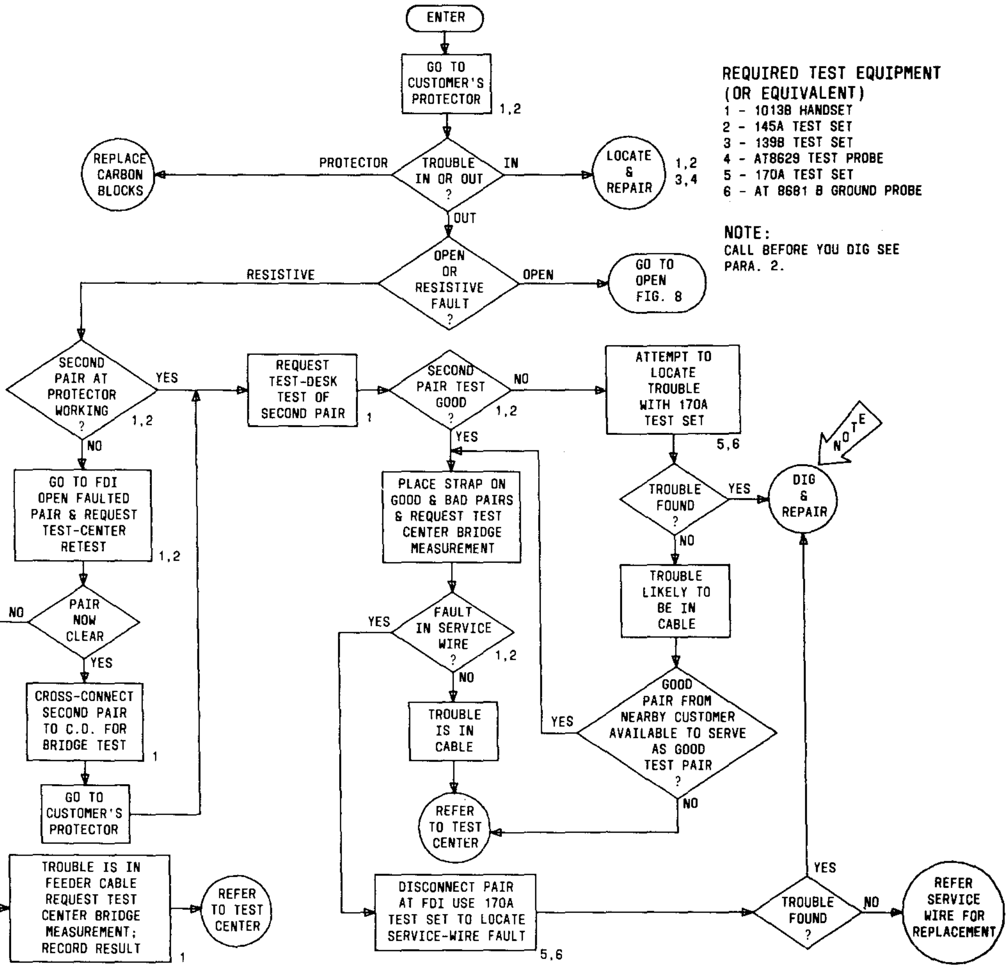


Fig. 7—Wire Repair—Buried Out of Sight

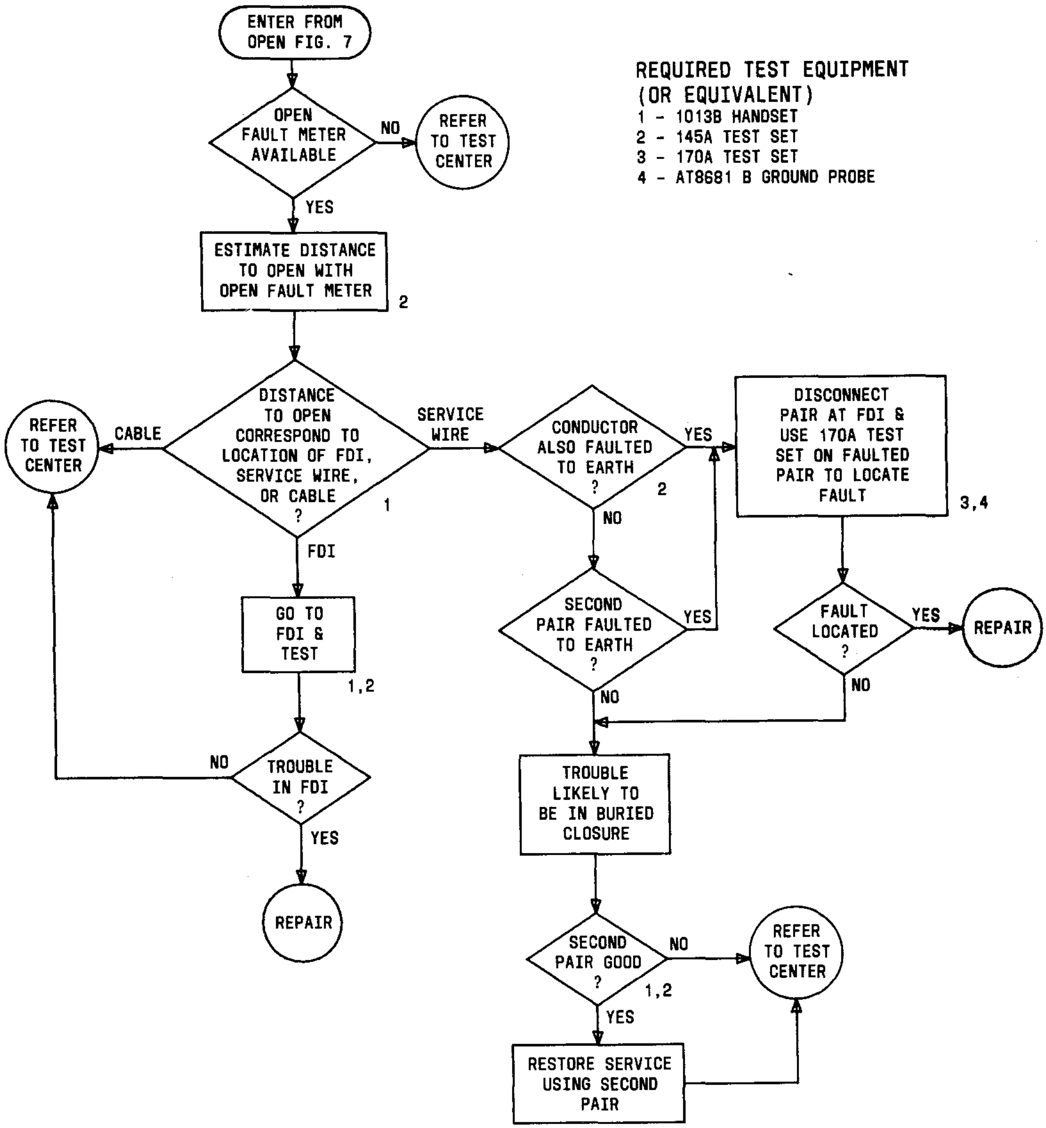
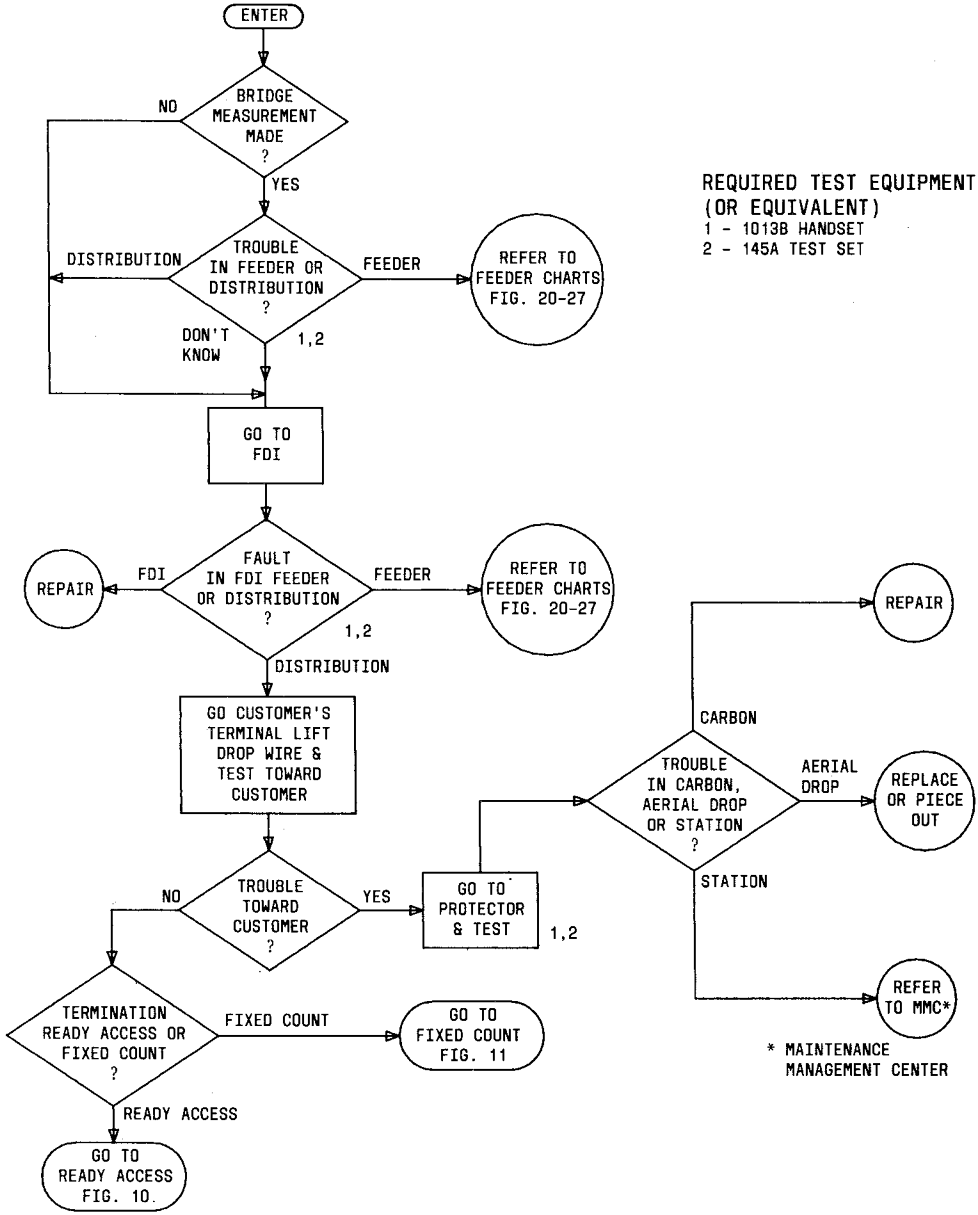


Fig. 8—Wire Repair—Buried Out of Sight (Open Fault)

5. CABLE REPAIR

5.01 Fault locating procedures for cable repair are shown in Fig. 9 through 27. These procedures cover:

- Aerial distribution
- Buried distribution with pedestal closures
- Buried out-of-sight distribution
- Aerial feeder
- Buried feeder with pedestal closures
- Buried out-of-sight feeder
- Underground feeder.



REQUIRED TEST EQUIPMENT
(OR EQUIVALENT)
1 - 1013B HANDSET
2 - 145A TEST SET

Fig. 9—Cable Repair—Aerial Distribution

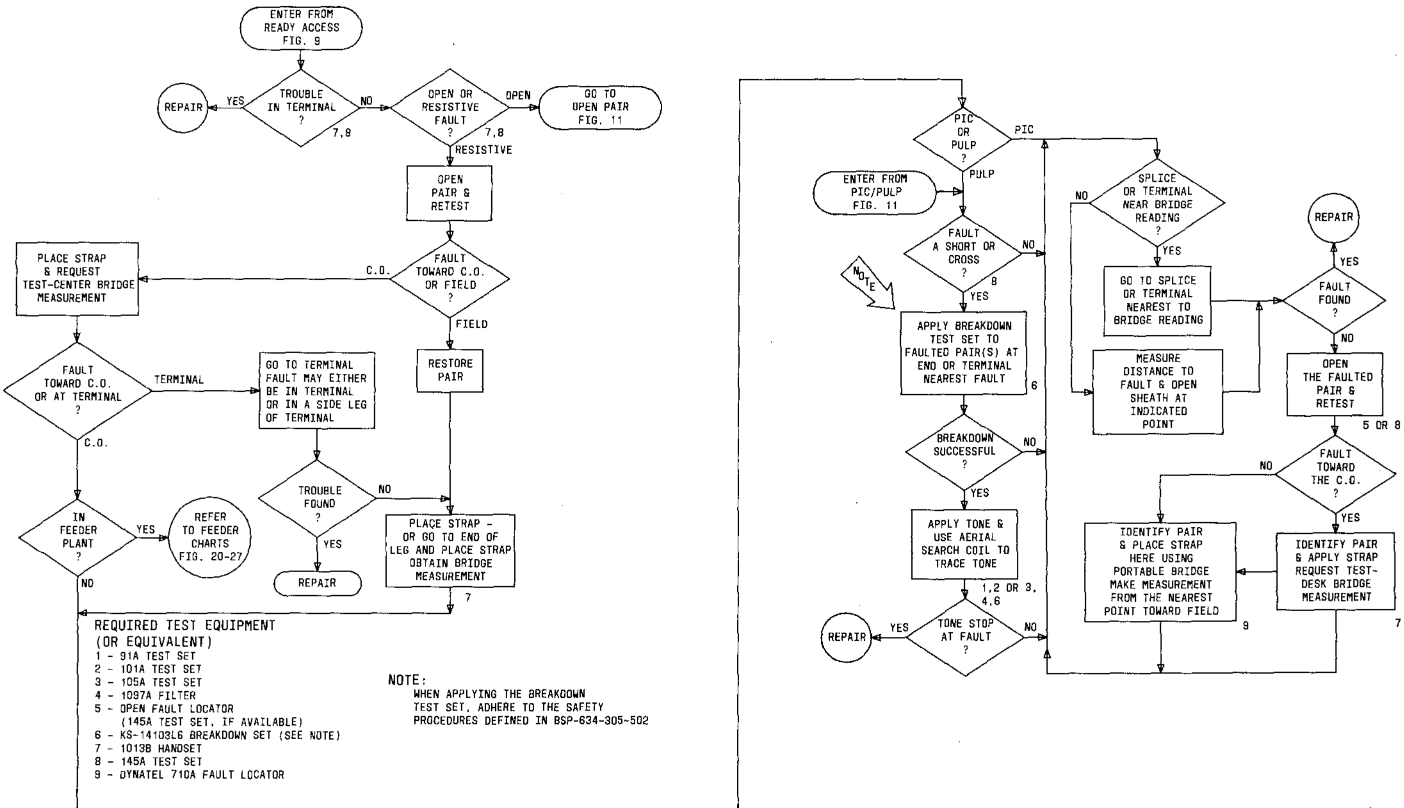


Fig. 10—Cable Repair—Aerial Distribution (Ready Access)

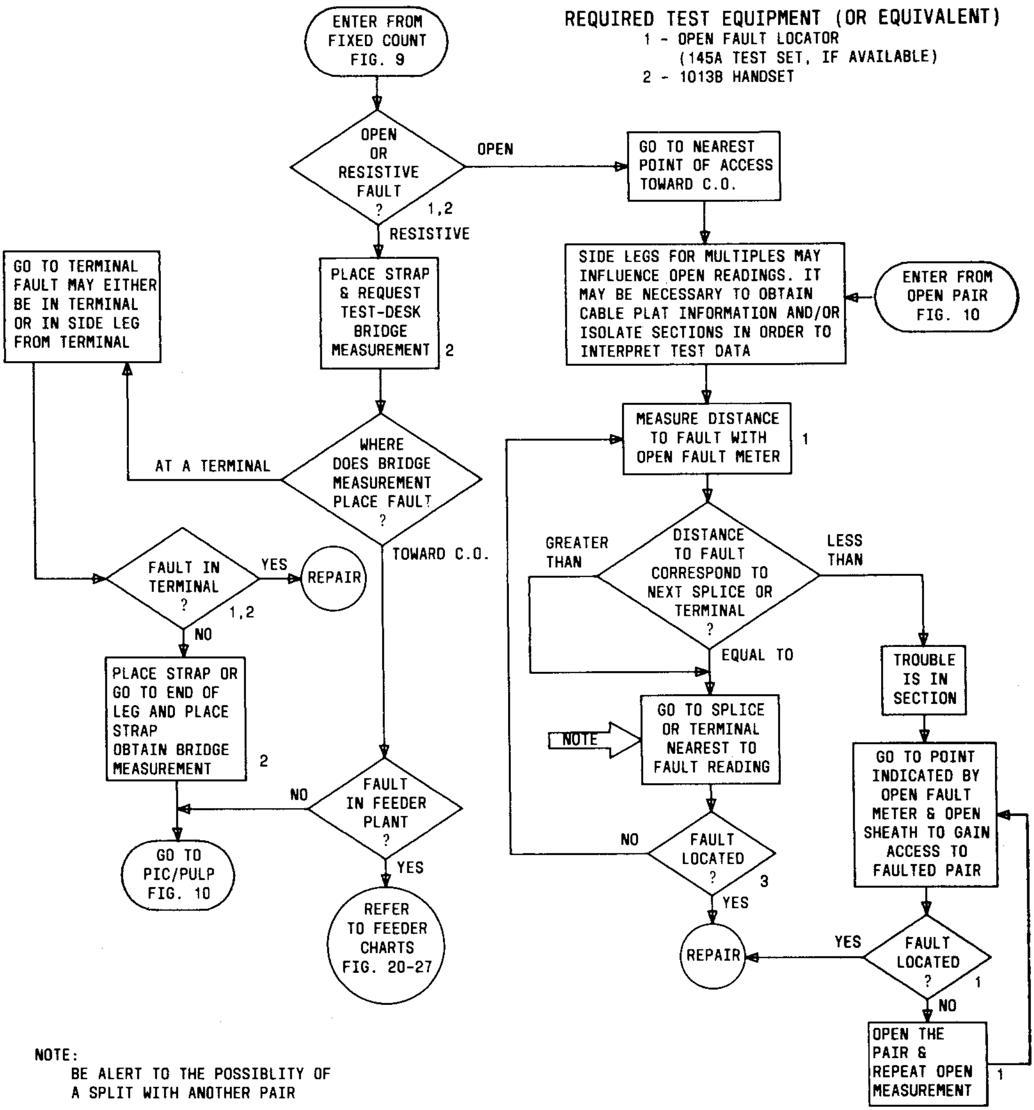


Fig. 11—Cable Repair—Aerial Distribution (Fixed Count, Open Fault)

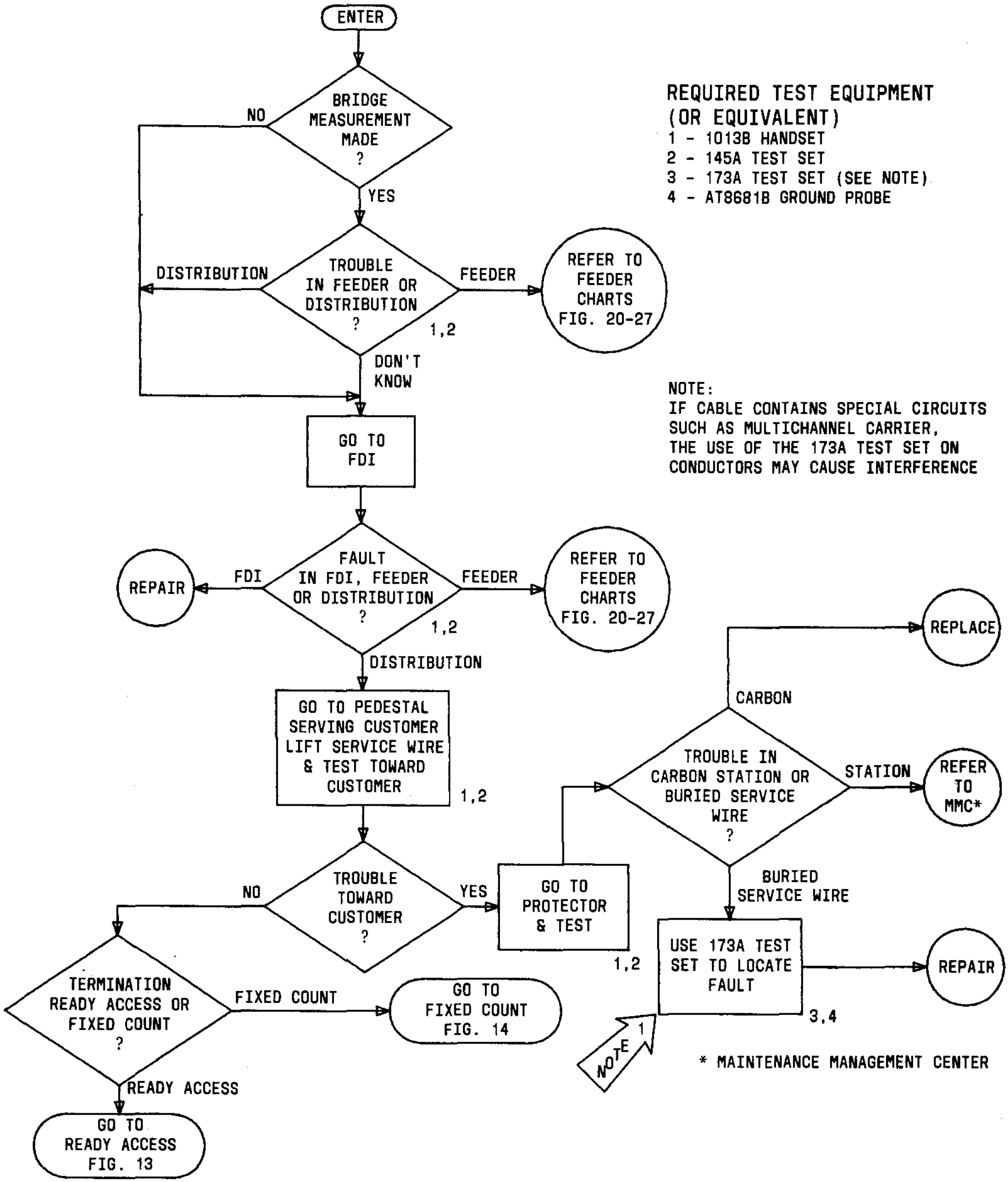


Fig. 12—Cable Repair—Buried Distribution With Pedestal Closures

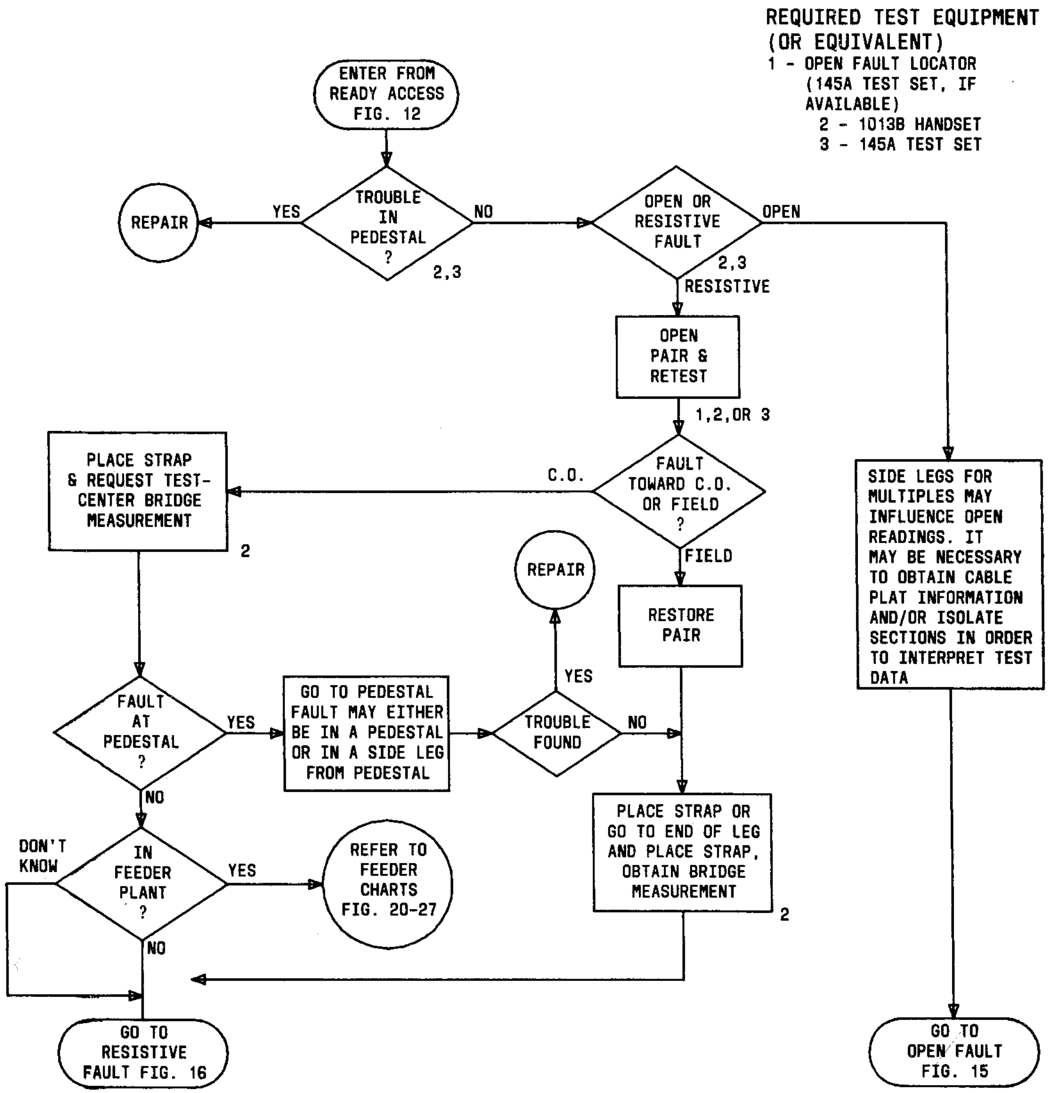


Fig. 13—Cable Repair—Buried Distribution With Pedestal Closures (Ready Access)

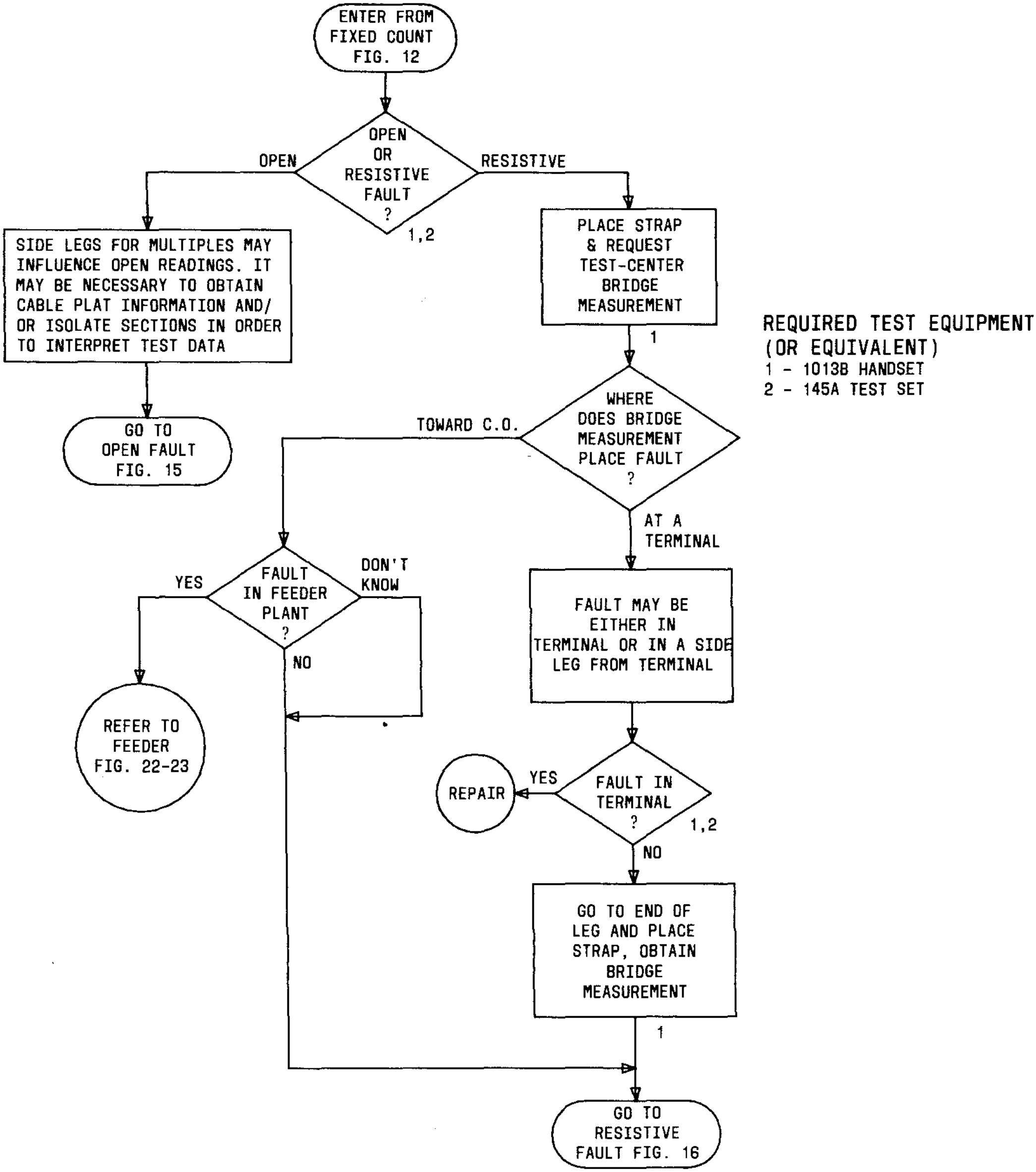


Fig. 14—Cable Repair—Buried Distribution With Pedestal Closures (Fixed Count)

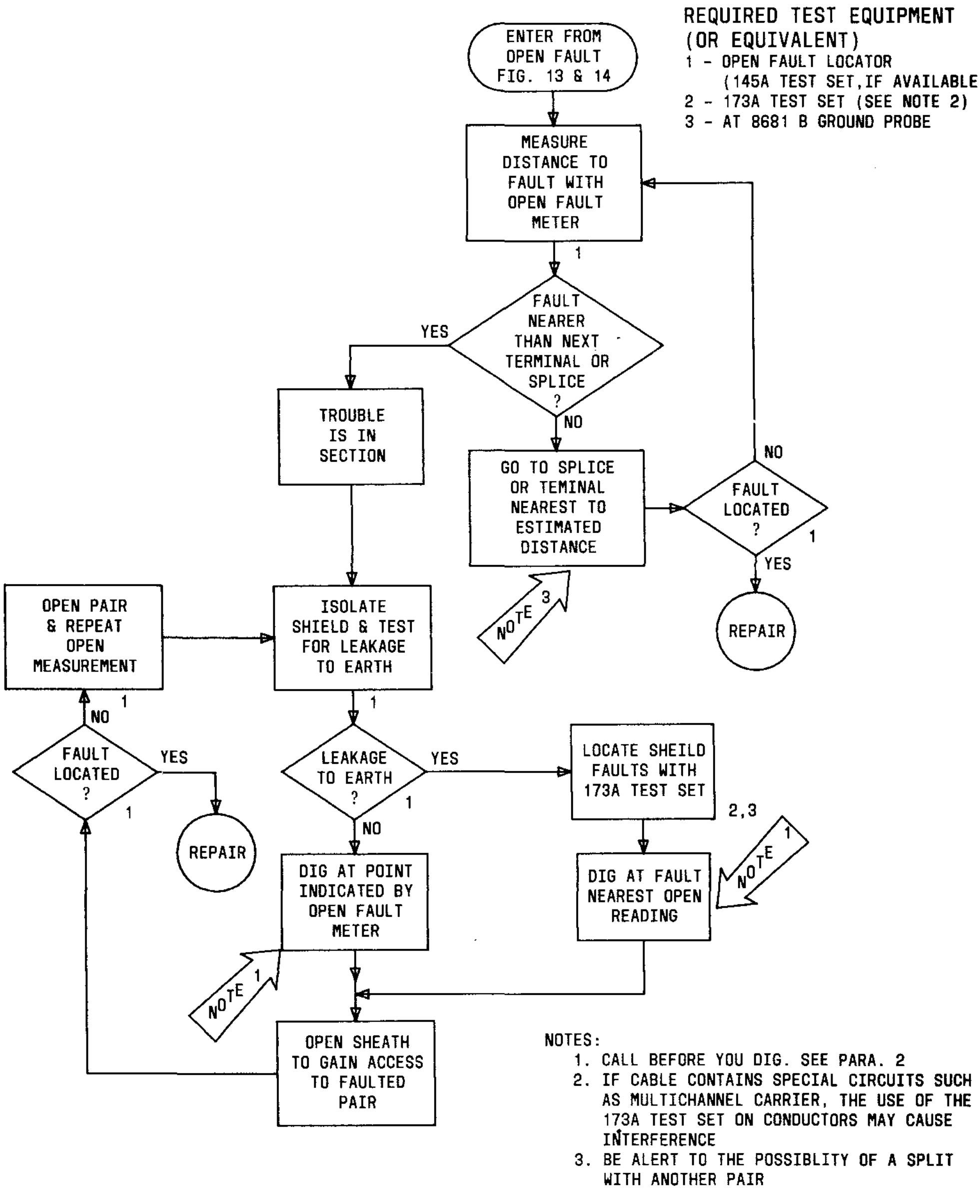


Fig. 15—Cable Repair—Buried Distribution With Pedestal Closures (Open Fault)

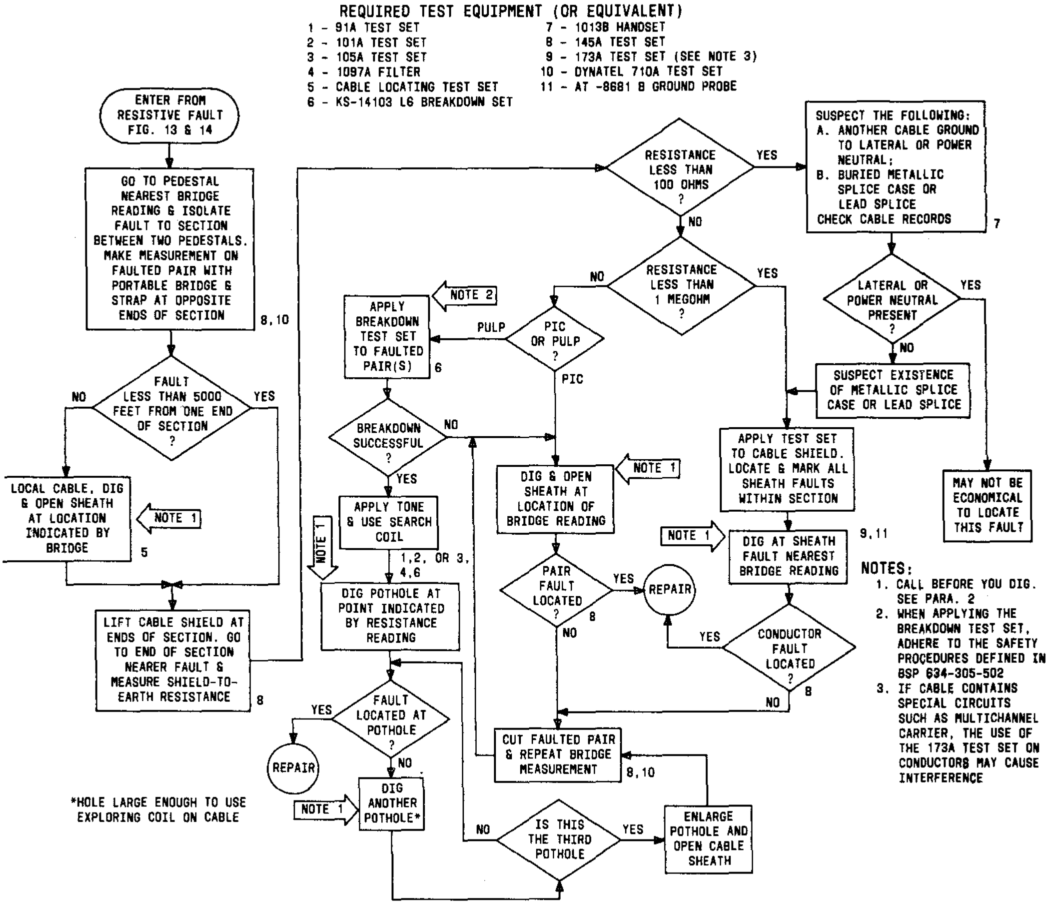


Fig. 16—Cable Repair—Buried Distribution With Pedestal Closures (Resistive Fault)

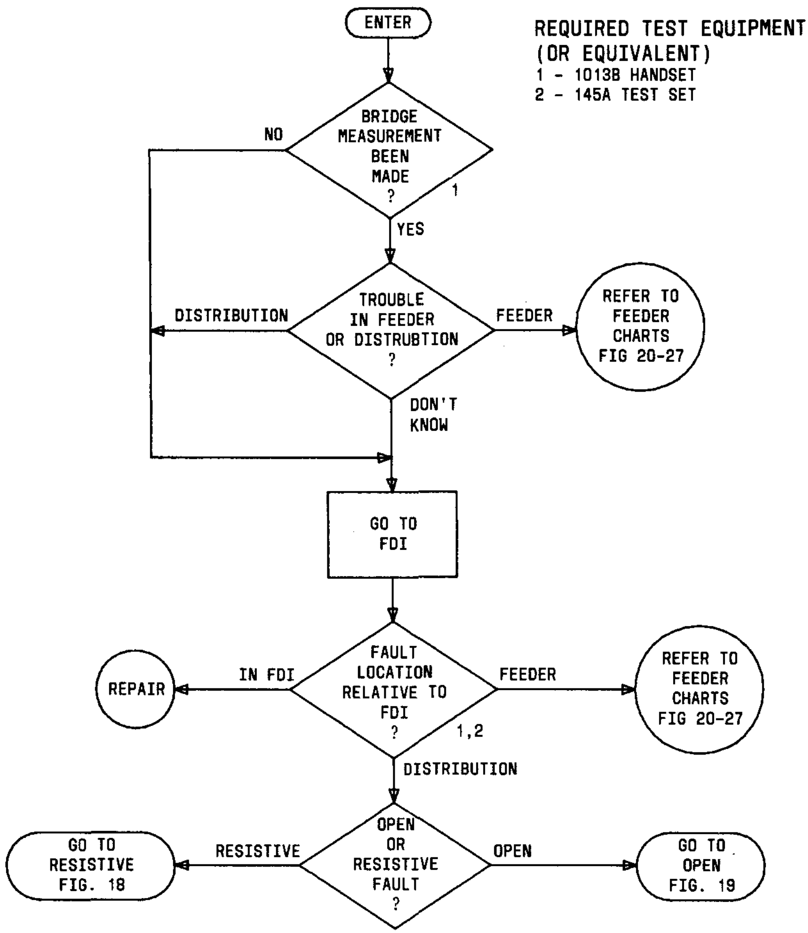
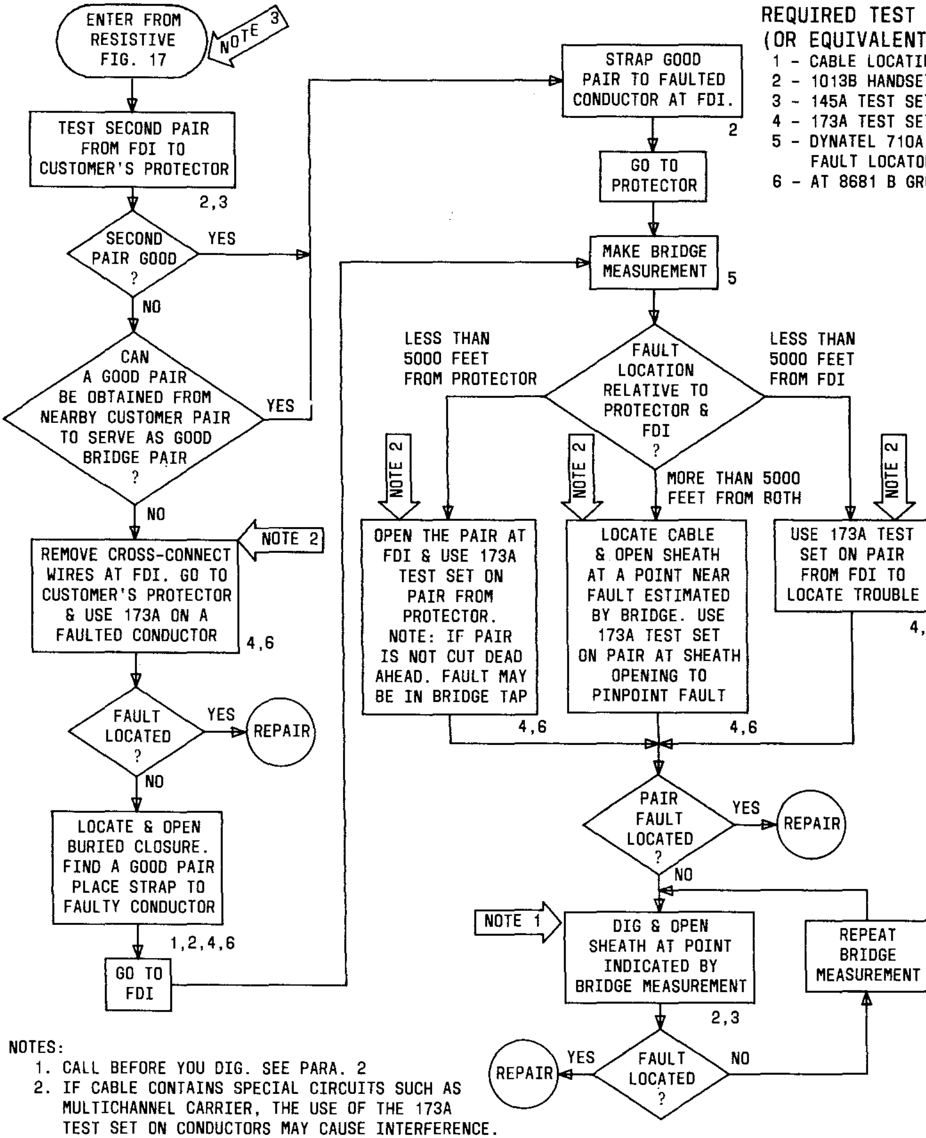


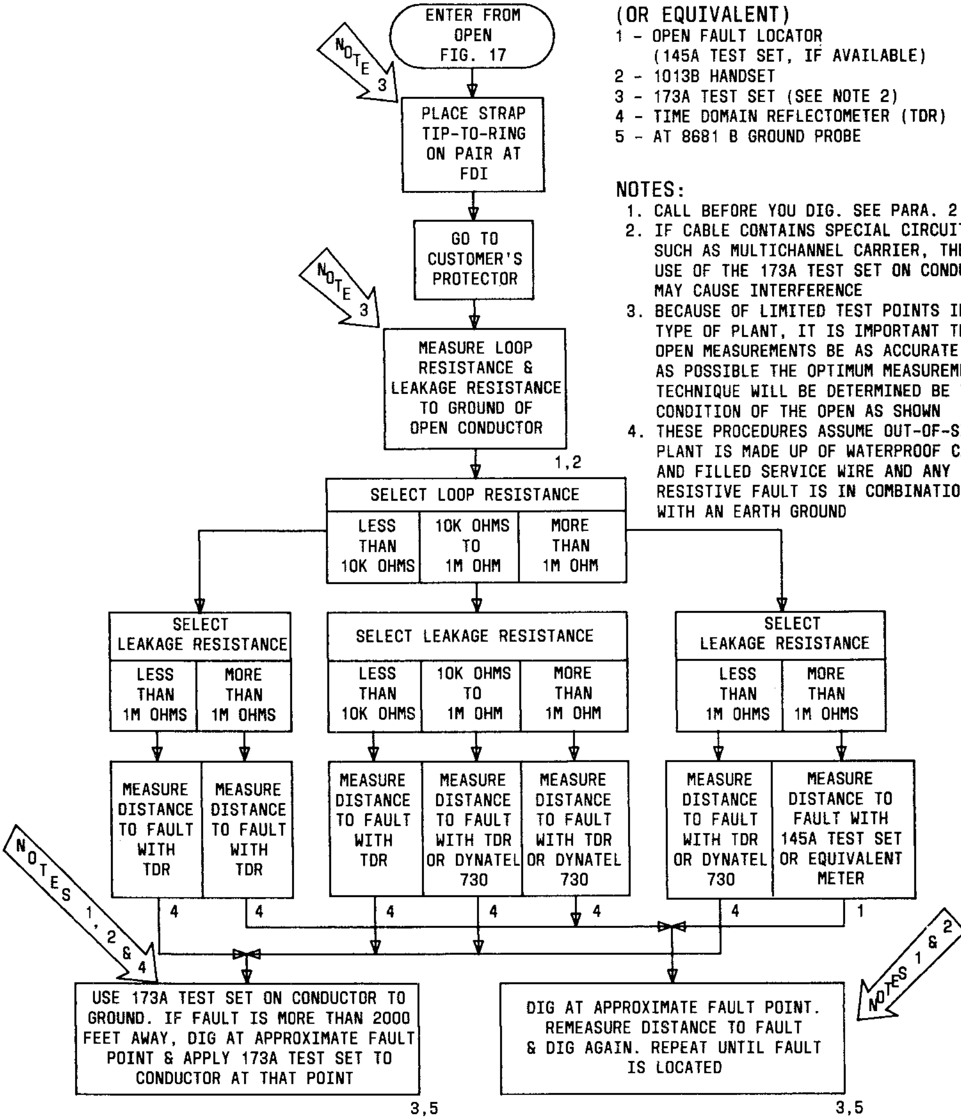
Fig. 17—Cable Repair—Buried Out-of-Sight Distribution



REQUIRED TEST EQUIPMENT (OR EQUIVALENT)
1 - CABLE LOCATING TEST SET
2 - 1013B HANDSET
3 - 145A TEST SET
4 - 173A TEST SET
5 - DYNATEL 710A FAULT LOCATOR
6 - AT 8681 B GROUND PROBE

NOTES:
1. CALL BEFORE YOU DIG. SEE PARA. 2
2. IF CABLE CONTAINS SPECIAL CIRCUITS SUCH AS MULTICHANNEL CARRIER, THE USE OF THE 173A TEST SET ON CONDUCTORS MAY CAUSE INTERFERENCE.
3. THESE PROCEDURES ASSUME OUT-OF-SIGHT PLANT IS MADE UP OF WATERPROOF CABLE AND FILLED SERVICE WIRE AND ANY RESISTIVE FAULT IS IN COMBINATION WITH EARTH GROUND

Fig. 18—Cable Repair—Buried Out-of-Sight Distribution (Resistive Fault)



REQUIRED TEST EQUIPMENT (OR EQUIVALENT)

1 - OPEN FAULT LOCATOR (145A TEST SET, IF AVAILABLE)
2 - 1013B HANDSET
3 - 173A TEST SET (SEE NOTE 2)
4 - TIME DOMAIN REFLECTOMETER (TDR)
5 - AT 8681 B GROUND PROBE

NOTES:

1. CALL BEFORE YOU DIG. SEE PARA. 2
2. IF CABLE CONTAINS SPECIAL CIRCUITS SUCH AS MULTICHANNEL CARRIER, THE USE OF THE 173A TEST SET ON CONDUCTORS MAY CAUSE INTERFERENCE
3. BECAUSE OF LIMITED TEST POINTS IN THIS TYPE OF PLANT, IT IS IMPORTANT THAT OPEN MEASUREMENTS BE AS ACCURATE AS POSSIBLE THE OPTIMUM MEASUREMENT TECHNIQUE WILL BE DETERMINED BE THE CONDITION OF THE OPEN AS SHOWN
4. THESE PROCEDURES ASSUME OUT-OF-SIGHT PLANT IS MADE UP OF WATERPROOF CABLE AND FILLED SERVICE WIRE AND ANY RESISTIVE FAULT IS IN COMBINATION WITH AN EARTH GROUND

Fig. 19—Cable Repair—Buried Out-of-Sight Distribution (Open Fault)

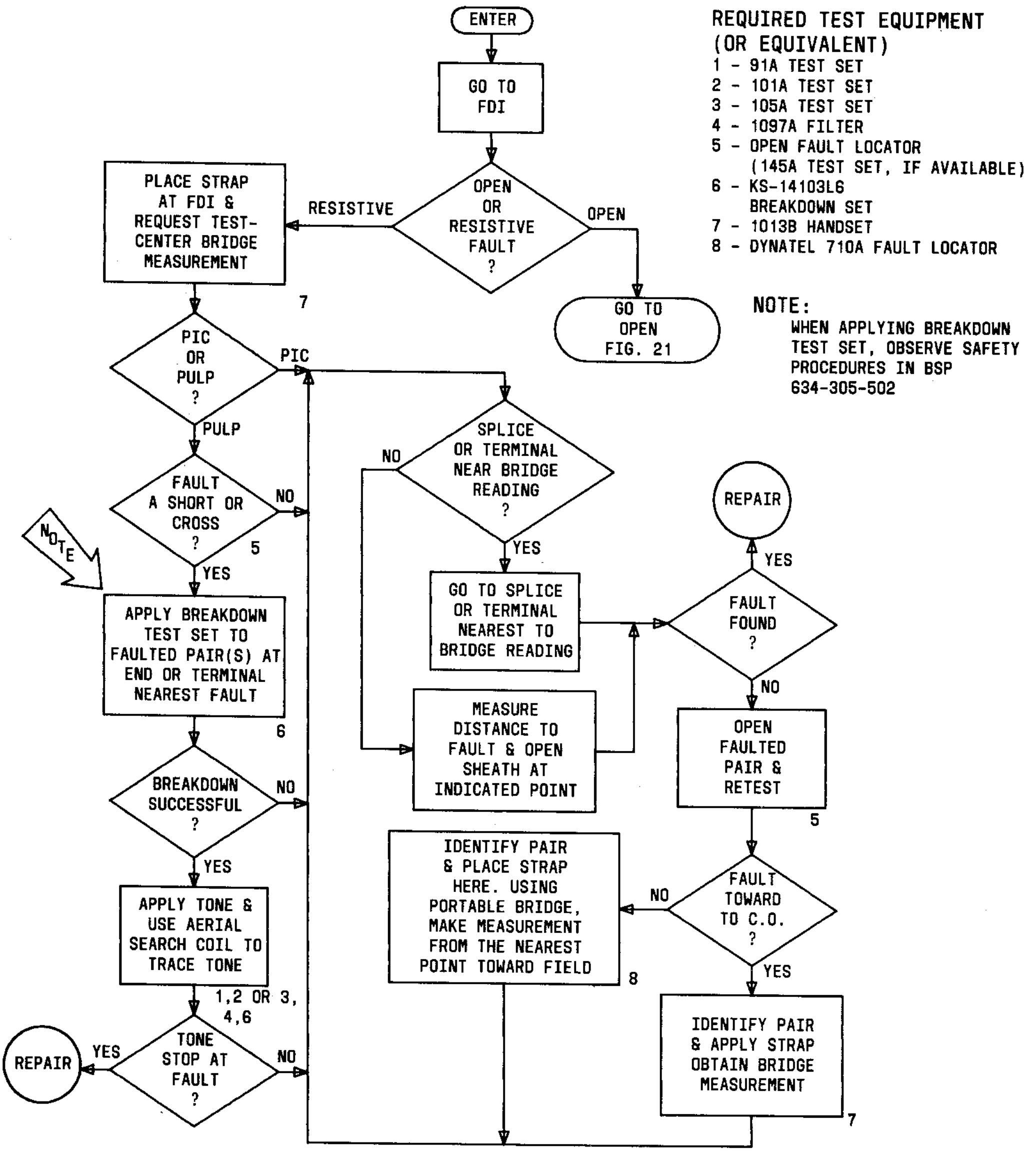


Fig. 20—Cable Repair—Aerial Feeder

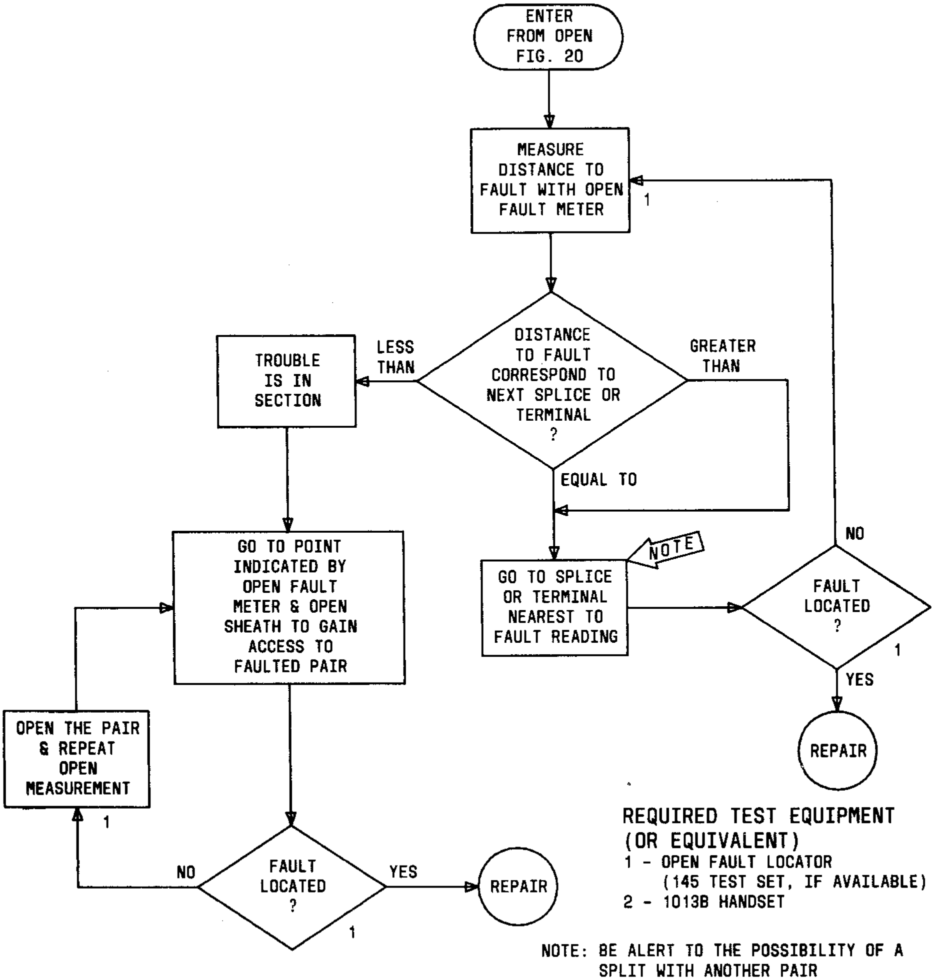


Fig. 21—Cable Repair—Aerial Feeder (Open Fault)

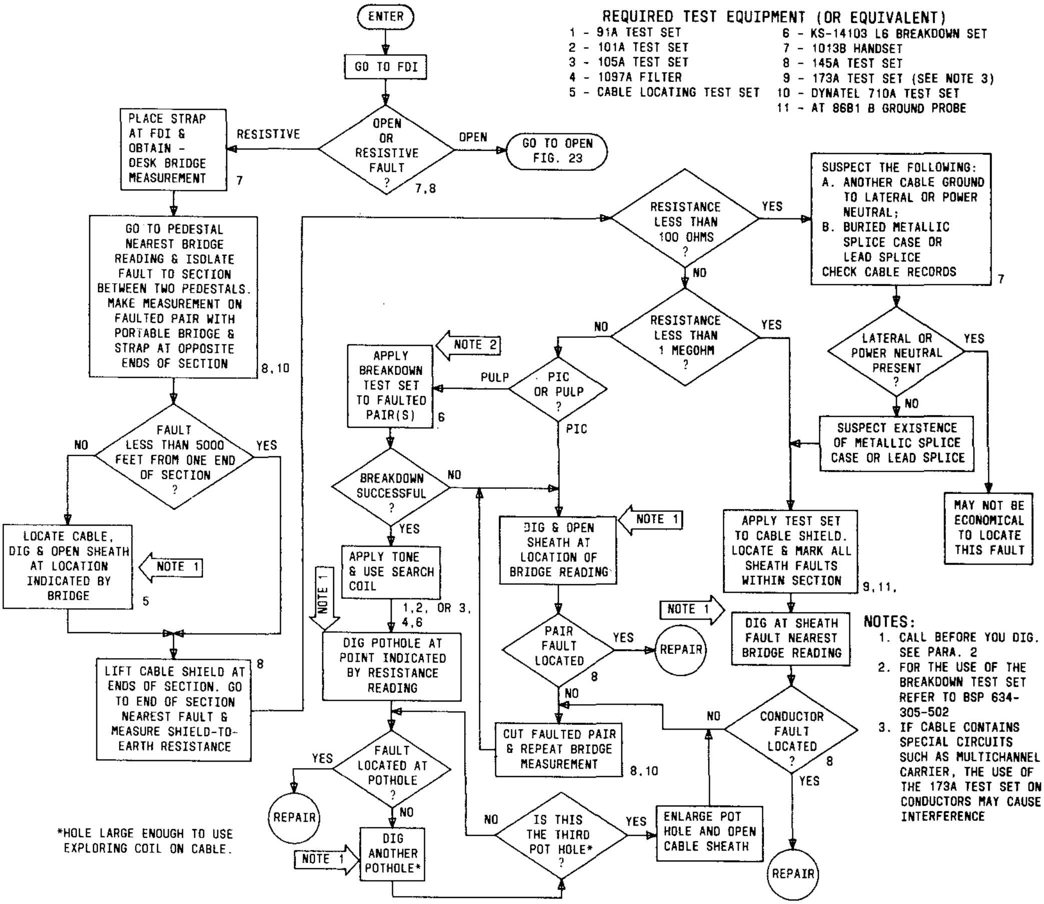
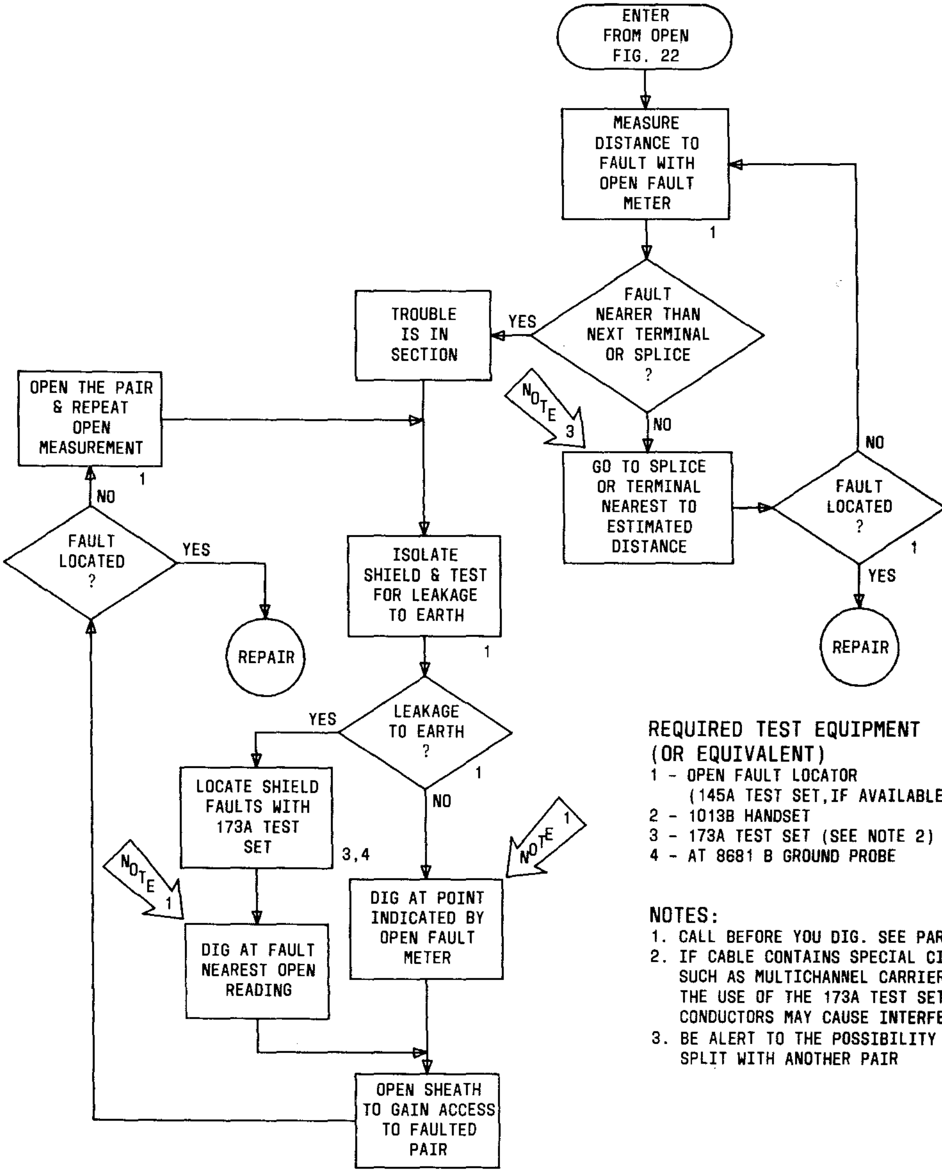


Fig. 22—Cable Repair—Buried Feeder With Pedestal Closures



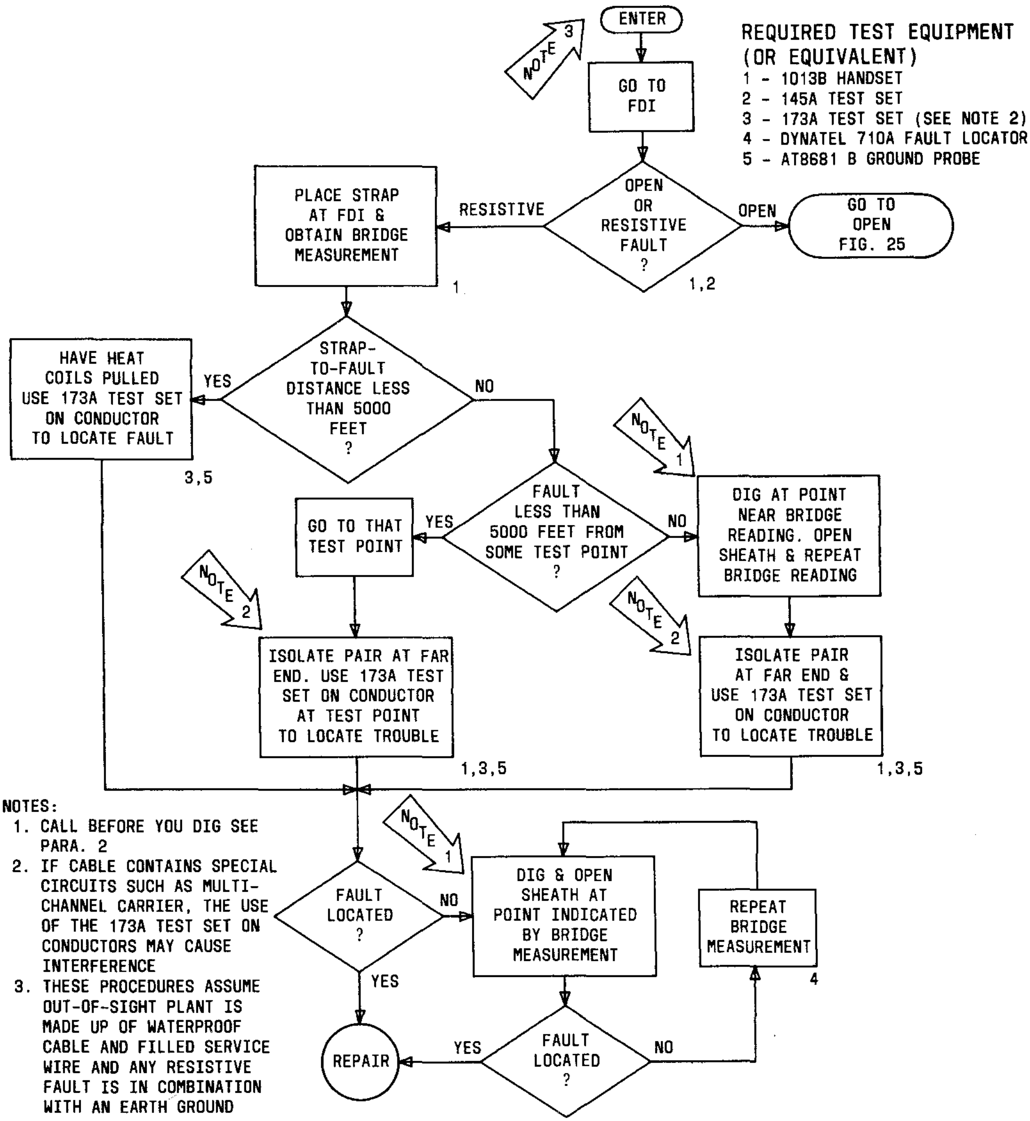
REQUIRED TEST EQUIPMENT
(OR EQUIVALENT)

1 - OPEN FAULT LOCATOR
    (145A TEST SET,IF AVAILABLE)
2 - 1013B HANDSET
3 - 173A TEST SET (SEE NOTE 2)
4 - AT 8681 B GROUND PROBE

NOTES:

1. CALL BEFORE YOU DIG. SEE PARA. 2.
2. IF CABLE CONTAINS SPECIAL CIRCUITS SUCH AS MULTICHANNEL CARRIER, THE USE OF THE 173A TEST SET ON CONDUCTORS MAY CAUSE INTERFERENCE
3. BE ALERT TO THE POSSIBILITY OF A SPLIT WITH ANOTHER PAIR

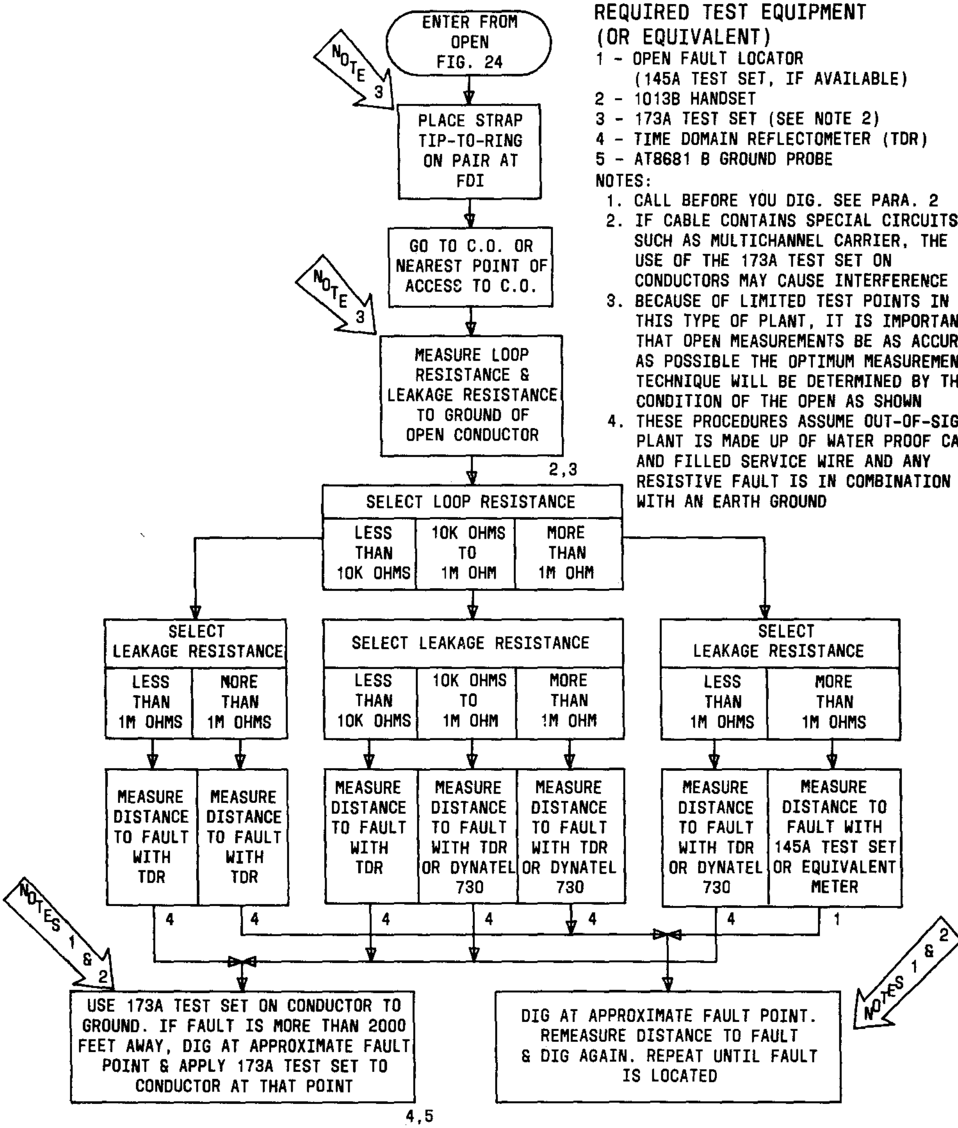
Fig. 23—Cable Repair—Buried Feeder With Pedestal Closures (Open Fault)



NOTES:

1. CALL BEFORE YOU DIG SEE PARA. 2
2. IF CABLE CONTAINS SPECIAL CIRCUITS SUCH AS MULTI-CHANNEL CARRIER, THE USE OF THE 173A TEST SET ON CONDUCTORS MAY CAUSE INTERFERENCE
3. THESE PROCEDURES ASSUME OUT-OF-SIGHT PLANT IS MADE UP OF WATERPROOF CABLE AND FILLED SERVICE WIRE AND ANY RESISTIVE FAULT IS IN COMBINATION WITH AN EARTH GROUND

Fig. 24—Cable Repair—Buried Out-of-Sight Feeder



REQUIRED TEST EQUIPMENT
(OR EQUIVALENT)

1 - OPEN FAULT LOCATOR
(145A TEST SET, IF AVAILABLE)
2 - 1013B HANDSET
3 - 173A TEST SET (SEE NOTE 2)
4 - TIME DOMAIN REFLECTOMETER (TDR)
5 - AT8681 B GROUND PROBE

NOTES:

1. CALL BEFORE YOU DIG. SEE PARA. 2
2. IF CABLE CONTAINS SPECIAL CIRCUITS SUCH AS MULTICHANNEL CARRIER, THE USE OF THE 173A TEST SET ON CONDUCTORS MAY CAUSE INTERFERENCE
3. BECAUSE OF LIMITED TEST POINTS IN THIS TYPE OF PLANT, IT IS IMPORTANT THAT OPEN MEASUREMENTS BE AS ACCURATE AS POSSIBLE THE OPTIMUM MEASUREMENT TECHNIQUE WILL BE DETERMINED BY THE CONDITION OF THE OPEN AS SHOWN
4. THESE PROCEDURES ASSUME OUT-OF-SIGHT PLANT IS MADE UP OF WATER PROOF CABLE AND FILLED SERVICE WIRE AND ANY RESISTIVE FAULT IS IN COMBINATION WITH AN EARTH GROUND

Fig. 25—Cable Repair—Buried Out-of-Sight Feeder (Open Fault)

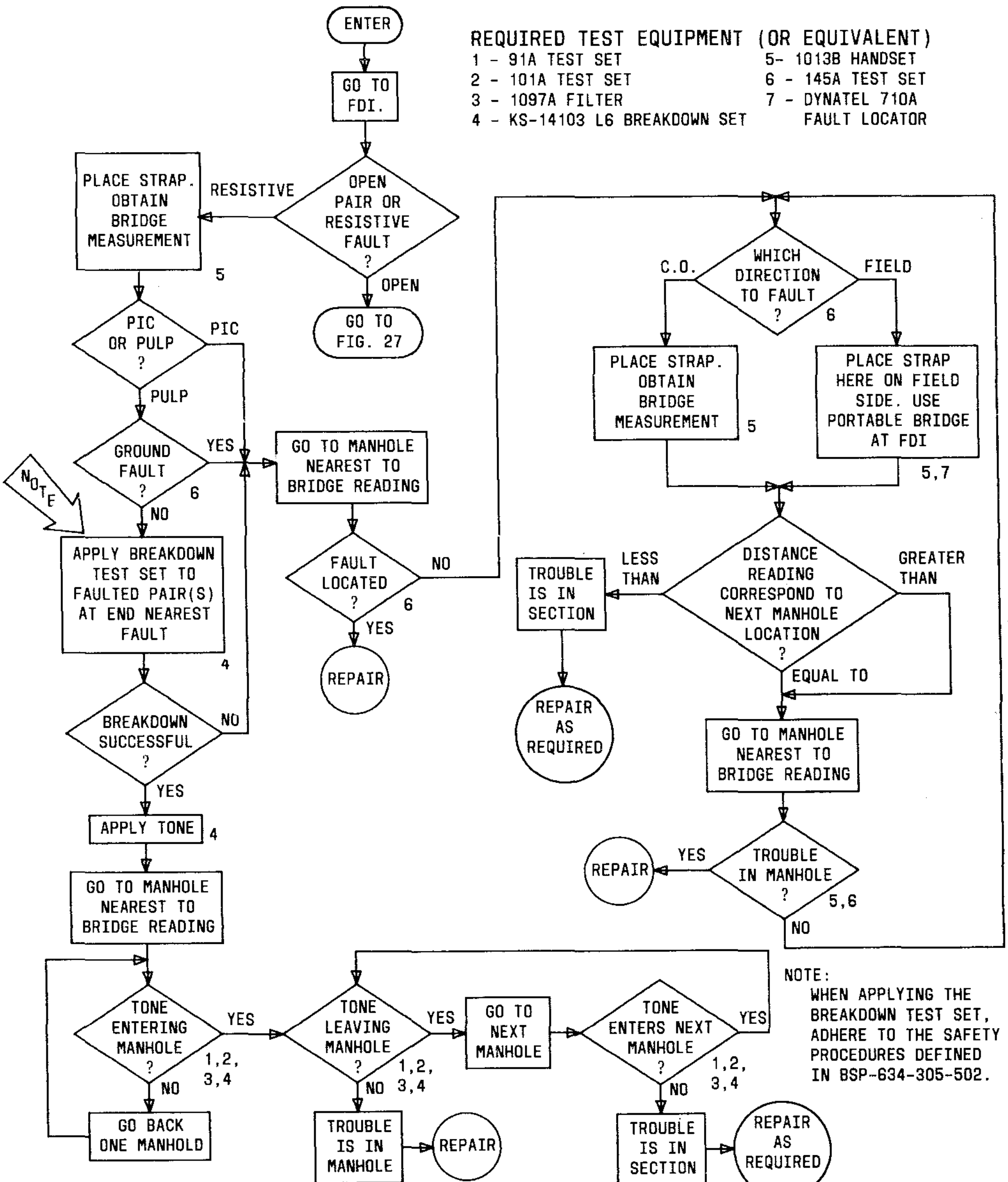


Fig. 26—Cable Repair—Underground Feeder

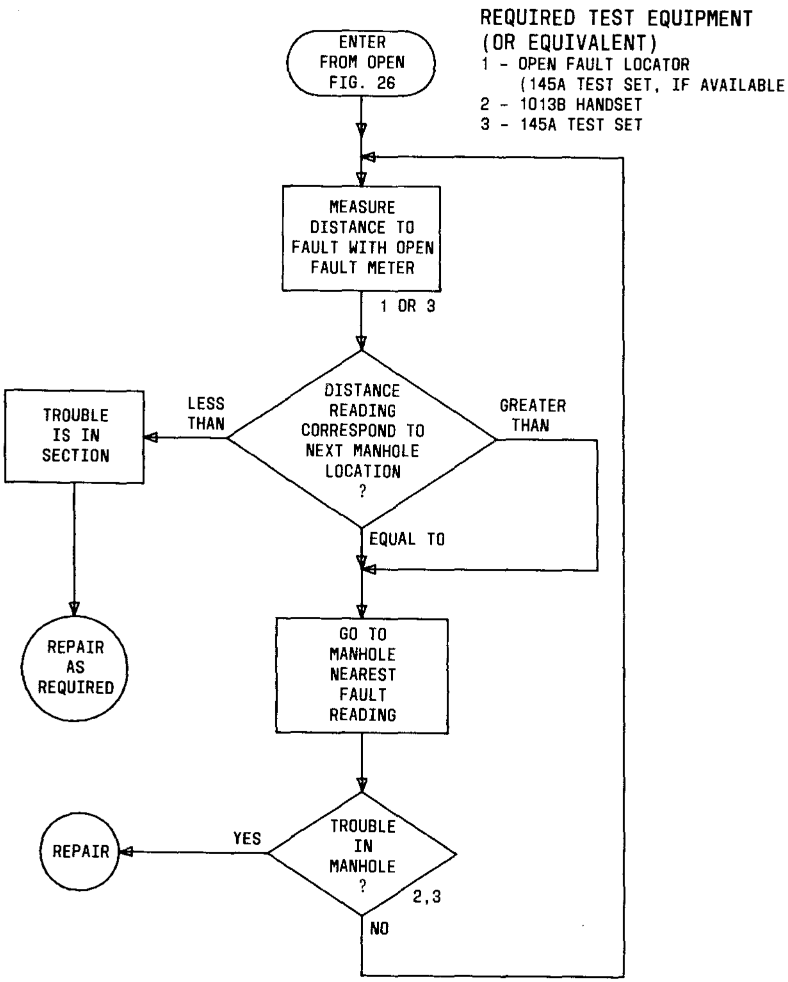
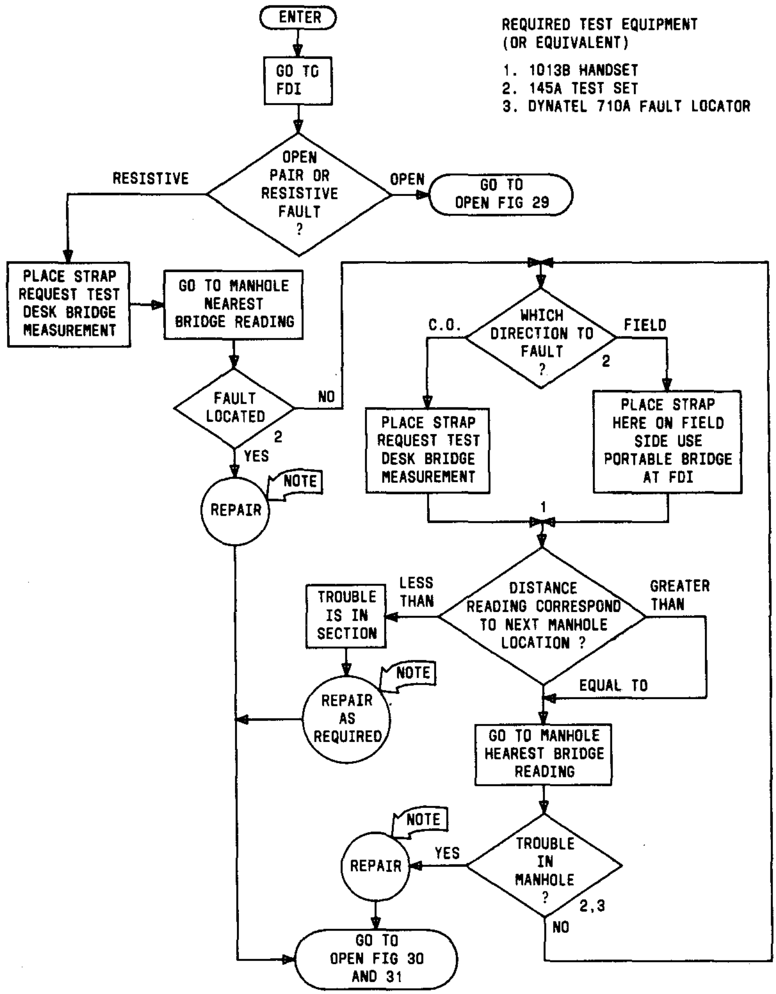


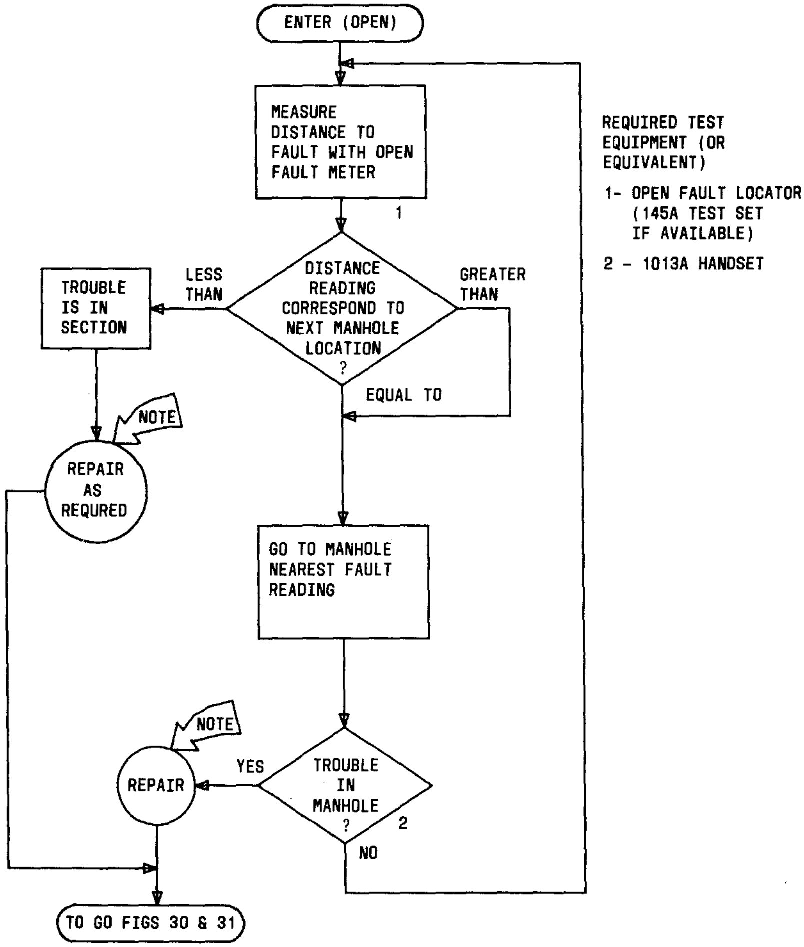
Fig. 27—Cable Repair—Underground Feeder (Open Fault)

5.02 The detection of conductor faults in cable plant is usually associated with customer trouble reports, ALIT, noisy carrier circuits and the like. These faults are usually caused by water entering the cable, lightning surges, physical damage to the sheath or other similar mishaps. The various techniques for locating conductor faults consist of a series of flowcharts that are designed to provide a systematic approach to fault location. Figures 28 and 29 are flowcharts relating to PIC cable repair in the underground plant. In addition, Fig. 30 and 31 cover the procedure to be followed when the cable trouble is known or suspected to be water related.



NOTE:
AFTER REPAIR OF RESISTIVE FAULT IS COMPLETED, AND IT IS SUSPECTED THAT THE TROUBLE WAS WATER RELATED, TESTS USING THE 176A SICK PIC OR TDR SHOULD BE MADE IN BOTH DIRECTION FROM THE OPEN SPLICE TO ENSURE THAT NO WATER IS PRESENT IN ADJACENT CABLE SECTIONS - SEE FIGURES 30 AND 31

Fig. 28—Resistive Fault—Underground PIC



NOTE:
AFTER REPAIR OF OPEN FAULT IS COMPLETED, AND IT IS SUSPECTED THAT THE TROUBLE WAS WATER RELATED, TESTS USING THE 176A SICK PIC OR TDR SHOULD BE MADE IN BOTH DIRECTION FROM THE OPEN SPLICE TO ENSURE THAT NO WATER IS PRESENT IN ADJACENT CABLE SECTIONS - SEE FIGURES 30 AND 31.

Fig. 29—Open Fault—Underground PIC

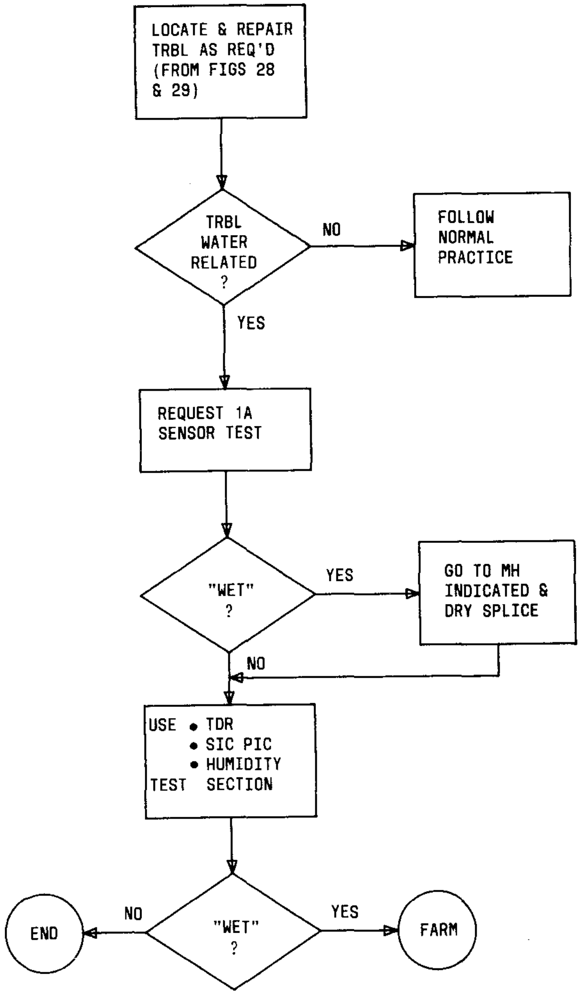


Fig. 30—Craft Procedure

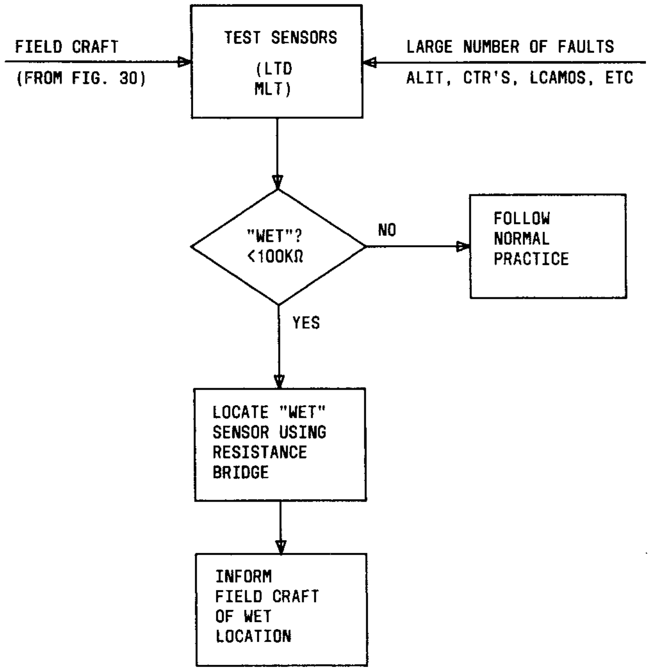
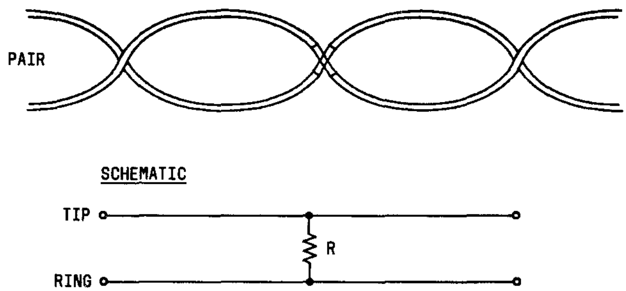


Fig. 31—Test Center Procedure

6. TYPE OF FAULTS

6.01 Typical faults to be found along with a description of the fault, symptoms and probable causes are shown in Fig. 32 through 38.

6.02 Splicing errors can include opens and crosses. However, the most common would include splits, transpositions, splice backs, and reversals. Since splicing errors should be corrected during acceptance testing, these kinds of faults have ***not*** been included in this section.

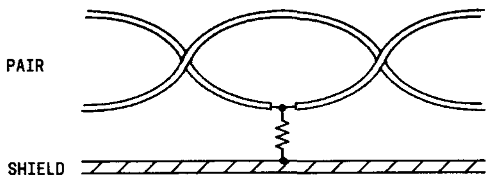


DESCRIPTION - THE TWO WIRES OF A PAIR ARE IN CONTACT WITH EACH OTHER OR IN CONTACT WITH EACH OTHER THROUGH A RESISTIVE PATH

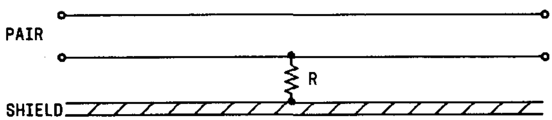
SYMPTOMS -
- RESISTANCE FROM TIP TO RING IN RANGE OF 0 TO 2 MEGOHM
- MAY BE A REDUCTION IN SIGNAL LEVEL
- MAY HAVE PERMANENT DIAL TONE
- CUSTOMER'S LINE MAY BE NOISY

PROBABLE CAUSES -
- BREAKDOWN TEST APPLICATION
- CABLE DAMAGE
- MOISTURE
- METALLIC CONTACT OF WIRES
- LIGHTNING DAMAGE
- ABRASION OF SERVICE WIRE
- TERMINAL DETERIOATION
- CORROSION
- INSECT OR RODENT ACTIVITY

Fig. 32—Short



SCHEMATIC



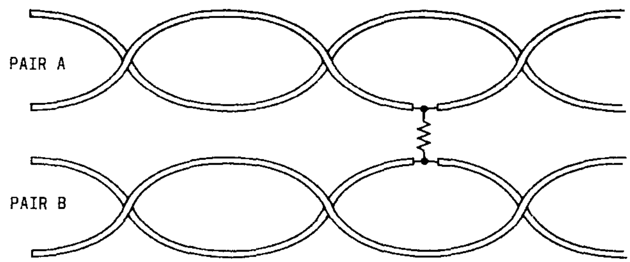
DESCRIPTION - EITHER TIP OR RING OR TIP AND RING ARE IN CONTACT WITH SHIELD OF THE CABLE OR OTHER GROUNDED OBJECT

SYMPTOMS -
- RESISTANCE FROM TIP OR RING TO SHIELD OF CABLE OR OTHER GROUNDED OBJECT
- MAY HAVE REDUCTION IN SIGNAL LEVEL
- MAY HAVE PERMANENT DIAL TONE
- CUSTOMERS LINE MAY BE NOISY

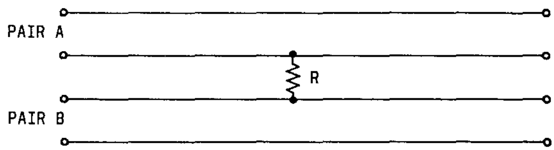
PROBABLE CAUSE -
- BAD CARBON IN PROTECTOR
- MOISTURE
- CABLE OR WIRE DAMAGE
- LIGHTNING DAMAGE
- TERMINAL DETERIORATION
- INSECT OR RODENT ACTIVITY
- CORROSION
- WATER IN CABLE
- POOR INSULATION

CAUTION - A CROSS TO TIP OF ANOTHER PAIR MAY APPEAR AS A GROUND

Fig. 33—Ground



SCHEMATIC

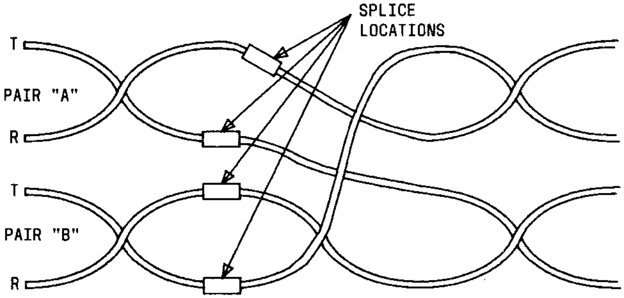


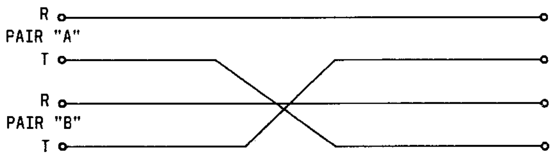
DESCRIPTION - ONE WIRE OF ONE PAIR IN CONTACT WITH ONE WIRE OF ANOTHER PAIR OR IN CONTACT WITH EACH OTHER THROUGH A RESISTIVE PATH.

SYMPTOMS -
- MAY HAVE CROSS
- MAY HAVE FOREIGN BATTERY
- CAPACITANCE UNBALANCE BETWEEN CONDUCTORS AND GROUND
- MAY HAVE REDUCTION IN SIGNAL LEVEL
- MAY HAVE PERMANENT DIAL TONE
- CUSTOMER'S LINE MAY BE NOISY
- MAY APPEAR AS A GROUND IF CROSSED TO TIP OF ANOTHER PAIR

PROBABLE CAUSE -
- MOISTURE
- CABLE DAMAGE
- LIGHTNING
- TERMINAL DETERIORATION
- INSECT OR RODENT ACTIVITY
- CORROSION
- WATER IN CABLE
- POOR INSULATION

Fig. 34—Cross



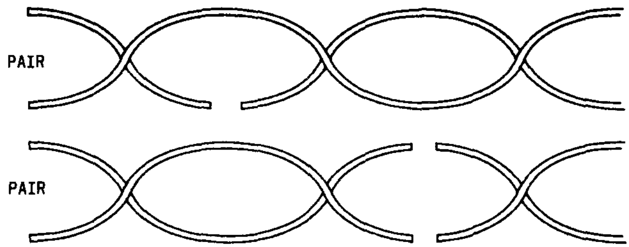


DESCRIPTION - TIP OF ONE PAIR IS CONNECTED TO TIP OF ANOTHER OR RING OF ONE PAIR IS CONNECTED TO RING OF ANOTHER

SYMPTOMS -
- NO CONTINUITY BEYOND SPLIT
- IF SPLIT IS MIDWAY ON PAIR THE TIP TO RING LENGTH MEASUREMENT WILL BE SHORT
- IF SPLIT BEYOND POINT OF SERVICE CONNECTION, PAIR WILL BE NOISY
- IF SPLIT IS NEAR THE END THE PAIR WILL LOOK LIKE A BALANCED OPEN FAULT

PROBABLE CAUSE - SPLICING ERROR (WILL ALWAYS BE LOCATED AT POINT OF PAIR CONNECTION WORK).

Fig. 35—Splits



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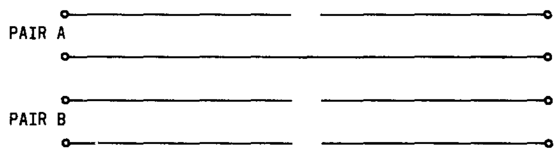
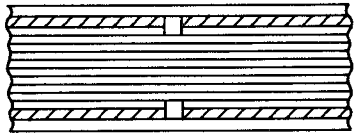


DESCRIPTION - EITHER TIP, RING OR BOTH TIP AND RING ARE OPEN

SYMPTOMS -
- NO DIAL TONE
- NO C.O. BATTERY
- MAY HAVE UNBALANCE BETWEEN CONDUCTORS
- MAY BE NOISE ON PAIR

PROBABLE CAUSE -
- CORROSION
- BAD SPLICE CONNECTION
- LIGHTNING DAMAGE
- CABLE OR WIRE DAMAGE
- RODENT DAMAGE
- ABRASION
- TERMINAL DETERIORATION

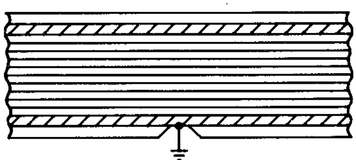
Fig. 36—Opens



DESCRIPTION - LACK OF SHIELD CONTINUITY
SYMPTOMS - • NOISE ON LINES
• NO SHIELD CONTINUITY
• MAY BE NUMBER OF PAIRS IN TROUBLE AT SAME LOCATION

PROBABLE CAUSE - • CORROSION DUE TO MOISTURE
• POOR CONNECTION AT BOND CLIP
• BOND OMITTED
• LIGHTNING
• POWER LINE CONTACT

Fig. 37—Open Shield



DESCRIPTION - INTEGRITY OF SHEATH VIOLATED
SYMPTOMS - • WATER IN CABLE
• NUMBER OF PAIRS IN TROUBLE AT SAME LOCATION
• DC RESISTANCE BETWEEN SHIELD AND EARTH

PROBABLE CAUSE - • SHEATH DAMAGED DURING INSTALLATION
• CABLE OR SERVICE WIRE DAMAGED AFTER INSTALLATION
• LIGHTNING
• RODENT DAMAGE

Fig. 38—Sheath Break

FAULT LOCATING

OUTSIDE PLANT

1. GENERAL

1.01 This addendum supplements Section 644-104-090. Place this addendum ahead of page 1 of this section.

1.02 This addendum is issued to assist cable repair technicians in locating and correcting transmission and inductive interference problems. It consists of three major parts:

(a) SECTION 4. BASIC THEORY

This section contains general information about the nature of transmission and inductive interference.

(b) SECTION 5. PROCEDURAL FLOWCHARTS - CABLE REPAIR

This section details step-by-step methods for finding and solving transmission and interference problems for cable repair technicians.

(c) SECTION 6. DIAGNOSTIC SAMPLE PROBLEMS

This section offers a case study approach to solving some specific noise problems.

Two appendices contain additional material:

- Appendix A presents sample calculations of db values.
- Appendix B shows the circuit setup used for making noise measurements.

1.03 The flowcharts (Figures 5-12) have been developed for use with the test sets listed in Part 3. These test sets or their equivalent and the flowcharts should be available to the cable repair technician.

2. PRECAUTIONS

2.01 Although not listed in the flowcharts, safety procedures and precautions shall be observed at all times.

3. TEST SETS

3.01 Test sets required by the cable repair force for fault locating transmission and inductive interference faults are listed below:

- 1013B (or equivalent)

(Section 106-020-113) This handset has dial capability for communication in outside plant.

- Wilcom T136BSB (or equivalent)

(Section 100-102-904WT) This circuit test set is capable of measuring transmission and noise on subscriber loops. This test set requires the 1013B handset as its communication link

- Wilcom T139 (or equivalent)

(Wilcom T139 Instruction Manual) This circuit termination set is a balanced switchable termination and is used in conjunction with the T136BSB circuit test set. The Wilcom T279 is an equivalent circuit termination set with an additional feature which is not used in this practice.

(•)Wilcom T304 (or equivalent)

(Wilcom T304 Instruction Manual) This cable shield splice continuity tester is capable of detecting defects in the bonding and grounding of cable shields. The Wilcom T304 is used most effectively on buried cable plant in addition to aerial and underground cable plant.

4. BASIC THEORY

4.01 This section of the guide contains general information about the causes and solutions of inductive interference problems. It covers noise parameters and the units used to measure them, the design of basic power systems, the theory behind shielding and grounding, and the functions of loop aids and ring isolators (equipment used to solve noise problems).

4.02 All physical trouble, e.g. short, ground, cross, leakage, capacitive unbalance, must be cleared using standard procedures prior to attempting to locate transmission or inductive interference problems.

A. Noise Parameters

4.03 Circuit noise:

Circuit noise or noise metallic, is the noise measured between the tip and ring conductor of a circuit. This is the noise the customer hears.

4.04 Power influence:

Power influence is the noise between ground and the tip and ring conductors tied together, as measured by the Wilcom T136 or its equivalent. The customer does not hear the power influence; however, its magnitude will determine the magnitude of circuit noise that the customer does hear. Power influence may be decreased by improving the cable shield.

4.05 Balance:

Balance denotes how much the impedance characteristics of one conductor in a pair resemble those of the other conductor. The electrical components of longitudinal impedance of a cable pair are capacitance, resistance, and inductance. Inductance is negligible as far as power current harmonics are concerned; therefore, balance denotes how much the capacitance and resistance characteristics of one conductor of a pair resemble those of the other conductor. The more alike these conductors are, the higher the balance and, consequently, the less susceptible they are to induction. Balance may be defined as follows:

Balance = Power Influence - Circuit Noise

B. Units of Noise Measurement

4.06 *Decibel (dB)*: The balance of a cable pair is measured by a meter calibrated in decibels (dB). The decibel unit expresses the ratio of two quantities. In noise work, the quantities are usually voltages, currents, or power levels. Voltages or currents can be compared in terms of dB by the following equations.

(a) For voltages:

$$dB = 20 \log 10 \left| \frac{V\,2}{V\,1} \right|$$

(b) For currents:

$$dB = 20 \log 10 \left| \frac{I\,2}{I\,1} \right|$$

These equations relate the voltage, V 2 , or the current, I 2 , to some other voltage, V 1 , or current, I 1 , respectively. The value in dB can be positive or negative. If V 2 is less than V 1 , the dB value will be negative. The same applis to current and power ratios. Power levels, however, are compared in terms of dB by the following equation.

(c) For power levels:

$$dB = 10 \log 10 \left| \frac{P\,2}{P\,1} \right|$$

For examples using these equations, see Appendix 1.

4.07 It is not necessary for the cable repair technician to fully understand dB in mathematical terms to effectively work with noise levels - what is satisfactory, what is slightly noise, and what constitutes a severe noise problem.

4.08 *dBm*: Power levels are generally of greatest interest in telephone work. For this reason, a standard reference power level (dBm) has been established. This reference level is one milliwatt (or 10 -3 watts) of 1000-Hz power dissipated in a 600-ohm resistor. Substituting this into our dB equation, with dBm replacing dB to designate our reference of P 1 = 10 -3 watts, we have:

$$dBm = 10 \log 10 \left| \frac{P\,2}{10^{-3}} \right|$$

where P 2 is in watts.

4.09 *dBrn*: Noise powers are almost always less than one milliwatt. This means that the dBrn values would normally be negative. Since it is desirable to express all noise powers as positive quantities, a new unit of measurement, dBrn, has been defined as follows:

0 dBm = 90 dBrn

The "r n" stands for "reference noise" power. This reference noise power is a quantity of noise which has a negligible effect on the transmission of speech.

4.10 *dBrnc*: the physical characteristics of the telephone receiver and the human ear cause some frequencies of noise to appear louder and more disturbing than others, even though the noise signals of the different frequencies have the same power level.

4.11 A weighting curve which expresses this difference in disturbing effective relative to the disturbing effect of a 1000-Hz signal of the same power level has been developed to show the response of the telephone receiver and the average human ear to various frequencies in the audible range.

4.12 Measuring noise in dBrn with C-message weighting (dBrnc) takes into account the relative interfering effects of the various frequencies which make up a noise signal and, therefore, is a more accurate measurement of the noise the telephone user actually hears.

C. Basic Power System

4.13 Figure 1 illustrates a three-phase, Y-fed, multi-grounded neutral power distribution system. This is the configuration of most power distribution systems in the United States.

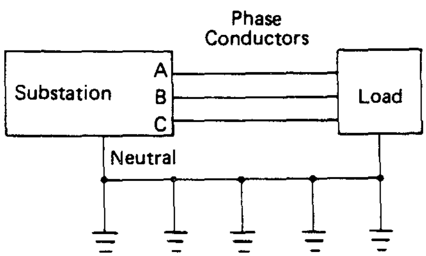


Figure 1: A Power Distribution System

4.14 Assume that this distribution system furnished power to only three customers, each with an identical electrical load connected to phase A, B, and C, respectively. If each customer places the same load on the line at the same time, the power system load will be balanced, and currents of equal magnitude will flow through phases A, B, and C.

4.15 For unequal loads, however, these currents will be somewhat different in magnitude. The geometric sum of these currents must return to the substation (I R) via the neutral wire and the earth. As a general rule, 40 percent of the current returns through the neutral wire and 60 percent returns through the earth, as shown in Figure 2.

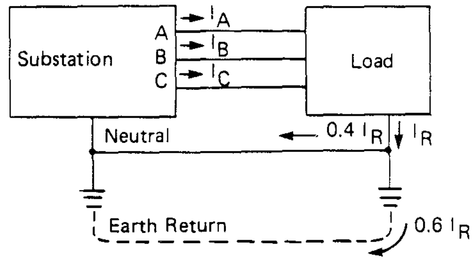


Figure 2: Current Return Paths

4.16 Alternating current flowing through a wire sets up a magnetic field which alternates with the frequency of the current. For three-phase power lines, each of the phase currents produces a magnetic field and the returning currents produce opposing magnetic fields.

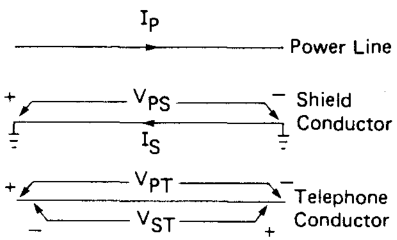
4.17 The residual current, which is the sum of the phase currents and the neutral current, has a magnetic field which is not cancelled. the resultant magnetic field will induce a voltage in any conductor in its vicinity. Thus, a telephone conductor near a power system will experience an induced longitudinal voltage whose magnitude depends upon the distance to the power lines, the length of cable exposed, and the current and balance of the power system.

4.18 There is always some unbalance in three-phase distribution systems. In a properly planned and constructed power system, the residual current is usually 60 Hz. However, if, for example, a transformer is overexcited, the residual current will also contain exceptionally large harmonic components (whole number multiples of 60 Hz). the largest harmonics are generally the odd triples (180 Hz, 540 Hz, etc.). Very little intelligible sound is carried at very low frequencies; since there is so much 60 Hz near a power line, the phone set has been designed to reject the low frequencies. Thus, it is the harmonics that lie within the voice band that produce audible noise.

D. Shielding and Grounding

4.19 If another conductor is placed near the power line parallel to the telephone conductor and is grounded at both ends, it will help shield the telephone conductor from interference. Shielding and grounding make up the first line of defense against external influences to the telephone system.

4.20 Figure 3 shows a telephone conductor with a shield conductor, both under the influence of a power line. The shield conductor may be any conductor with a ground return path (grounded at both ends). In the telephone system, the metallic sheath of the cable serves as a shield when properly bonded and grounded.



Figrue 3: Telephone and shield conductors Under Influence of Power Line

4.21 The residual power line current (I P) generates logitudinal voltages on the shield conductor and the telephone conductor. These are designated V PS and V PT , respectively. These voltages are of such polarity that they both would cause a current flow in their respective conductors opposite to the current in the power line if the current were free to flow. The current, I S , is free to flow in the shield because of its ground return path. Since we are studying the effect of the shield on longitudinal voltages in the telephone conductor. The current, I S, will also induce a voltage, V ST , on the telephone conductor. Since I P and I S flow in opposite directions, the voltages they will induce on the telephone conductor will be opposite in polarity and will, therefore, partially cancel each other. Because of this cancellation, the net longitudinal voltage induced on the telephone conductor will be much less with the shield than without it.

4.22 The cancellation of induced voltages on the telephone conductor is due to the voltage, V ST , which is induced by the current flow in the shield conductor. In most cases, increasing the current flow in the shield conductor will increase the cancellation effect and reduce the net induced voltage on the telephone conductor. to keep this shield current as great as possible, the shield must be continuous at all points and properly grounded through low resistance bonds. If good shielding techniques are applied, all areas of the inductive noise problem will be improved.

E. **Loop Aids**

4.23 Importance of Loop Current Measurement:

There is more to transmission improvement than fixing noise problems. For the customer, the ability to hear and be heard is just as important. But before either noise or hearing problems become a concern, the customer must first be connected with the called party. This is established by the loop current.

4.24 In general, the relays in the CO require a minimum of 20 MA to operate reliably. A customer line with very low loop current often has an interesting trouble history characterized by comments such as "no dial tone (NDT)," "can't break dial tone (CBDT)," "get wrong numbers (GWN)," or "bell rings after answer (BRAA)." A low loop current condition is usually the result of a circuit exceeding the typical design limit of 1300 ohms or the long route designs, e.g., Resistance Zone (RZ) 18 (1800 ohms) and RZ28 (2800 ohms). All circuits designed to exceed 1300 ohms require range extension equipment to aid the C.O. battery.

4.25 Importance of Circuit Loss Measurement:

Circuit loss measurements indicate how well the customer can hear or be heard. For proper service, a line should not exceed 8.5 dB of loss to the milliwatt termination. A customer with a higher loss may have a trouble history characterized by comments such as "can't hear (CH) - can't be heard (CBH)" or "can't hear on Direct Distance Dialing (CH on DDD)."

4.26 If a repairperson tests this line by calling the testboard, it will sound like a good circuit. However, when the customer calls across town or long distance, the additional loss on the far-end loop might make it sound like a poor circuit. Since what is heard by calling the test board can be deceiving, the loss measurement must be used to evaluate the line. Loops with losses greater than 8.5 dB can be corrected by repair, redesign, or the addition of voice frequency amplifiers, whichever is determined to be appropriate.

4.27 Why Cables are Loaded:

A capacitor is two conductive plates separated by an insulator. A cable pair may be thought of as two very narrow, very long plates separated by an insulating material; as a result, telephone cable pairs are highly capacitive. Since this causes inefficient use of voice power, the cable pair must be modified to transmit voice power very far. This is done by adding inductance periodically to offset the capacitance. This process is called loading; it improves the efficiency of a cable pair by improving the power factor and the frequency response.

4.28 Because some inefficiency can be tolerated for short distances, customers close to the CO are served by nonloaded cable pairs. Loaded pairs serve customers with loops beyond 15,000 feet (or 18,000 feet depending on the plant design rules used).

4.29 The H88 loading scheme requires that load coils be placed 6,000 feet apart along the pair. The first load point out of the CO will be 3,000 feet out so that customer lines will be spaced correctly through the CO section. Load spacing is critical, particularly in the first four sections from the CO, because loop aids (such as repeaters and range extenders with gain) are designed to work on properly loaded cable pairs. Missing or improperly spaced load coils will degrade the transmission quality of the cable pair.

4.30 Two other situations will prevent loaded pairs from working porperly: a customer line or bridged tap located between two load points. All customers on a loaded pair must be located in the end section, the portion of the cable beyond the last load coil. Bridged tap may be used in an end section, too, as long as the total cable length past the last load coil does not exceed 12,000 feet or less than 3,000 feet.

4.31 Several problems may arise if these requirements are not met:

- poor frequency response may prevent Touch-Tone telephone digits from registering correctly,
- the customer may have trouble hearing, or
- there may be transmission distoration.

4.32 To detect bridged tap or a customer line in a loaded cable, measure and compare the loop current and circuit loss. If the loop current seems correct for the distance from the CO but the loss is high, this suggests one of the following:

- the customer line is being fed between loads,
- there is bridged tap in the loaded sections, or
- for nonloaded cable, there is more than 6,000 feet of bridged tap.

F. Ringer Isolators

4.33 If the tip and ring could be perfectly balanced, no noise would be heard on the telephone line. The design of CO equipment, cable, and station equipment minimizes the differences in tip and ring, but perfect balance is never found. Perhaps the biggest single source of unbalance in multiparty lines is more ringers to ground on one side of the line than on the other. This is especially difficult to control because every disconnection or addition to the line changes the balance. The answer is to have no ringers to ground. This can be accomplished with ringer isolators.

4.34 A ringer isolator is a switch between the ringer and ground which is normally open. It monitors the tip and ring looking for the negative superimposed battery current which accompanies the ringing signal. Whenever ringing is present, the ringer is connected to ground. At all other times, the ringer is not grounded; therefore, it cannot unbalance the line during a phone call. Using ringer isolators on all parties of a multiparty line can improve the balance by as much as 15dB.

G. Guidelines

4.35 The Guidelines for Transmission and Noise in the Wisconsin Telephone Company are the values shown in Table A.

4.36 Each transmission and noise measurement has a value range which can be categorized as *Satisfactory*, *Marginal* or *Unsatisfactory*. The measurement value ranges are shown in Table A.

(a) *Satisfactory* - Provides acceptable service and should not result in a trouble report.

(b) *Marginal* - May provide a poor level of service that boarders the unacceptable area. The circuit possibly is not out of service, but will almost certainly cause a trouble report due to customer dissatisfaction. Corrective action should be taken to improve the level to satisfactory.

(c) *Unsatisfactory* - Provides unacceptable service. If a circuit is considered to be out of service. Corrective action must be taken to restore service.

TABLE A
GUIDELINES FOR NOISE MITIGATION

Category	Circuit Noise (Noise Metallic)	Power Influence (Noise to Ground)	Circuit Balance (PI-CN)	Station Current	Suggested Action to be Taken
Satisfactory	<20 dBrnc	<80 dBrnc	>60 dB	>23 ma	None
Marginal	>20 dBrnc <30 dBrnc	>80 dBrnc <90 dBrnc	>50 dBrnc <60 dBrnc	>20 ma <23 ma	Note 1
Unsatisfactory	>30 dBnrc	>90 dBrnc <95 dBrnc	<50 dB	>20 ma	Note 2
		>95 dBrnc			Note 3

Reference - > More   < Less

Note 1 - Refer to supervisor for review and possible noise mitigation.
Note 2 - If noise cannot be corrected locally have condition reported to ICEP Entineer for assistance and mitigation. Send speed letter to Manager Network Planning and Engineering - ICEP with completed N1 and N2 forms attached. Explain corrective action taken.
Note 3 - Have condition reported to IDEP Engineer for assistance and mitigation. Send speed letter to Manager Network Planning and Engineering - ICEP with completed M-137 and N2 forms attached.
Note 4 - Station current measurement with a T 136 test set having a DC resistance of 430 ohms.

* This measurement to be made with a T136 test set having a DC resistance of 430 ohms.

† A possibility exists that a marginal or unsatisfactory balance will occur when noise and power influence are in the satisfactory range. When this happens, the balance should be considered satisfactory if noise is less than 20 and power influence is less than 70. If noise is more than 20, balance is not considered satisfactory and corrective action should be taken.

5. PROCEDURAL FLOWCHARTS - CABLE REPAIR

5.01 Fault locating and correction procedures for transmission problems are shown in Fig. 5 and Fig. 6.

5.02 Fault locating and correction procedures for inductive interference problems are shown in Fig. 7 through 12.

6. DIAGNOSTIC SAMPLE PROBLEMS

6.01 This section offers a case study approach to solving some specific noise problems.

6.02 Case 1

Problem - There is a sudden rash of trouble reports in a confined area.

Solution - A number of things could cause this situation. This discussion addresses the problem of blown capacitor bank fuses.

Figure 13 illustrates a typical arrangement of a capacitor bank. Note that the capacitors are rectangular in contrast to transformers which are cylindrical. The fuses in this figure are in the closed position; the capacitor bank is in service.

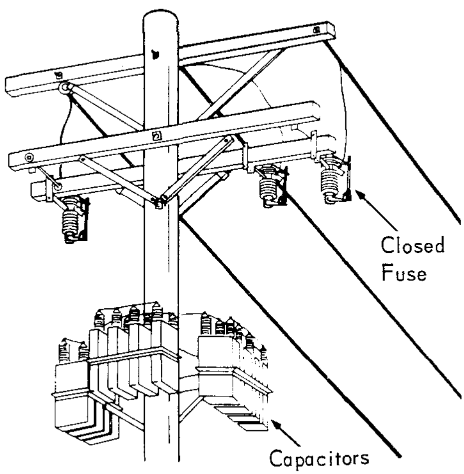


Figure 13

Figure 14 illustrates the arrangements when all fuses are open; this capacitor bank is out of service. This, also, is a normal arrangement. This situation occurs when the capacitor bank is needed only for a peak power load season (such as summer air conditioning); for the rest of the year, the bank may not be needed.

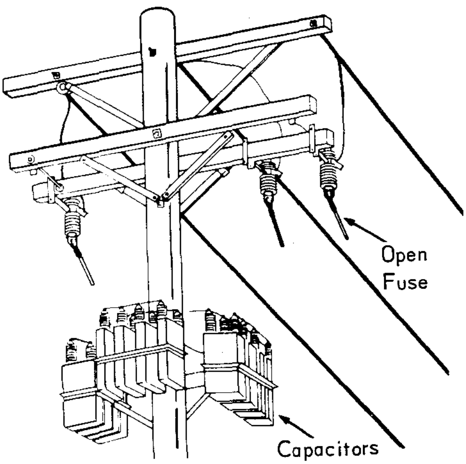


Figure 14

Figure 15 illustrates the problem which can cause a large increase in the noise heard on a telephone line. When only one or two fuses are closed, the power line is extremely unbalanced.

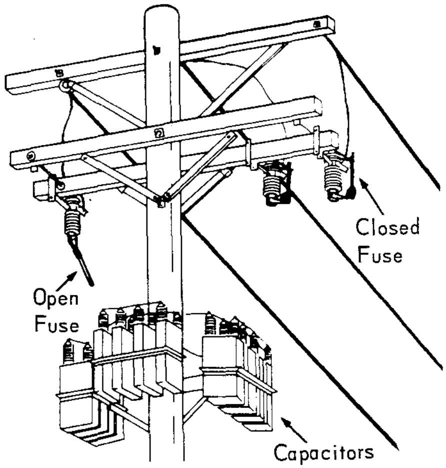


Figure 15

The capacitor bank fuses are visible from the ground and may be noted while you are driving along a road paralleling the power line. Watch for any such irregularities while traveling to the customer who reported the circuit noise problems.

Report the location of any unbalanced capacitor banks to the ICEP engineer. Once these unbalances are corrected, investigate any remaining noise problems.

6.03 Case 2

Problem - There is a chronic noise problem.

Solution - Since many chronic trouble conditions are intermittent, ordinary testing methods frequently fail to identify the problem. This is particularly true in the case of poor connections where applying test battery temporarily "seals" the poor connection and results in multiple TOK's.

The Varley test is designed to locate these intermittent poor connections; however, if the test battery is applied to the line just prior to the Varley test or if the repairperson calls the testboard on the line in question, the trouble probably will not show up on the Varley.

Use the lowest possible battery voltage for the Varley test (20V or, preferably, less). Always call the testboard on a line *other than the line in trouble* to request a Varley. Ask the test board to avoid putting any test battery on the line other than the 20V Varley. If the Varley results do not show a problem, ask the tester to open the line to you and tell the tester you will call back to restore it later.

With the line open to you, begin sectionalizing the cable with the noise measurement set and the T139 or 120H coil to determine whether the trouble is in the station wiring or in the cable facilities. With the T139 or equivalent in the circuit, record the circuit noise toward the station and toward the CO. Monitor the noise reading until the trouble appears on the line (usually within ten minutes). A substantial increase in circuit noise will indicate trouble (it usually pegs the meter). Once the trouble appears, it will remain until battery is applied to the line.

If the trouble is toward the station, it can be isolated by lifting IW's, sets, etc. If it is toward the CO, continue sectionalizing the cable to isolate the trouble.

6.04 Case 3

Problem - "Touch-Tone telephone digits fail to work," "cannot hear," or "distortion."

Description - When measured at the station, the loop current seems acceptable for the distance from the CO, but the circuit loss is quite high.

Solution - One of three things may be causing this situation:

- the customer line is being fed between load coils,
- there is bridged tap in the loaded sections of the cable, or
- for nonloaded cable, there is more than 6,000 feet of bridged tap.

If the customer line is fed between load coils or is fed by nonloaded cable, request a change to another cable pair. If not, find the bridged tap in the loaded section and remove it.

6.05 Case 4

Problem - There is a balance problem in B-buried service wire.

Solution - Measure the balance of both pairs in the B-buried wire and use the pair with the best balance. If the balance of neither pair is acceptable, the wire must be replaced.

6.06 Case 5

Problem - There is unbalance in the loop.

Solution - Use the following chart to determine the cause of the problem, then correct it.

TYPE OF UNBALANCE	WHAT TO LOOK FOR
Leak to ground (high resistance ground)	Moisture in terminals Dirty carbons Tree limbs touching open wire Wire insulation damaged by lightning
Series resistance	Cable below manufacturing standards Resistance in splices Cable damaged during construction
Capacitance unbalance	Cable below manufacturing standards Split pairs Bridged tap with one side open Side crosses to dead conductors Unbalanced ringers on party line