MAINTENANCE SYSTEM FOR AIR CORE POLYETHLENE-INSULATED CONDUCTOR (PIC) CABLE IN UNDERGROUND PLANT

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1. GENERAL

1.01 This section provides an overview of the information covered in various Bell System Practices that relate to the methods and means for the design and implementation of a maintenance system for air core PIC cable in the underground environment.

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

1.03 With the introduction into the underground plant of new designs of ***air core*** PIC cables, such as STEAMPETH, MAT, and DUCTPIC, it is imperative that an appropriate maintenance strategy accompany these new cable designs. In this regard, it is recommended that Section 930-200-001 covering Engineering and Implementation Methods System (EIMS) be reviewed. In addition, reference should be made to the current AT&T Company policy guidelines relating to cable pressure systems (Section 637-020-011).

1.04 The basic philosophy underlying any cable sheath maintenance system is to provide a scheme to prevent or minimize the entrance of water into the core of the cable. Toward this end, it is essential that air core underground PIC cable be maintained under continuous air pressure in the same manner as other air core cable systems in the underground plant. Although plastic insulation is more tolerant of water and moisture than pulp, ***water in PIC cable cannot be ignored.*** While most pairs will continue to "work" in a wet PIC cable, conductor corrosion will occur whenever water reaches defects in the plastic insulation, with a resultant degradation of service and, ultimately, loss of pairs.

1.05 A properly designed and continuously monitored and maintained pressure system will prevent the entrance of water through all but catastrophic leaks that may occur in the cable sheath. However, procedures must be established and strictly adhered to which will ensure prompt response to pressure alarms and restoration of the cable to dry conditions in the event of water entry.

1.06 With regard to water entry, the 1A sensor device (Section 644-201-105) is available as an option to aid in locating water in splices in the event of a sheath break. This simple device is bridged across a common pair at splice points during construction and, in the presence of water, will test as a low-resistance fault. Location of the wet sensor is determined by standard bridge measuring techniques.

1.07 Since PIC insulation is not adversely affected by the use of filled connectors as is pulp, it is strongly recommended that the filled series of the 710 Connector System or equivalent be used in all splicing operations to provide additional protection against possible moisture entry.

1.08 In the event that water enters the cable core and contaminates a cable section, the Forced Air Restoration Method (FARM) is available for the restoration of the wet section. This method involves the injection of air at high pressures into the cable and thereby forces large quantities of dry air through the wet section to remove the water and restore the cable to a dry condition.

1.09 Of major importance in maintaining cable in the underground loop plant is the necessity for pressure plugs at all PIC-pulp interfaces. This arrangement is required to prevent a concentration of moisture in the pulp at the junction splice due to permeated moisture which will be transported by the normal air flow through the nonhygroscopic core of the PIC cable section. This isolation of PIC-pulp sections will, of course, require that each section be maintained as a separate pressure section, both from pressure feed and monitoring standpoints.

1.10 The following sections highlight the more important elements of the overall maintenance strategy. Complete details are covered in the appropriate Bell System Practices.

2. PRESSURIZATION DURING CONSTRUCTION

Related Bell System Practices — Sections 637-305-303 and 637-450-011

2.01 Pressurized cables are shipped from the factory under 10 psi pressure. As covered in Section 637-450-011, pressure readings should be made and recorded on the proper form for each cable length immediately after delivery, and at periodic intervals if extended storage is required, to detect any leaks that may occur. Similar readings should be taken and recorded before removing the reel from the storage yard and again immediately after a reel length has been placed to ascertain that no leaks have developed during the placing operation. If a leak is detected after the cable is pulled into the duct and tests show that the leak is not at the exposed ends, the cable should be removed from the duct and the leak repaired or the cable section replaced.

> *Note:* During any occasion when a leak has occurred and the cable has been exposed to water, the tests and procedures described in Section 644-104-090 (Fig. 5 and 6) should be followed to detect and remove any water that may have entered the cable.

2.02 Pressure measurements should be made and recorded just prior to opening the cable for splicing. If a leak is indicated, a pressure source should be connected to the section and the leak located and repaired or the cable replaced. ***During splicing operations, or whenever the cable sheath is opened, the procedures outlined in Section 637-305-303 covering pressure buffering should be followed to ensure that the cable sections are adequately protected against water entry.***

2.03 As splicing progresses, the completed sections between the work location and the office pressure plug or section end should be connected to an air source near the plug or end point. As the distance to the splicing work from this air source increases, additional sources should be introduced at such intermediate points as required to maintain a minimum pressure of 5 psi in the completed sections.

2.04 When all splicing work has been completed, the cable should be connected to permanent air sources and pressurized to the normal monitored pressure of at least 6 psi. The pressure alarm devices should then be placed into operation and the cable monitored by automatic means such as the Cable Pressure Monitoring System (CPMS) as part of the overall pressure network. If the cable maintains the monitored pressure objective of 6 psi for seven consecutive days after all splicing work has been completed and the automatic monitoring procedures have been implemented, the responsibility for the cable may then be transferred to the maintenance organization.

3. PRESSURE SYSTEM DESIGN

A. Exchange Cable

Related Bell System Practices — Sections 901-473-050, 930-200-001, 930-200-010, and 637-020-020

3.01 Exchange cable pressurization is an engineering design function and should be planned and designed by the engineer of outside plant with the aid of the Air Pressure Analysis Program (AIRPAP) covered in Section 901-473-050. AIRPAP is a time-shared computer program administered by the Western Electric Company as part of the Engineering, Planning, and Analysis Systems (EPLANS).

3.02 This program eliminates the necessity of doing the time-consuming and tedious manual calculations required to analyze an exchange pressurization system, a task that is impractical to attempt manually. While AIRPAP is primarily intended to assist engineers in the design of a complete pressurization network, it can also be used to redesign any segment of an existing pressurization network.

3.03 Design information is provided in the program to ensure that a minimum design pressure of 5 psi is achieved throughout the pressurized underground cable network. In addition, the program recommends specific monitoring device locations so that adequate surveillance of the entire pressure system is ensured.

3.04 Based on data input to the program, AIRPAP design output information includes the following:

(a) Recommended auxiliary air source locations

(b) Recommended locations for monitoring devices

(c) Estimated air usage for the cable network

(d) The location of potentially low pressure points

(e) Route mileage of the pressurized cable network

(f) Installed cost of the pressurization hardware.

B. Toll and Trunk Cable

Related Bell System Practices — Sections 930-200-001, 930-210-100, 930-210-200, and 637-020-020

3.05 Toll and trunk cable pressurization is also an engineering design function and should be planned and designed by the engineer of outside plant. The pressurization system should be designed in accordance with the guidelines contained in Sections 930-210-100 and 930-210-200, Design of Air Sources for Toll and Trunk Cable and Guidelines for Locating Monitoring Devices on Toll and Trunk Cable, respectively.

3.06 The practices provide in tabular and graphical form the design information necessary for the engineer to position air source and monitoring locations in trunk and toll cable with a minimum of calculations and analysis. In general, source spacings of up to 8 miles with monitoring devices placed at the one-quarter, one-half, and three-quarter points are typical pressurization designs for this type of plant. However, every advantage should be taken of situations where toll or trunk cables parallel a subscriber cable in an underground network. In such cases, monitoring coverage can be easily and inexpensively obtained by utilizing the subscriber monitoring arrangement for pressure transducer surveillance of the toll or trunk cable.

4. PRESSURE MONITORING

Related Bell System Practices — Sections 930-210-020, 930-210-200, 637-222-101, 637-225-215, and 637-600 Series

4.01 Underground PIC cable must be maintained under the constant surveillance of an automatic cable pressure monitoring system in the same manner as other cables in the underground environment. Continuous monitoring of pressure and flow related devices will warn of slow pressure leaks that may develop as well as major sheath breaks. It is essential that pressure alarms be responded to immediately and a thorough investigation be made to find and correct the cause of the alarm.

4.02 The system standard, Cable Pressure Monitoring System (CPMS), is a centralized scanning and reporting system for the automatic surveillance of pressure monitoring devices associated with pressurized cable over a large geographical area. With CPMS, a computerized central terminal controls the assembly of alarm and status information from a large number of devices located throughout the pressurized cable network. Information gathered at the central terminal is analyzed and automatically disseminated to the responsible maintenance center for action. CPMS provides a very effective means of monitoring all standard pressure-related sensors and is, therefore, recommended as the most desirable vehicle for the complete surveillance of all pressure systems.

4.03 Where CPMS is not available, an automatic pressure monitoring system having features which include the following should be used:

(a) 24 hour surveillance

(b) Selected priority scanning and reporting of device status

(c) Reporting of alarms on an exception basis

(d) Reporting alarm information to remote locatings

(e) Compatibility with standard pressure-related sensing devices.

5. MAINTENANCE

A. Sheath Breaks

Related Bell System Practices — Sections 637-410-011, 637-410-504, 644-104-090, and 637-412-500

5.01 The use of pressure measuring transducers located at strategic points in underground cable plant by AIRPAP and under the surveillance of an automatic cable pressure monitoring system such as CPMS is the most effective means for detecting sheath breaks as they occur. Prompt response to alarms will permit the clearing of essentially all but catastrophic breaks on a routine basis before they become service affecting.

5.02 When a sheath break has been detected by a loss of pressure, the break must, of course, be located and repaired. Standard methods covered in the Bell System Practices include the use of pressure gradients and flow analysis means to locate the source of the leak. In this regard, experience has shown that in underground plant approximately 80% of the sheath breaks occur in manholes. In the event that the break is indicated to be in the section, and the cause is not obvious (ie, dig-up or the like), consideration should be given to the relative economics of replacing the cable section versus locating, exposing the conduit, and repairing the leak.

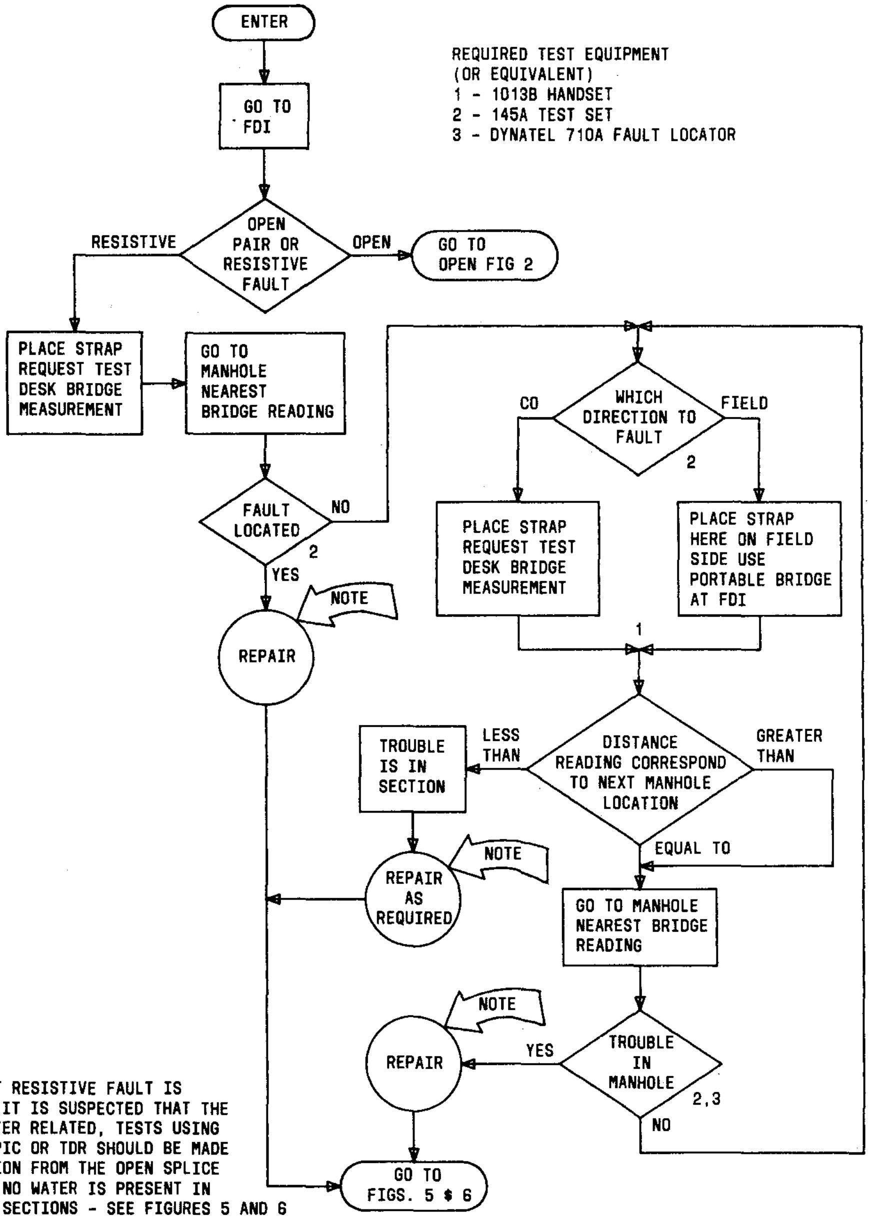
> *Note:* During any occasion when a leak has occurred and the cable has been exposed to water, the tests and procedures described in Section 644-104-090 should be followed to detect and remove any water that may have entered the cable.

B. Cable Repair

Related Bell System Practices—Sections 634 Series and 644-104-090

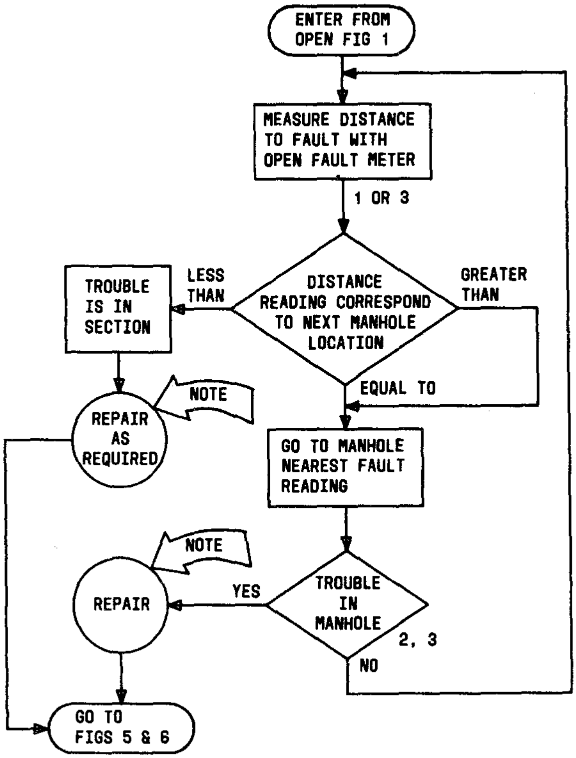
5.03 The detection of conductor faults in cable plant is usually associated with customer trouble reports, Automatic Line Insulation Test (ALIT), noisy carrier circuits, and the like. These faults are usually caused by water entering the cable, lightning surges, physical damage to the sheath, or other similar mishaps.

5.04 The various techniques for locating conductor faults are covered in the 634 series of the Bell System Practices. In addition, a fault locating strategy is covered in a handbook entitled Fault Locating Strategy for Wire and Cable Maintenance (and Section 644-104-090). This information has been prepared to assist in locating conductor and cable troubles in the various outside plant environments. It consists of a series of flowcharts that are designed to provide an easy-to-follow, systematic approach to fault location. Figures 1 and 2 are modified versions of the flowcharts relating to PIC cable repair in the underground plant. These charts lead the field craft through a systematic, iterative procedure, using the proper test sets, to locate both resistive type and open conductor faults. In addition, Fig. 4 and 5, which are extensions of these charts, 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 5 AND 6

Fig. 1—Cable Repair—Underground PIC Plant (Resistance Fault)



REQUIRED TEST EQUIPMENT (OR EQUIVALENT)

1 - OPEN FAULT LOCATOR (145A TEST SET IF AVAILABLE)
2 - 1013A HANDSET
3 - 145A TEST SET

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 5 AND 6

Fig. 2—Cable Repair—Underground PIC Plant (Open Fault)

5.05 In general, the outside plant instruments used in the routine maintenance of PIC cable include resistive bridge-type test sets, open fault locators, and time domain reflectometers.

C. Water Entry

Related Bell System Practices — Sections 637-305-303, 634-305-514, 644-104-090, 644-200-030, and 644-201-105

5.06 Although PIC insulation is more tolerant of water and moisture than pulp, ***water in PIC cable cannot be ignored.*** While water in PIC cable may not affect service initially, conductor corrosion will occur where insulation defects are exposed to water, resulting in a degradation of service. In this regard, it is recommended that the encapsulated series of the 710 Connector System or equivalent be used in all splicing operations in PIC cable in the underground plant.

5.07 A properly designed and adequately monitored pressure system will prevent or minimize the entrance of water through most sheath breaks. However, ***it is imperative that during any occasion when a leak has occurred and the cable has been exposed to water, the recommended procedures covered in Section 644-104-090 to detect and clear any water that may have entered the cable be strictly adhered to.*** In addition, proper pressure buffering procedures, as outlined in Section 637-305-303, must be followed whenever the cable sheath is opened to ensure that the cable sections are adequately protected against water entry during this period.

5.08 A device coded the 1A sensor is available as an option to aid in locating water in splices (Section 644-201-105). As shown in Fig. 3, the 1A sensor is a short length (approximately 12 inches) of paired conductors, one side of which is PIC with the insulation removed at one end, and the other side, pulp. A plastic cap at the exposed end ensures close contact of the pulp conductor with the bare copper. This arrangement results in a "junction" that is sensitive to water in that when dry, the resistance between sides of the pair is in the megohm range, but drops to less than 100 kilohms when wet.

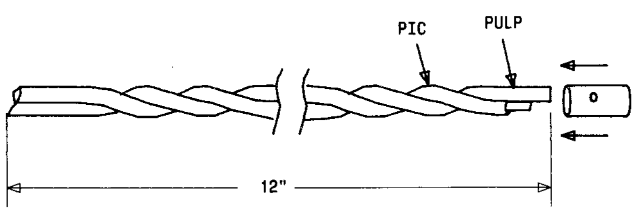


Fig. 3—1A Sensor

5.09 In practice, 1A sensors are bridged across a common dedicated pair at each splice point during construction. A second dedicated pair is required in the cable as a fault-locating pair to aid in identifying a "wet" sensor. As shown schematically in Fig. 4, these pairs are terminated on the MDF, but are not connected to automatic monitoring or alarming systems. In the event that water entry is suspected, the sensors may be accessed via a shoe at the MDF or a dedicated telephone number.

5.10 In addition to providing a means to aid in locating a "wet" splice should water enter a cable, the 1A sensor arrangement also provides a means for verifying splice dryness after initial installation, rearrangements, or at any time moisture entry is suspected.

5.11 Figures 5 and 6 are an extension of Fig. 1 and 2, and show in flowchart form the procedures to be followed by the field craft and test center, respectively, when water is suspected of having entered the cable. Essentially, these procedures require that whenever the field craft or the test center has reason to suspect water related troubles in a cable*, a test of the 1A sensor pair be made. If this test indicates a "wet" sensor, then the suspect sensor is identified by the test center using automatic bridge fault location techniques as covered in Section 634-305-514.

*Such as a large number of cable faults indicated by ALIT, customer trouble reports, etc.

5.12 At this point, the field craft goes to the indicated manhole location and dries the splice in the normal manner. In addition, tests should be made at this time in both directions from the open splice to ensure that no water is in the adjacent cable sections. Instruments that may be used to conduct these tests include the 176A SICK PIC test set, time domain reflectometers, or humidity-sensing devices.

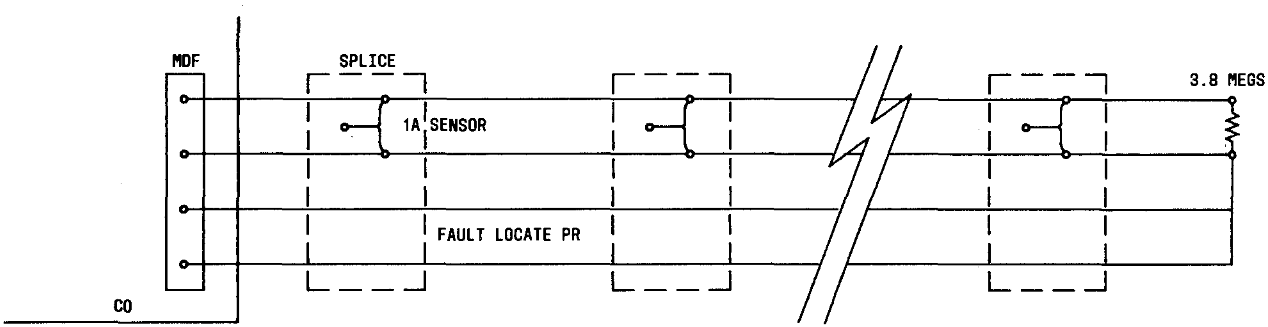
5.13 As shown in Fig. 5, if a cable trouble is suspected of being water related and the 1A sensor test indicates "dry" sensors, it is recommended that, while the cable is open at the trouble location, tests be made in both directions to ensure that no water is in the adjacent cable sections.

D. Water Removal

Related Bell System Practice — Section 644-200-030

5.14 In the event that water enters a cable and it is determined that the area of contamination is confined to a splice, the wet splice should be dried in the usual manner such as using dry air or nitrogen and absorbent cloth. If the 1A Sensor System is used, the wet sensor in the splice should, of course, be replaced and the sensor pair again tested after the drying operation. In cases where it is determined that water is present in the section(s), the FARM process is available to dry the section(s) and restore the cable to a dry condition. The restoration of wet PIC cable by the FARM process is intended primarily for use in cases of "one-time" water entry such as that resulting from damage to the sheath or entry prior to installation. Before restoration procedures are initiated, any cable sheath damage that will affect the ability of the cable section to maintain pressure must be located and repaired.

5.15 The removal of water from wet PIC cable by FARM as covered in Section 644-200-030 is a two-step process. In the first step, the bulk of the water in the cable section(s) is removed by forcing high pressure air through the cable core. The air acts similarly to a "piston" in that it forces the water out of the cable at selected vent points. This "blast" approach results in removal of approximately 85% of the water in the cable section(s).



<u>ACCESS</u>

- SHOE AT MDF
- DED TEL #-(NO CUSTOMER)

<u>VERIFY</u>

- LTD
- MLT

<u>LOCATE</u>

- STD BRIDGE TECHNIQUES

Fig. 4—1A Water Sensor System

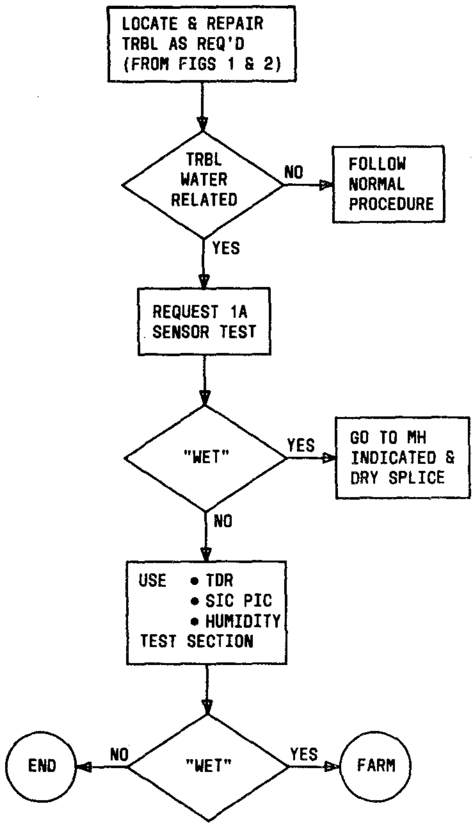


Fig. 5—Craft Procedures

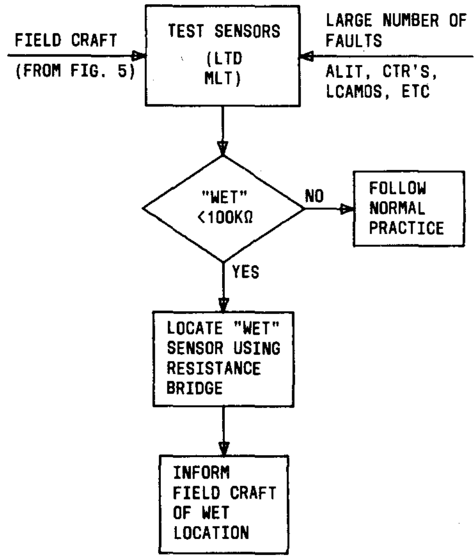
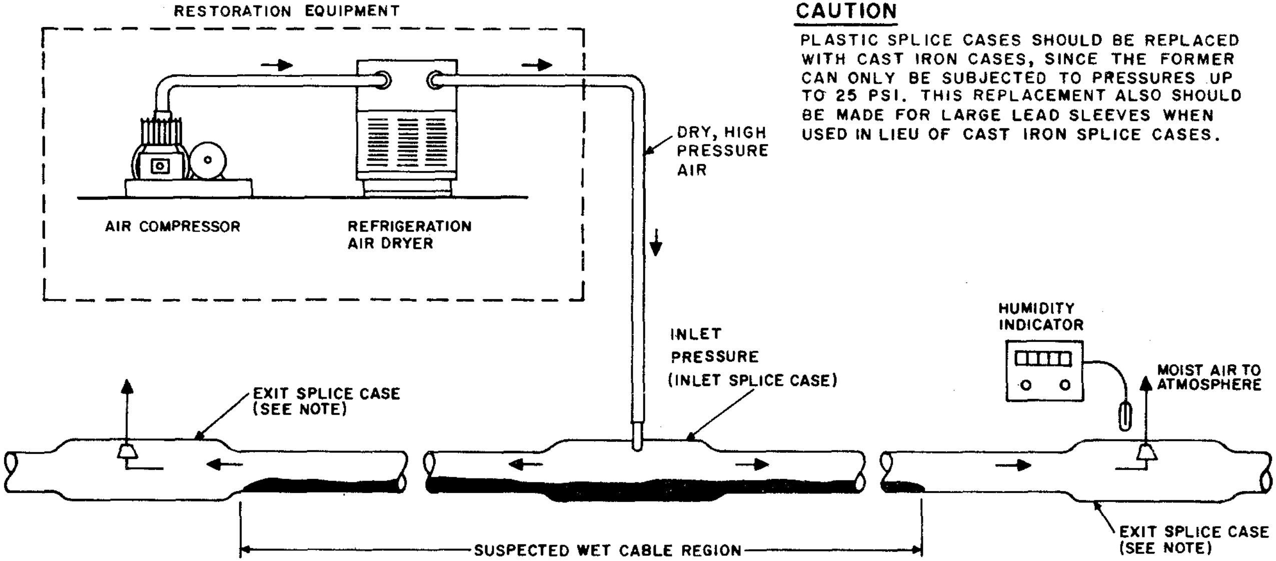


Fig. 6—Test Center Procedures

5.16 The second step in the restoration process removes by evaporation the residual water that remains, usually in the form of droplets and small puddles in the cable core. This is accomplished by forcing large quantities of high pressure dry air through the cable. The dry air vaporizes and purges the remaining water from the cable. This procedure is continued until the humidity of the air exiting from the cable at the vent points is reduced below an acceptable level (35% rh).

5.17 A typical arrangement of the FARM techniques as used to purge a wet PIC cable is shown schematically in Fig. 7.



CAUTION

PLASTIC SPLICE CASES SHOULD BE REPLACED WITH CAST IRON CASES, SINCE THE FORMER CAN ONLY BE SUBJECTED TO PRESSURES UP TO 25 PSI. THIS REPLACEMENT ALSO SHOULD BE MADE FOR LARGE LEAD SLEEVES WHEN USED IN LIEU OF CAST IRON SPLICE CASES.

NOTE:
THE EXIT SPLICE CASES MUST BE REMOVED DURING INITAL PURGE.

Fig. 7—Water Removal Arrangement for Underground Cable

E. PIC-PULP Interfaces

Related Bell System Practices — Sections 637-242-201 and 637-241-011

5.18 While it is recommended that underground PIC cable runs be constructed on an "end-to-end basis", the use of PIC cable in the underground exchange network will inevitably result in interfaces with pulp core branch cables and the like. In this regard, it is essential that pressure plugs be constructed at these interfaces to isolate the pulp from an air flow standpoint from the PIC. As covered in Section 637-242-201, the plugging arrangement is required to prevent a buildup of moisture in the pulp at the junction splice due to moisture permeation through the plastic jacket of the PIC section. The permeated moisture is transported by normal air flow through the nonhygroscopic core of the PIC and results in a concentration of moisture "downstream" at the pulp interface. In the absence of a pressure plug, the "blotter" action of the pulp will result in low insulation resistance at this point and a degradation of service.

> ***Note:*** Under no circumstances should the pressure plug be circumvented by a by-pass arrangement, as this would violate the isolation of the pulp from the PIC. This isolation of PIC-pulp sections requires that each section be maintained as a separate pressure section, both from pressure feed and monitoring standpoints.

5.19 It is recommended that the 10-type series of stubs be used when joining PIC to pulp sections. If larger PIC-to-pulp junction stubs are required than are available in the 10-type series, the PIC can be plugged using the procedures outlined in Section 637-241-011 and J plug compound. Where J plug compound is used, it will be necessary to remove the core binder and "balloon" the core to allow penetration of the compound.

6. RELATED BELL SYSTEM PRACTICES

SECTION	TITLE
901-473-050	Air Pressure Analysis Program (AIRPAP)
930-200-001	Engineering and Implementation Methods System (EIMS)
930-200-010	Cable Upkeep System Selection
930-210-020	Cable Pressure Standards
930-210-100	Design of Air Sources — Trunk and Toll Cable
930-210-200	Guidelines for Locating Pressure Monitoring Devices on Trunk or Toll Cables
634 Series	Electrical Cable Testing and Identification
637-020-020	Pneumatic Resistance of Cables
637-222-101	F Underground Pressure Transducer System
637-225-215	B Airflow Transducer (AT-8720)
637-241-011	Pressure Plugs
637-242-201	Plugging Plastic-Insulated Conductor (PIC) Cable
637-305-303	Cable Pressure Systems — Buffering
634-305-514	Locating Faults Using Dynatel 710A Test Set
637-410-011	Leak Locating Methods
637-410-504	Gradient Method of Leak Locating
637-412-500	Precision Leak Locating
637-450-011	Cable Pressure System — Procedures During Placing and Splicing
637-600-	Cable Pressure Monitoring System
644-104-090	Fault Locating Strategy for Wire and Cable
644-200-030	Restoring Wet PIC Cable Using Air Drying
644-201-101	Maintenance System for PIC Cable in Underground Plant
644-201-105	1A Water Sensor System