Errata

Document Title: Successful Buried Cable Fault Locating (AN 285)

Part Number: 5952-4957

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HP References in this Application Note

This application note may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this application note copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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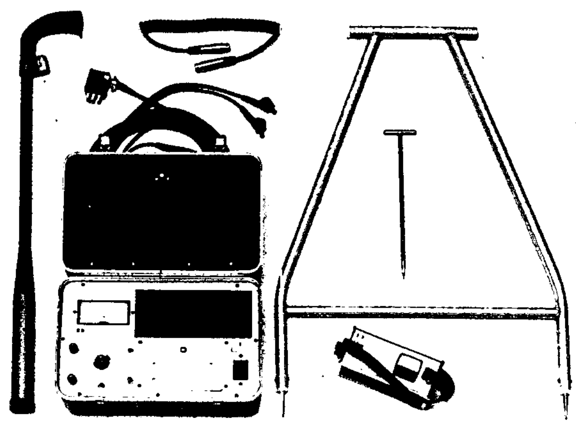
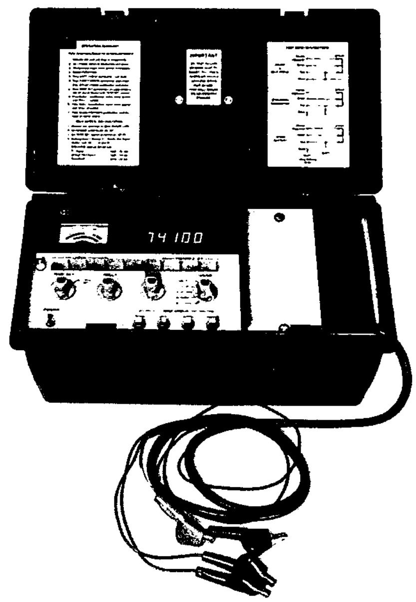
Application Note 285

Successful Buried Cable Fault Locating



HP 4904A Cable Fault Locator



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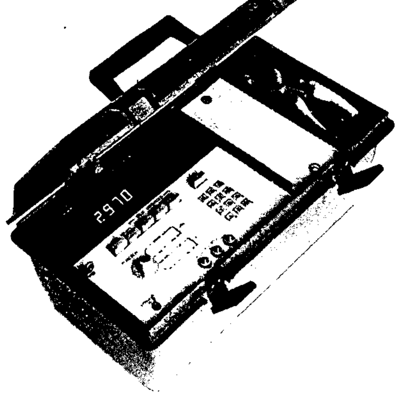

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Abstract

This Application Note describes concepts and procedures for locating faults in buried telephone cable with Hewlett-Packard Cable Maintenance and Construction (CMC) test sets. Based upon practical field experience, this information has resulted in a faster clearing time and overall cost savings.

This Application Note is based upon reports from hundreds of craftspersons and the combined experiences of the Hewlett-Packard staff. A high degree of success, faster clearing time and overall cost savings have resulted where these methods are used. Recognizing that there are wide variations in plant construction and fault conditions, some of the specific techniques mentioned may require modifications to suit the circumstances. But the basic concepts should apply universally.

The Tools

Distance-to-Fault: 4910G Open and Split Fault Locator. The 4910G provides automatic open and split fault-distance locating at the push of a button, and it works in the presence of cross battery voltages and leakage resistance. It can be used with or without a reference good pair. It has a fault-distance averaging system that automatically averages several samples of fault readings on a pair to compensate for noise-causing errors. The distance to a fault is displayed on a large, autoranging, digital display.

Distance-to-Fault: 4930A Conductor Fault Locator. Distance to shorts, grounds, crosses and battery crosses is measured by the 4930A. Readings can be made from either end of the cable without moving the Locator's position. Non-service affecting troubles can be located as easily as solid faults. Use of a second good wire is optional in all modes of operation. Distance appears on a large, auto-ranging, digital display, easily visible under all lighting conditions.

Pinpoint Fault: 4904A Cable Fault Locator. The most versatile tone set around, the 4904A pinpoints faults in buried, underground and aerial cable. It locates grounds, shorts, crosses and splits in all cables plus the path and depth of buried cable. This is a complete, self-contained troubleshooting system designed for one-man operation. Readings are visual, on a meter, and audio, on a built-in speaker or headset.

Steps To Clearing Trouble

A logical plan of attack is essential to successful fault locating. While it's true that you can sometimes hit a fault the first time on a hunch, the odds are poor in the long run. Hit-and-miss troubleshooting can result in a lot of unnecessary digging, unlocated faults and even further damage to the plant.

The flowchart shown in figure 1 illustrates the various steps necessary to isolate and repair a fault. Sometimes a step can be eliminated, or two steps can be combined into one operation. However, the important thing is that the tests always be performed in the sequence shown. In addition, the trouble situation should be thoroughly analyzed at each step to make sure you're still on the right track and to provide additional clues as to the nature of the trouble.

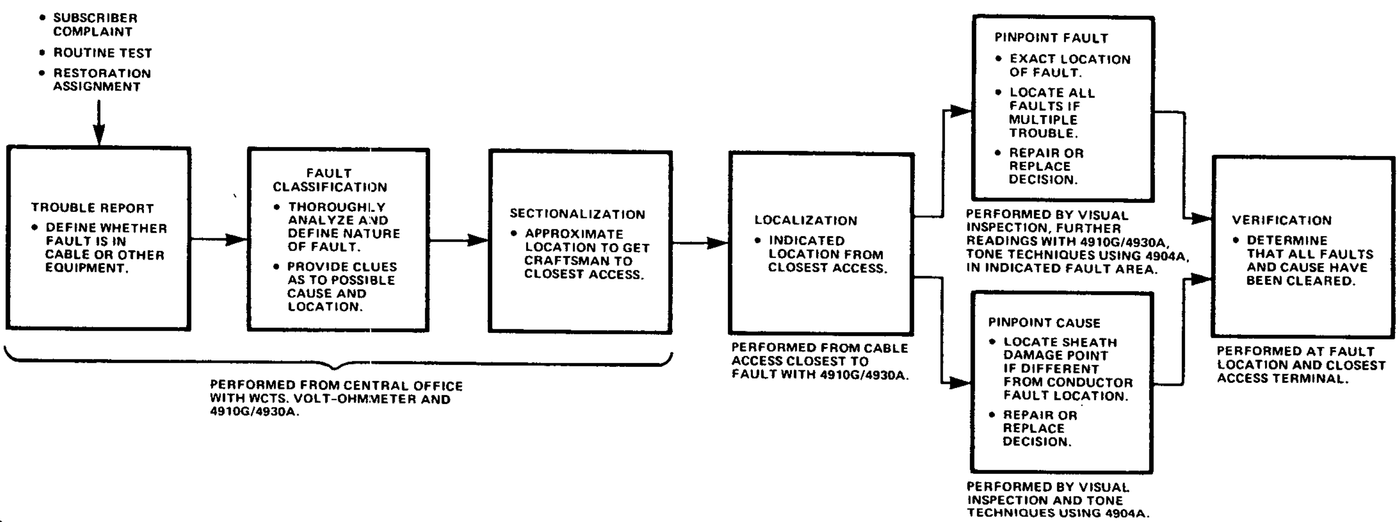


Figure 1. Fault Isolation and Repair Flowchart

Analysis – The Key to Success

Analysis is the process of investigating a problem and looking for clues that will help lead to a solution. The importance of fault analysis cannot be overstated. Trying to locate a fault in buried plant means you are literally working blind. Analysis provides the clues to help you visualize what's wrong with the cable and, therefore, provides a pretty good idea of what caused the fault.

Analysis also helps you to determine the extent of the damage. In other words, you should be looking for multiple faults on other pairs, which may or may not be at the same damage spot.

Complete analysis will also help you decide which fault locating instruments and techniques to use and whether it is more economical to repair or replace the faulty cable section. Remember – the key to fault locating success and fast clearing time is *analysis.*

The Trouble Report

Trouble reports originate through subscriber complaints, line insulation testing (LIT), cable acceptance testing in new plant or through efforts to restore abandoned pairs in existing cables. Hopefully, faults can be detected before they are service-affecting and before other pairs in the cable are affected. Preventative maintenance can then be performed before moisture entry causes more extensive damage. *It is essential that repairs be made immediately after the condition is discovered to prevent further deterioration of the cable.*

As soon as a trouble is reported it should be determined whether it is a fault in the cable or in other equipment, such as the subscriber's set, switching equipment, etc. This test is easiest to perform from the test board.

Classification

After determining that the trouble is due to a fault in the cable, the next step is to classify the fault and to look for possible clues as to its cause. Usually, these tests are performed from the test board but they can also be performed at the Main Distribution Frame (MDF) or in the field.

Classifying the fault can be done with simple test equipment. All that is required is a voltohmmeter (VOM) and handset.

The VOM can be used to test for conductor grounds, shorts, crosses, opens, loop resistance and foreign battery. The headset is convenient for monitoring crosstalk and noise on the circuit and otherwise checking the circuit transmission quality. The craftsperson soon learns to interpret these phenomena and relate them to possible trouble causes.

In general, there are five types of conductor faults (see figure 2):

1. **Short.** This fault results when one conductor of a pair makes contact with its mate (i.e., Tip to Ring). A short can be a metallic contact or leakage through moisture in the cable. It can measure several million ohms in wet plastic insulated cable (PIC) down to a solid short (zero ohms) where there is metallic contact between conductors. Shorts can be caused by left-in drops but are usually caused by physical damage to the cable; therefore, there are probably other shorts, crosses and grounds at the same spot. It is likely that there will be battery or ringing voltage on the faulty pair.
2. **Cross.** This fault results when there is electrical contact between conductors of different pairs, such as Tip #1 to Tip #2, Ring #1 to Ring #2, Tip #1 to Ring #2 or Tip #2 to Ring #1. The other characteristics of a cross are the same as those of a short. The cross can be any resistance, and there are usually other crosses or shorts at the same place.
3. **Ground.** From the standpoint of fault locating, there are three types of grounds. The conductor-to-shield ground may result from metallic contact, but may also be the result of water in the cable. Since working tips are usually grounded, the second type of ground is actually a cross to a working tip. This fault appears to be a ground when analyzed and is difficult to distinguish from a conductor-to-shield ground. The two types of grounds described above are service-affecting faults. A third type of ground is the shield-to-earth fault which by itself is seldom service-affecting. This fault is most often caused by damage to the PVC sheath. It can be a water entry point and can result in shorts and crosses several to several hundred feet away. There may also be conductor damage at the sheath damage point if the damage is severe.
4. **Open.** An open is a break in one or both sides of the pair. Most opens are man-made, almost always appearing in splices or ready access closures. An open can also be caused by excessive tension during plowing-in operations or by cable severage. Cable severage will also inevitably result in shorts, crosses, and grounds and for the purpose of troubleshooting it is usually better to treat this type of fault as a ground, if possible. Partial or high resistance opens may also result due to poor wire connections in splices/closures as well as wire deterioration prompted by battery cross-electrolysis action.
5. **Split.** This is a splicing error where a conductor of one pair is spliced to a like conductor of a different pair but the mates of these conductors are spliced correctly (figure 2 illustrates this condition). A split results in a serious imbalance on both pairs and can cause excessive noise and crosstalk on both circuits. Occasionally, a split will be corrected at a subsequent splice or terminal. This is often referred to as a *corrected split* or a *split* and *resplit.* A *corrected split* does not solve the problem, however. An imbalance still exists, which must be cleared.

Once the fault has been classified as one of these five types there are other important bits of information that can be of help to the craftsperson who will be doing the actual fault location. Look for clues, such as:

- Does a conductor ground disappear when a working tip is lifted at the frame? By methodically disconnecting working tips in the trouble count, a cross to a working tip can

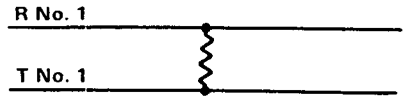
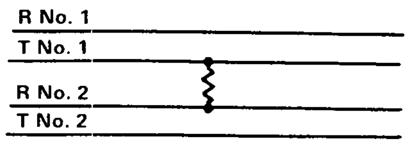
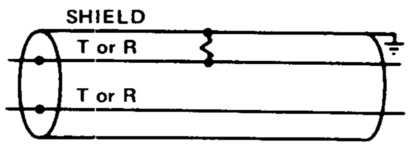
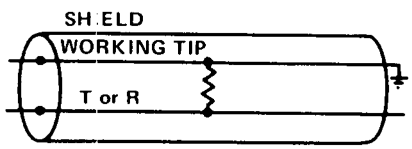
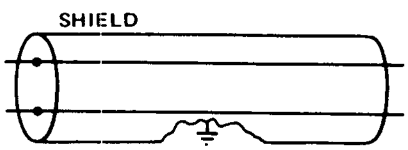
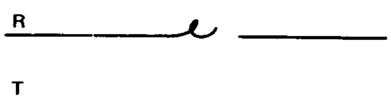
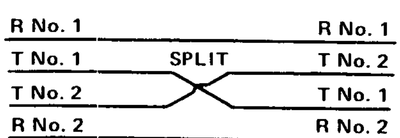
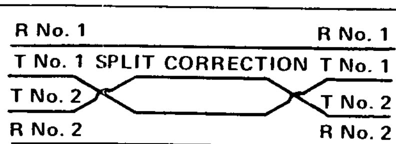
<table>
<tr><th>FAULT</th><th>EXAMPLE</th><th>CHARACTERISTICS</th></tr>
<tr><td>Short</td><td>
</td><td>1. Electrical contact between mates of a pair.
2. Contact can be metallic or through water in cable.
3. Usually results from physical damage to cable.
4. Usually occurs with several other faults on other pairs at same location.
5. If caused by water in cable, actual fault may be at a different location from water entry point.
6. Likely that it will be crossed with battery from faulted conductors.</td></tr>
<tr><td>Cross</td><td>
</td><td>1. Electrical contact between conductors of different pairs.
2. All other characteristics same as Short.</td></tr>
<tr><td>Ground (Conductor-To Shield)</td><td>
</td><td>1. Electrical contact between conductor and shield.
2. May also be caused by water in cable.</td></tr>
<tr><td>Ground (Cross-To-Working-Tip)</td><td>
</td><td>1. Electrical contact between conductor and working tip grounded at C.O.
2. Actually a Short or a Cross, but appears as Ground when analyzed.
3. All other characteristics same as Short or Cross.</td></tr>
<tr><td>Ground (Shield-To-Earth)</td><td>
</td><td>1. Electrical contact between shield and earth.
2. Usually caused by physical damage to cable sheath.
3. Potential water entry point.
4. Conductors may be damaged at sheath damage point and, if damage is severe, throughout wet section if water entry is significant.</td></tr>
<tr><td>Open</td><td>
</td><td>1. Electrical discontinuity in one, or both, sides of pair.
2. Usually man-made.
3. Usually occurs in a closure.
4. May be partially open.</td></tr>
<tr><td>Split</td><td>
</td><td>1. Splicing error. One side of pair is cross-connected; mates connected properly.
2. Always occurs in a closure.
3. Pairs are usually adjacent count.</td></tr>
<tr><td>Corrected Split</td><td>
</td><td>1. Splicing error. Split is corrected at subsequent closure.
2. Correction does not cure problem of split.</td></tr>
</table>

Figure 2. Faults and their Characteristics

sometimes be confirmed. In many offices the working tip causing the ground can be located by placing a tone on the faulted conductor and searching for the tone at the frame.

- Is there an excessive amount of noise, crosstalk, power line hum, dial tone or dial pulse noise on the pair? This can indicate serious imbalances in the cable caused by water, multiple faults, defective shield bonds, defective shield grounding, splits or corrected splits.
- What is this pair's (or cable's) repair history? A particularly vulnerable trouble spot may be acting up again. The fault might be in an old trouble splice.
- Are there any reports of digging or construction near the cable path?
- Are there any load coils, build-outs, or bridge taps on the faulty pair? Where? These devices can affect fault location readings and must be taken into account.
- Do you have other knowledge of the plant that can help? Are the plant records up to date?
- What is the condition of other pairs in the trouble count? This information will help to determine the extent of damage so that a repair or replace decision can be made later. It also gives the craftsperson some alternative faults to attack in case valid reading cannot be obtained on the reported pair.
- The condition of other pairs also gives an indication of whether the fault is in a closure or mid-span. Many pairs in trouble indicate a closure, such as a wet splice. A single fault infers a mid-span or an isolated pedestal location.

Sectionalization

After defining the fault, the next step is to determine its rough location. Usually, this task can be performed from the test board or MDF. Sectionalizing is done to locate the closest cable access point to the fault so that a craftsperson can be dispatched to pinpoint and repair the damage. A final fault location reading can seldom be made from the C.O. because of the distances involved, wire gauge changes and other error factors. The Model 4930A Conductor Fault Locator and the 4910G Open and Split Fault Locators have been used very successfully by operating telephone companies for this fault sectionalization.

These instruments simplify the fault locating procedures by providing a fast, direct reading of the distance to the fault. They are much easier to use than traditional bridge techniques and require no special training or mathematics.

When sectionalizing a short, cross or ground from the C.O. it will be necessary to strap the cable at some point beyond the fault in order to complete the fault locating loop. In the case of subscriber loops the strap should be made as close to the subscriber's drop as possible. On non-repeated trunks, such as interoffice and PBX trunks, it is usually convenient to place the strap at the distant frame.

With the 4930A Conductor Fault Locator three fault distances can be measured:

1. The distance from the near-end to the fault.
2. The distance from the strap (far-end) back to the fault.
3. The overall distance from the test set to the strap.

These measurements are particularly useful when sectionalizing because in many cases gauge change calculations can be avoided. For example, if there is a gauge change but the fault is in the far-end gauge section, then setting in the gauge of the far-end section will give an accurate far-end to fault reading. Likewise if the fault is in the near-end gauge section then a correct reading to the fault can be measured by setting in the near-end gauge.

The 4910G Open and Split Fault Locator is not affected by gauge changes because it measures cable capacitance (which is not affected by changes in gauge). However, it must be compensated for bridge taps and build-out networks. The 4910G is also a direct reading split locator and can be used to sectionalize splits accurately. In most cases enough accuracy can be achieved using these test sets from the test board or MDF to dispatch a craftsperson to a reasonable spot to start localizing the fault.

Localization

Having defined the nature of the fault and determined its approximate location from the C.O., the fault can now be located exactly. This is the time to determine whether to replace the section of defective cable or to repair it. If a replacement decision is made, it will not be necessary to pinpoint the exact fault location, just isolate the fault between two access points.

If a repair decision is made, the next step will be to localize the fault from the closest cable access point. Localizing is merely the first step in pinpointing the exact fault location. More importantly, it tells where the fault is *not*.

Again, analysis plays an important role in achieving success. The following information is essential:

- Wire gauge of the cable and any gauge changes in the section if the fault is a short, cross, or ground. This information is necessary for setting up the 4930A.
- The capacitance of the cable if the fault is an open. This information is necessary for setting up the 4910G.
- Location and types of any load coils, build-out networks and bridge taps in the section. These devices must be taken into consideration when using the 4930A and 4910G.
- Path and depth of cable. This information is very helpful in relating the electrical distance reading of

the fault locating instrument to the actual footage to the fault. Most cable maps do not show the plant exactly as installed: cable path and depth are determined with the 4904A. Remember to take into consideration the length of cable on risers, slack loops, and other variations in the straight-line length.

Localizing the fault requires access to the cable at two adjacent access points (such as pedestals, terminals and ready-access splices) straddling the faulty section. The faulty pair(s) must be isolated at both access points. In the case of a shield-to-earth fault, the shield must also be isolated at both terminals.

If possible, the final fault location reading with the 4930A or 4910G should be taken from the access point closest to the fault: *measuring the shortest distance to the fault gives greatest accuracy.* The Fault Locator is connected to the cable and a reading taken following the procedures printed inside the test set's cover.

Special procedures must be followed if any of the following conditions exist:

- Change of wire gauge in the trouble section (4930A only).
- Load coils in the trouble section (4930A only).
- Bridge taps in the trouble section (4930A and 4910G).
- Build-out capacitors in trouble section (4910G only).
- Unknown wire gauge (4930A only).
- Unknown capacitance (4910G only).

Procedures for coping with the above conditions can be found in the Appendixes of the 4930A and 4910G Operating Manuals.

We now have an accurate reading of the distance from the terminal to the fault location. In most cases, this reading will put us within a few feet of the actual location. If the cable shows a number of faults, it is advisable to take readings on several pairs to confirm whether all of the damage is at one point or if it is distributed along several feet. If these readings show faults throughout a long section of the cable (typical of water in the cable), a decision may be made to replace the entire section.

Pinpointing

A good job of pinpointing the fault location will not only save a lot of unnecessary digging and sheath openings, but can also assure that the damage is completely repaired. In many cases of sheath damage, water will enter the cable at a high point and settle at a lower elevation, where it will cause conductor damage (see figure 3). So it is necessary to locate and repair both the cause and the effect.

The first step is to locate the reported fault (refer to figure 4). After localizing this fault from an access point, the actual location is taped off. Remember to take into consideration the length of cable on risers, slack loops, and other variations in the straight-line length. Use the 4904A to determine path and depth of cable.

Arriving at the indicated spot, make a thorough visual inspection along the cable path several feet in either direction. Be on the lookout for:

- Signs of fresh digging and new structures, such as fence posts, signs, fresh blacktop or concrete, trees, etc.
- Water filled depressions in the ground.
- Large cracks, shifts or frost heaving in the ground surface or pavement.

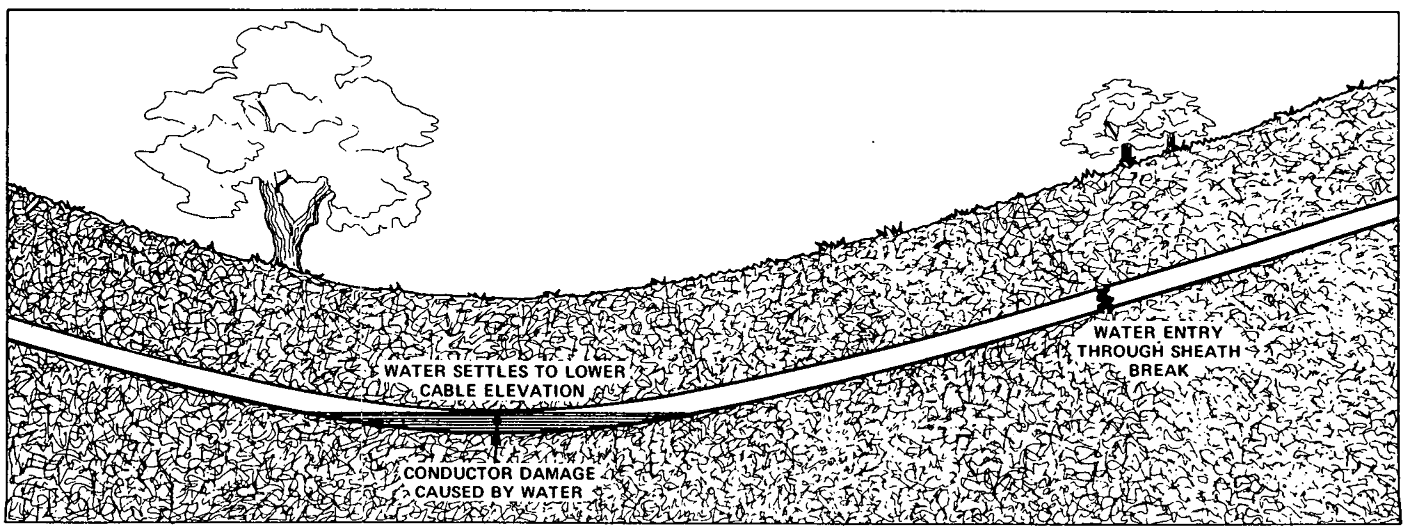


Figure 3. Water Flow in Cable

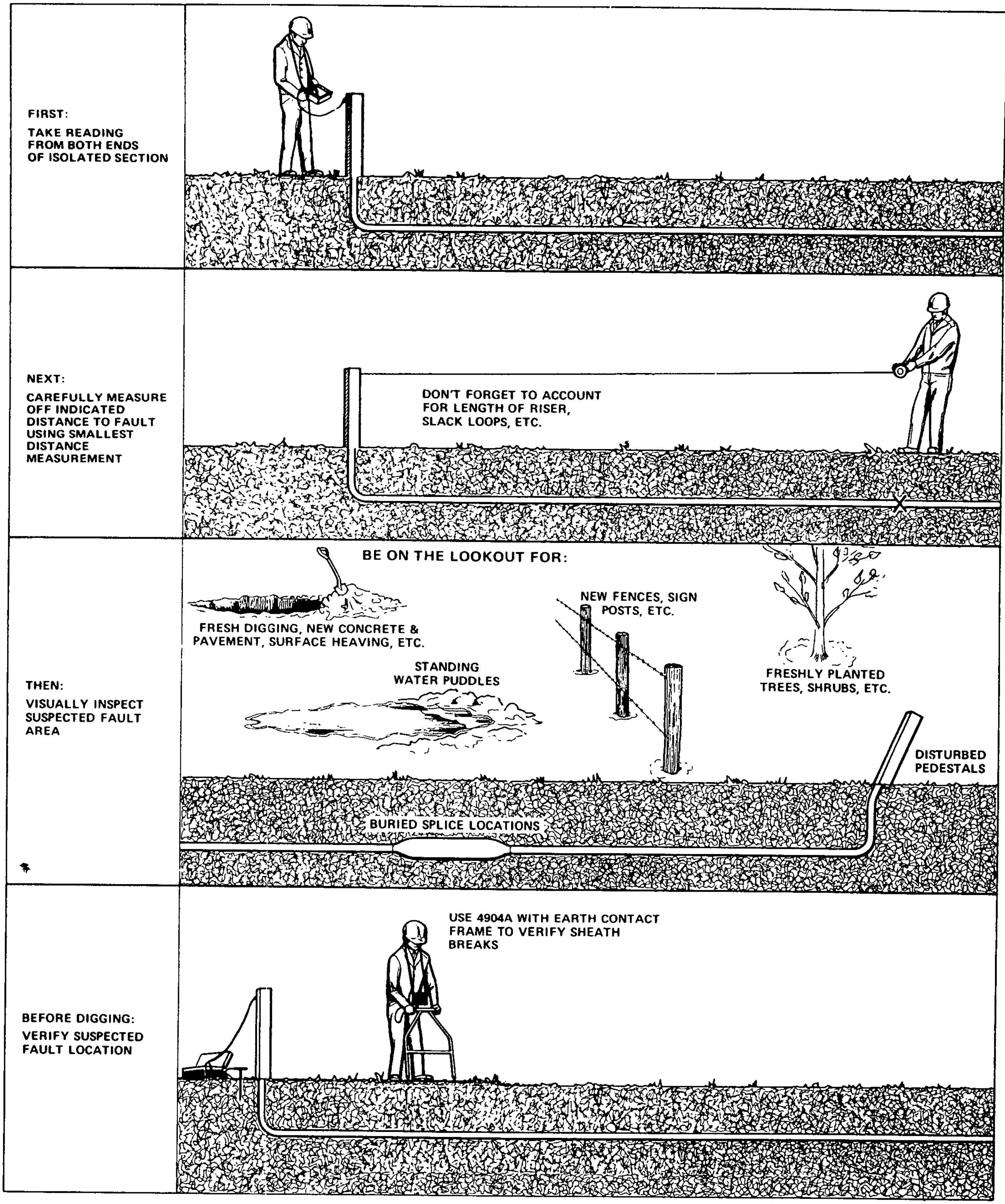


Figure 4. Pinpointing Fault Location

- Pedestals heaved or otherwise disturbed.
- Splice locations in vicinity of indicated fault location.

If a suspected spot is located, it should be examined more closely. If shield ground is present, the section should always be inspected with the 4904A and the Earth Contact (A) Frame to locate any sheath damage (water entry points).

In 99% of your trouble shooting cases, you will have successfully pinpointed the fault with the above techniques. Occasionally, you may need to apply alternate procedures.

If the cable section is exceptionally long, it may be necessary to open the cable and take another reading. The cable should be opened at the indicated location and readings taken in both directions. This will usually provide a location, accurate to within a few inches.

Pinpointing Sheath Damage

Up to now, we have been mainly concerned with locating the reported fault itself. It is not uncommon for the cause of the problem to be several feet away from the fault. In buried plant, the cause is usually water entering the cable through a sheath cut or leaky splice case (shown in figure 3).

Sheath damage is usually very easy to locate with the 4904A tone-type Cable Fault Locator and Earth Contact Frame. A tone is placed on the cable shield at the closest terminal and the suspected fault area is probed with the Contact Frame. The fault indication is positive and accurate to within a "shovel-width".

Pinpointing Opens

With very few exceptions, an open always occurs in a splice or ready access closure. This makes pinpointing easier, since all you need to look for is the closure that is closest to the indicated fault location. The Model 4910G Open Fault Locator will tell you this distance with a ±1% accuracy (see figure 5).

The only other major cause of opens is severe damage to the cable. If the cable is cut, it is likely that there will also be shorts, crosses, and grounds at this point. An open between splices can also be caused by corrosion due to water in the cable. Again, there will probably be other types of conductor damage at this spot (see figure 6).

The best way to pinpoint these "between-splices" opens is to go after the coincident shorts, crosses and grounds with the 4930A and 4904A. This assumes that the open is only a minor symptom of a big problem, therefore, you will need to locate the sheath damage point and the extent of other conductor damage to clear the fault completely.

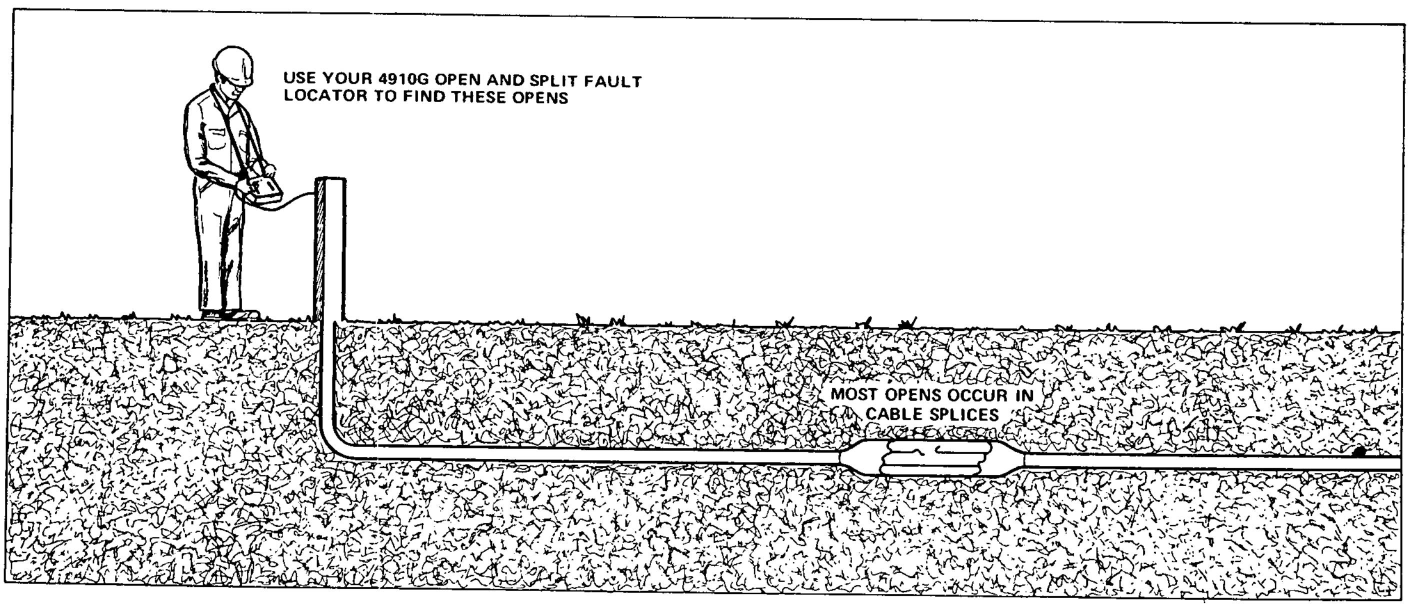


Figure 5. Pinpointing Location of Open

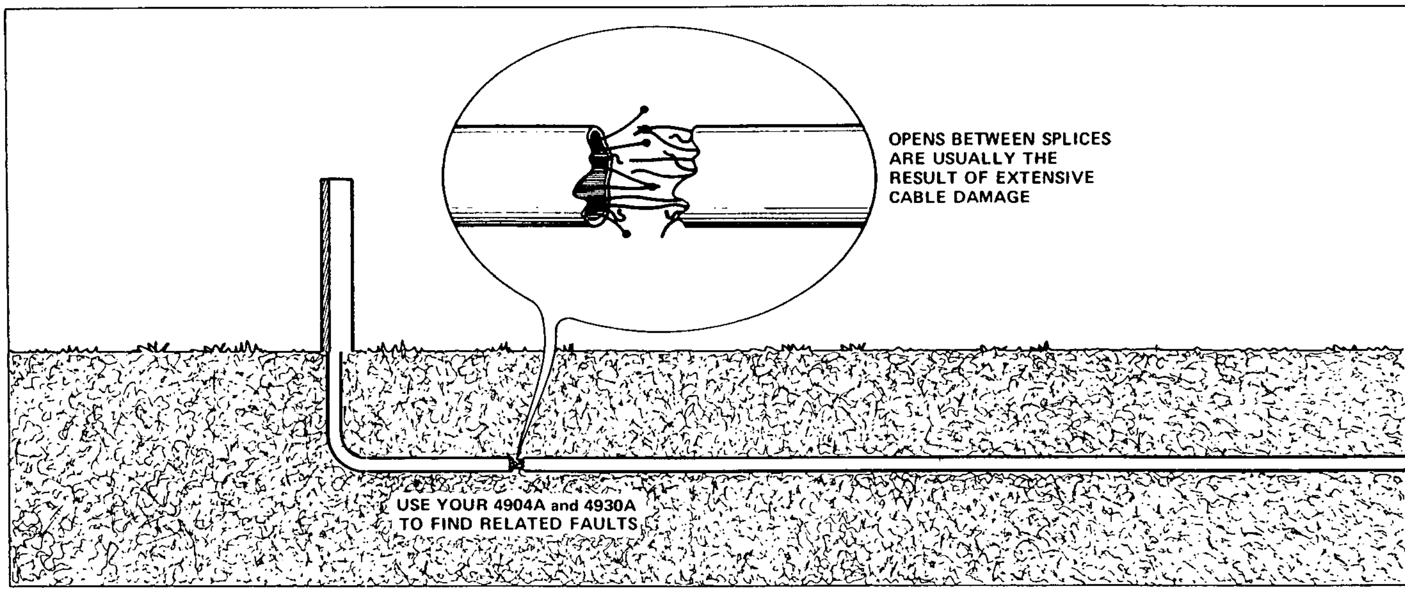


Figure 6. Finding Related Faults

Pinpointing Splits

As with most opens, splits always occur in a splice or ready access closure, eliminating the large area where the trouble is not located. Best results are obtained by shooting splits from the MDF to verify, isolate and confirm the location of the split.

Verify the split from the MDF with the help of a craftsperson in the field. He should provide test ground on the split pairs to verify and identify the split wires. This is necessary to assure proper hookup: improper hookup will result in false distance readings.

Isolate the split by taking several readings with the 4910G from the MDF. Then check plats to locate the nearest splice to the indicated reading.

Confirm the location with tone prior to opening the splice. Set up a 4904A tone set at the MDF with the required strap in the field in order to tone the split. Tone out the suspected splice and, if necessary, adjacent splices. This approach will result in checking a maximum of two closures, opening only the one where the split is located.

Verification

The final step in a successful fault locating mission is to verify that the fault has been completely cleared. Verification should include a check for multiple faults on the pair that has been repaired, determination of whether there are other pairs with faults in the same location, and assurance that the cause of the fault has been cleared.

A quick check for multiple faults on the same pair can be made at the repair location by testing the pair in both directions with an ohmmeter. Checks for leakage should be made between Tip and Ring and from both sides to ground. A more complete analysis for crosses to other pairs, crosstalk and noise should also be made from the test board or MDF.

Verification should *not* be used as a substitute for thorough fault analysis at the beginning of the job. Once the cable has been excavated and the sheath opened, faults may "disappear" temporarily. It's then virtually impossible to locate these faults until they reappear (which you can bet on the next time it rains). So, it's much easier in the long run to locate all the faults before you start to repair.

Summary

Locating faults in buried cable requires a unique interface between man and machine. You would be hard pressed to locate many faults without the help of good electronic fault locating instruments. On the other hand, locating faults requires additional information and proper techniques that only you, the skilled craftsperson, can provide.

Most of the really successful craftspersons we know employ the concepts in this article. By approaching every job methodically and avoiding "short cuts", these experts are achieving close to 100% success. They continually add to their expertise by learning from experience to develop new techniques.

Summarizing these secrets to success:

- *Analyze the problem thoroughly.* Determine the nature of the reported fault (such as short, cross, ground and open). Analyze the cable for other coincident faults. Look for other clues that can help to define the cause, extent, and possible location of the fault – *before* you attempted to locate and repair the fault.

- *Know the cable plant.* Find the path and depth, location of buried splices, load coils, buildout networks and bridge taps. Know the cable's repair history and idiosyncrasies. Be aware of any excavation or construction activities near the cable path.
- *Know your fault locating test sets.* Be aware of the capabilities of all the test sets available to you. Read the test set manuals thoroughly. Familiarize yourself with their operation on your cable training plant.
- *Sectionalize the fault.* Locate the cable access point nearest the fault from the C.O. *before* going into the field.
- *Localize the fault.* Take readings from the closest access point to locate the fault as near as possible. Take readings on all reported trouble pairs to determine the number of fault points in the isolated section.
- *Make "repair or replace" decisions.* Don't waste time trying to locate individual faults when it becomes evident that the whole cable section is shot.
- *Pinpoint the fault.* Accurately measure off *cable length* to indicated fault location. Visually inspect suspected fault area. Use alternate techniques to zero-in on fault if necessary.
- *Pinpoint the cause.* Locate and repair water entry point if separate from conductor damage points.
- *Verify the repair.* Determine that all faults have been cleared before closing up the cable. Make sure cause has been cleared.
- *Use only approved, high quality instruments.* Reliability, accuracy, and ease of operation pay off with faster trouble clearance, less hit and miss digging and greater safety to personnel and plant.
- *Consult with your HP Field Engineer.* He's available to help you out with difficult cases, provide training assistance, and to advise you on how to get the most out of your HP fault locators.

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