Mineral Insulated Cable
300-0I-009

Fault Location and Cable Repair Manual

EGS Electrical Group NELSON HEAT TRACING SYSTEMS

M.I. FAULT LOCATION & CABLE REPAIR

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I. Preface

During the warranty period, Nelson will repair or replace heaters defective because of our materials or workmanship at no cost. If the warranty has expired, or if the cable was damaged in the field, there will be a nominal charge for repair. To detect any field damage (and determine responsible party), the cables should be checked during various stages of installation. This will also minimize any rework expense, such as having to re-insulate or re-lag the piping. Such a program would include meggering the cables when they arrive, just prior to installation, just after installation and before insulation, and after the pipe has been insulated. The economics involved should favor return of shorter circuits to the factory for repair.

II. Trouble Shooting

If a heater circuit is not heating properly, the first thing to check is the wiring. In multiple heater circuits, assure all heaters are properly connected. Normally all heaters will be connected in series unless the isometric drawing shows a parallel heater. If all is correct, then isolate individual heaters and megger to determine the defective unit. Bear in mind that A and G form heaters have pigtails on one end and E and H form heaters have pigtails on both ends. The proper method for meggering is to completely disconnect the heater, wipe down the pigtail leads to remove dirt and condensation. Megger (500V DC) between all conductors and sheath. A new cable in the field should read 20 megohms or greater and an older heater that has been in service should read greater than 5 megohms.

After verifying that a heater cable is bad there are a few places to look for the cause. Ninety percent of cable failures are due to mechanical breakage. Inspect the insulation along the pipe for external damage. Feel the pigtail leads to assure the conductor has not been broken inside the pigtail insulation. Inspect the silver solder braze at the splice fittings to assure they have not been broken. If these checks don't turn up anything then use a fault locator such as the Biddle #655763 or cutting the cable to determine the location of the faulted section. Cut hot section three inches in from the splice fitting. Megger the remaining cable and cold section to determine the failed part. If the cable still checks bad, perform this procedure on the other end (pigtails or end caps).

If the cable still meggers bad then the "half way method is needed.

III. Fault Location Methods

The "halving" method is a procedure where you cut the hot section halfway down and megger each direction. Cut the remaining bad section halfway and megger both directions. Continue until a small (20' or less) bad section is isolated. Splice in a new section of cable and splice previous cuts with splice kits available from Nelson. This is a time consuming method of fault location. Much faster results can be obtained by using the Varley or Murray loop method. This requires a high impedance fault locator such as the Biddle #655763. Instructions for using the Biddle units start on page 8. When cutting M.I. cable, be sure to keep moisture out of the open ends by using RTV compound.

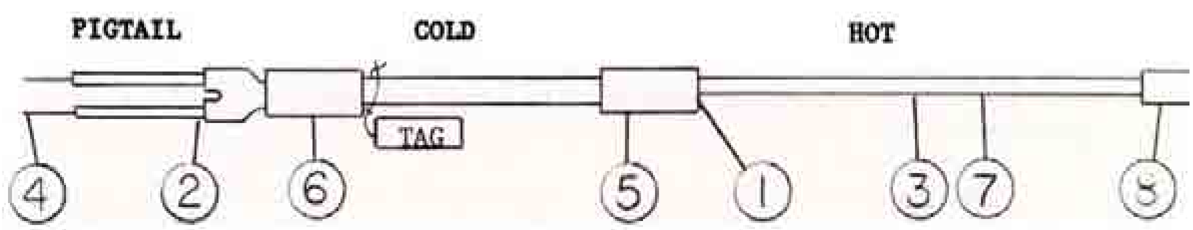
Open circuits in M.I. cables can be found using a ratio of the leakage currents on each side of the break. An example of how this is accomplished is shown on page 6. The example shows a two conductor situation, however it can be done with single conductors.

Another method of fault location in M.I. cable uses a "Thumper". This is not as accurate as the loop methods and should be used only by personnel experienced in the use of such equipment.

A fault location method used on communications cables is the time domain reflectometer or "Radar" type test set. These have not been too useful on "low megger" type M.I. faults but should work fine on open or direct shorts. If you have access to this type of unit, it might be worthwhile to try it. Improvements in these devices are constantly being made and your unit may be able to detect your type of fault.

IV. Review of Failure Modes

The metal sheath M.I. is the moat rugged, dependable electric heating cable available. However, failure may be caused by mechanical abuse or cor-rosion attack. For trouble shooting purposes, the locations of failure are listed below. Number one being the most frequent and number seven the least likely location.



Location	Description
(1)	Break in cable sheath permitting moisture entry. (Do not bend M.I. within 2" of splice fitting.)
(2)	Break in pigtail. (Do not use pigtails for pulling.)
(3)	Heating cable cut or broken during installation. (Protect heaters from other crafts during installation. Example: weld slag may burn thru heater sheaths.)
(4)	Check applied voltage to agree with tagging information (Incorrect voltage may have caused heater failure or insufficient heat output.)
(5)	Conductors may be open or shorted in hot to cold splice. (This is the most critical step in fabricating heaters.)
(6)	Moisture entry due to physical damage to cable.
(7)	Open or short in hot section. (If the sheath appears intact the magnesium oxide insulation may have de-teriorated due to a lightning surge or corrosion pen-etration of the cable sheath.
(8)	Conductor open or shorted in the end cap.

Figure 1

V. Detailed Instructions

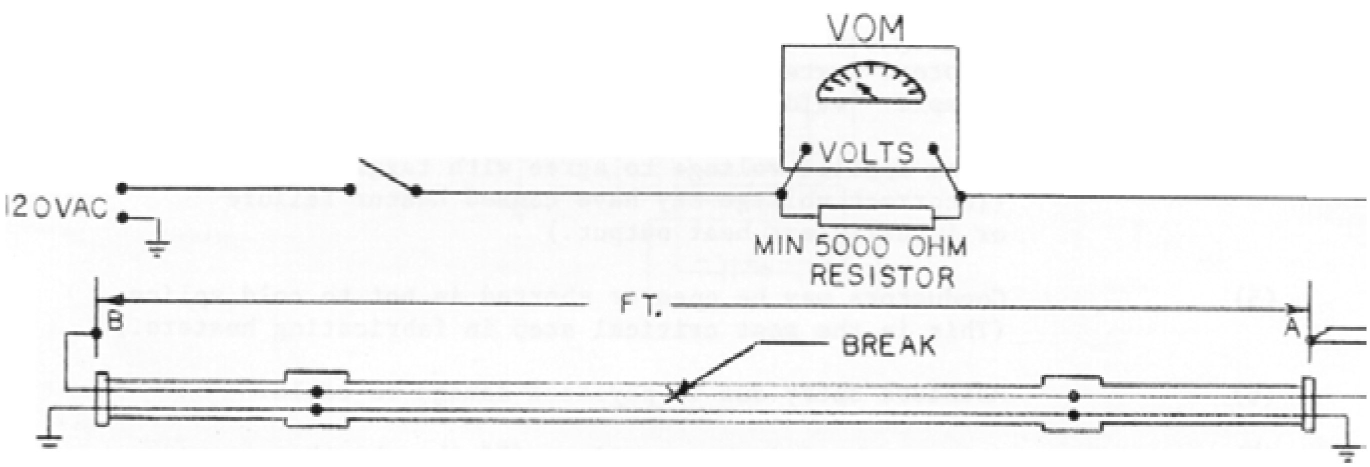
A more detailed explanation of "how to" using various methods and equipment is included in the section. The following is a general description of a leakage ratio detection method followed by a general description of a bridge method and instructions on use of the Biddle fault locator.

Locating an "OPEN" in a circuit with one conductor open

1. Ground the good conductor.
2. Connect the open conductor to the resistor as shown if Figure "A".
3. Record the voltage reading at point "A" and point "B".
4. By use of the following formula, the fault may be located in a very short section of the heater.

$$\text{Formula: } F = \frac{V_A}{V_A + V_B} \text{ X length}$$

F = Distance to "open" from Point A
V_A= Voltage reading at Point A
V_B= Voltage reading at Point B

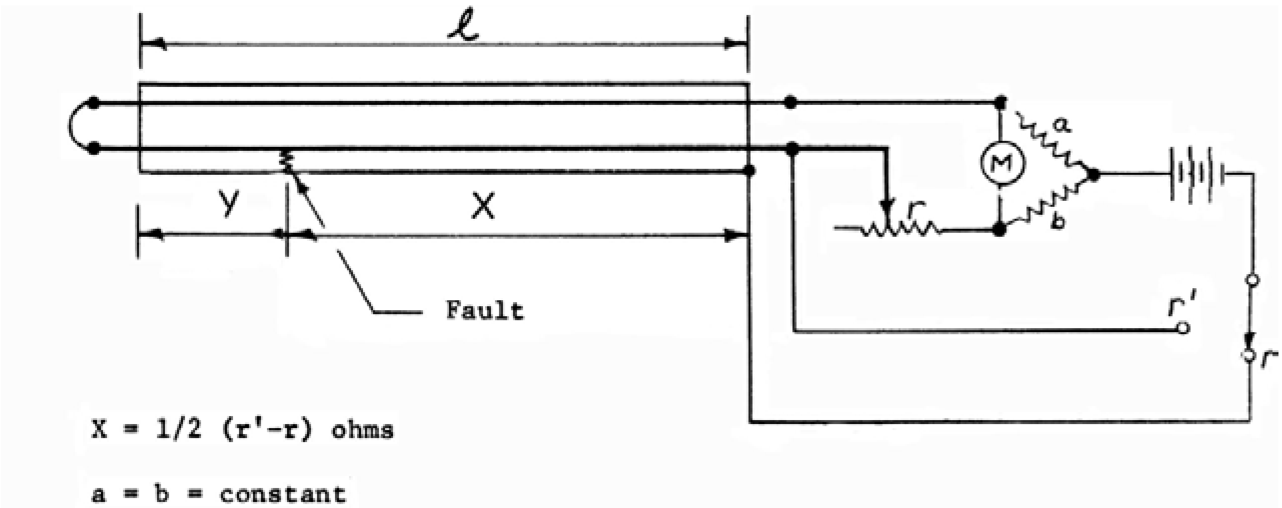


EXAMPLE: Heater Length = 250' - 0"
V_A = 10 volts
V_B = 15 volts
$$F = \frac{10}{10 + 15} \text{ X } 250' = 100'$$

Open is located 100 feet from Point "A".

NOTE: When using this method on pipe tracing measuring the distance to the "open", do not neglect the heater cable placed on valves, flanges, pipe supports, etc.

HIGH RESISTANCE GROUND FAULT LOCATIONS
<u>USING THE VARLEY LOOP METHOD</u>



In the Varley Loop, fixed resistors of equal value are used on two legs of the bridge and the bridge is balanced by adjusting r to the near leg of the faulty conductor. Note resistance of r. Reading r' can be taken by applying the battery to switch position r' and re-balancing the bridge.

We now have r and r'.

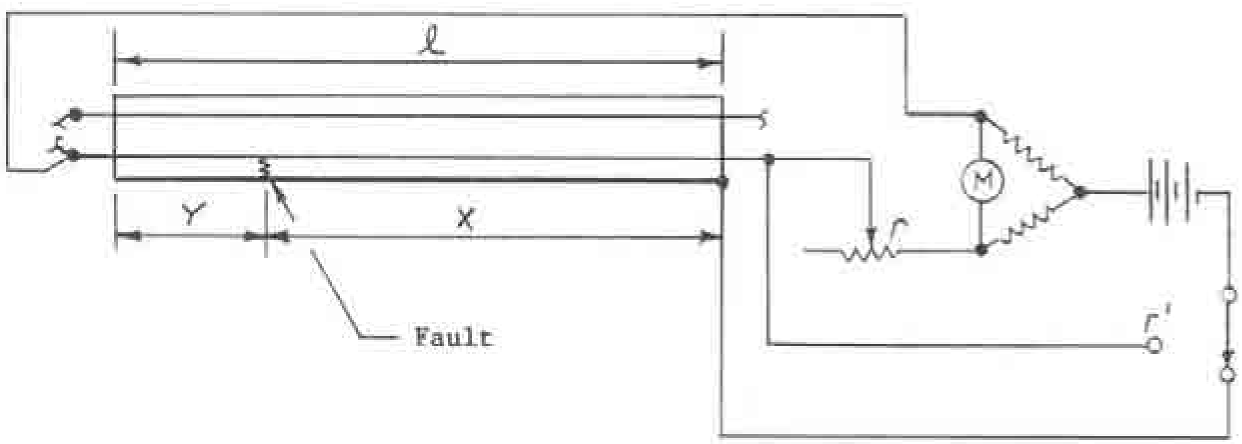
$$X = 1/2\ (r'-r) \text{ ohms}$$

$$= [1/2\ (r'-r)]/R \text{ (ft.)}$$

R(ft)= resistance/ft. of conductor

If segments A and B are slightly different, reverse the polarity of the battery and re-measure. This will give slightly different value for X with the fault existing between the two values.

If the cable is an E or H form, then connect per diagram below. Also if inconclusive readings are obtained from a "single ended" hook-up above, then gain access to the far end, cut off the end cap and connect per diagram below.



The following is a detailed instruction set on how to use the Biddle fault locator on M.I. cable.

INTRODUCTION

The Biddle High Resistance Fault Locating Bridge, Catalog No. 655763 utilizes a modified Wheatstone Bridge circuit in which the two sections of the faulted conductor - one on each aide of the fault - comprise the two external arms of the bridge. The remaining two arms of the bridge are contained in the instrument. By use of a detector circuit of extremely high imput resistance, it is possible to locate high resistance faults without loss of sensitivity. With this bridge arrangement, faults having resistances from 0 to 200 megohms in dielectrics such as rubber, PILC, and polyethylene can be located with an accuracy well within ±0.5%. A typical error would be 6 inches in 500 feet, or ±0.1%. Limitations are determined by the uniformity of the conductor.

Owing to the high sensitivity of this fault locator, a balance can often be obtained on a good conductor. This balance is due to normal cable leakage current and will result in a reading of approximately 50% in a cable of uniform insulation quality at a uniform temperature. For this reason, the existence of a fault should be established by insulation resistance measurement before attempting to locate. Use an ohmmeter to check for continuity of an M.I. cable and a megger to check for faults to ground.

SAFETY PRECAUTIONS

WARNING: BEFORE ATTEMPTING TO MAKE ANY CONNECTIONS, MARE SURE THAT ALL EXPOSED CABLES ARE DE-ENERGIZED.

For beat test results, precautions should be taken to avoid secondary leakage paths. The battery and the instrument should be insulated from earth by separate sheets of insulating material such as polyethylene. It may also be advisable for the operator to insulate himself from earth by standing on a sheet of insulating material when balancing the instrument. He should stand still if he is wearing highly charged clothing such as nylon overalls. The use of shielded test leads is strongly recommended. When locating very high resistance faults, movement of people in the vicinity of the test equipment or the cable can cause a transient disturbance of the bridge balance making it difficult to obtain a reading. This is caused by electrostatic charges on their clothing and they should stand still while the measurement is being made. This condition will be eliminated if the capacitors are used as described in paragraph "A".

OPERATION

1. Connections

A. CONNECTIONS WHEN BOTH ENDS OF THE FAULTED CONDUCTOR ARE AT THE SAME POINT. SEE FIGURES 2 & 3.

1) Strip back pigtail lead 4".

2) Using suitable connecting clips, connect potential leads at least 4 inches from conductor ends. Connect current leads to the ends of the conductor under test, then connect one of the current leads to a battery terminal. (A 6 or 12 volt lantern battery is recommended.) If maximum sensitivity is required, the potential leads should be soldered to the conductor or wrapped around it to insure proper contact around the entire conductor.

3) When testing conductors having a loop resistance of less than one ohm, use a one-ohm resistor in series with the battery. This limits the current to some value less than 12 amps from a 12-volt battery, providing adequate sensitivity without causing unnecessary current drain and conductor self-heating. In these applications an auto battery is recommended. (See Figures 2 and 3.)
NOTE: A one ohm, 100-watt resistor (Ohmite or equivalent) will be satisfactory in most cases.

4) Clamp or solder a lead to the sheath if the fault is between conductors.

5) Connect the sheath lead to the terminal labeled "SHEATH".

6) After balancing the null detector to zero, connect the current lead to the remaining battery terminal. By alternately touching and removing this lead, "zero" the null detector with the calibrated dial. After obtaining a zero, read the dial; this reading represents the percentage of the total length of the cable loop at which the fault is located from the "+" terminal. By multiplying the length by this number, the distance to the fault is directly indicated.

Note: that the dial reads 0-100, so a reading of 90.0 is equal to 90% or a multiplying factor of 0.90.

B. <u>CONNECTIONS WHEN THE ENDS OF THE FAULTED CONDUCTOR ARE NOT AT THE SAME PLACE, SUCH AS A CABLE IN SERVICE:</u>

Two connection methods may be used. The preferred method is to run out two insulated wires to the distant end to serve as current and potential leads. The resistance of these leads should be as low as possible, e.g., less than 1 ohm. Then make connections at the near end and follow remaining procedure as outlined in Section "A" above.

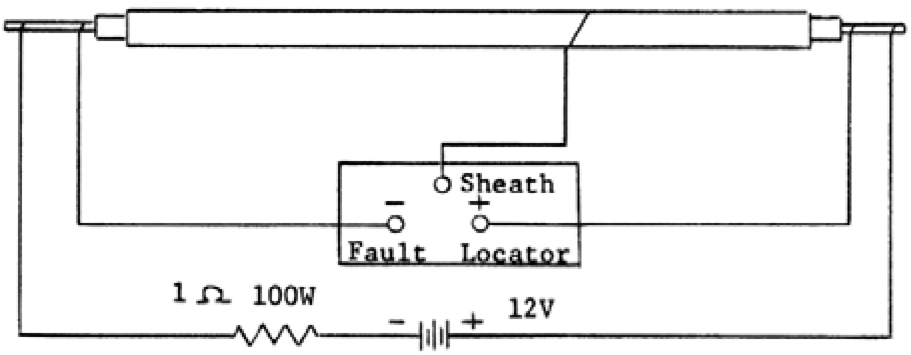


FIGURE 2: Fault to sheath; both ends of faulted conductor accessible at the same point.

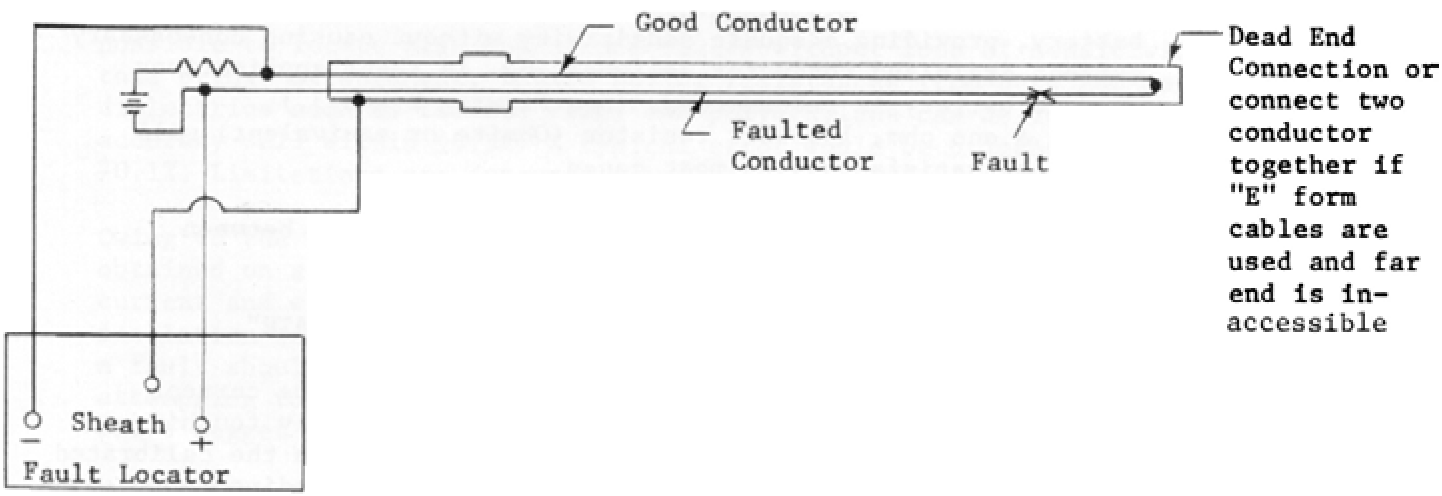


FIGURE 3: Fault to sheath, two conductor cable.

I. LOCATING A FAULT:

A. Follow procedures list in the previous section, entitled "Connections".

B. Reverse the "Potential" leads at the "conductor" terminals and re-balance the bridge. The sum of the readings obtained should total 100%. A sum other than 100% indicates possible multiple faults or faults which are not localized to one point. In the case of wet MGO due to a rupture in the sheath, both conductors would be "faulted" to the sheath. This could cause readings to sum at a value different than 100. If so, or if any doubt exists about the readings on a two conductor cable, see D below.

C. Failure of the Detector to respond indicates a non-faulted circuit or a circuit with faults of extremely high resistance.

NOTE: The total length of the cable loop means the total length of cable between the potential points, that is, the points at which the leads to the terminals of the instrument are connected to the cable. This equal to the length of the cable in the case shown in Figure 2 but is equal to twice the length of the cable in Figure 3.

D. On a two conductor, cable errors are introduced in the readings when both conductors are "faulted" to the sheath because of wet MGO. The most accurate readings may be obtained by following the operating procedures above and connected per Figure 4.

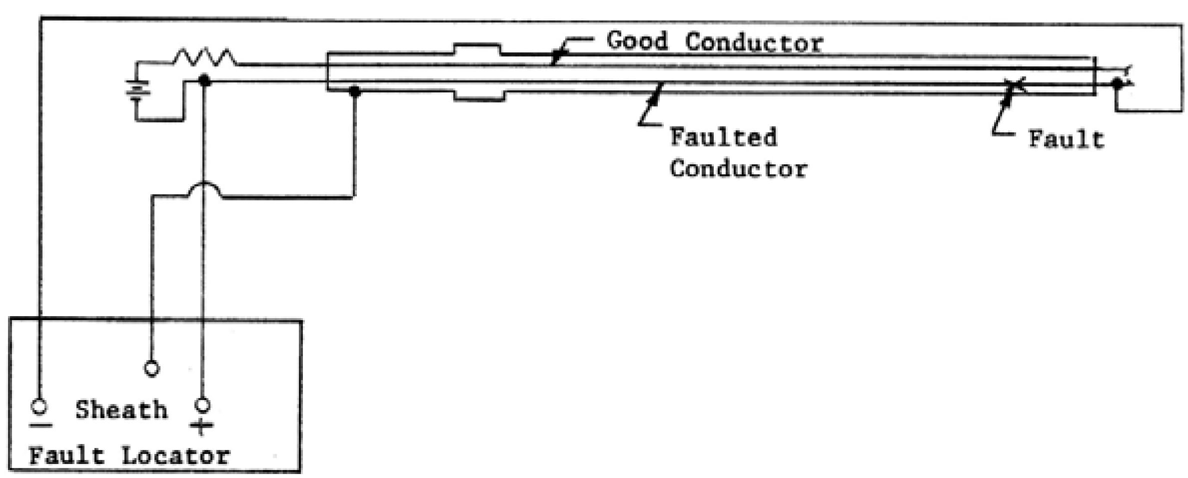


FIGURE 4: Fault to sheath, two conductor cable, removed end cap.

III. METHOD OF OVERCOMING ELECTROSTATIC CHARGES

A. When high resistance faults (greater than 1 megohm) are being located in a cable with high insulation resistance such as polyethlene, difficulty may be experienced when the air is dry due to electrostatic charges surging around the instrument and causing erratic behavior of the microammeter. An electrostatic suppression unit may be used to overcome this. It consists of two high-quality polystryene, or mylar capacitors of equal value connected to the guard terminal of the instrument. Refer to Figure 5 below if electrolytic capacitors are used to connect exact polarities together to create a non-polarized capacitance.

* luF-lOuF± 1%, luF preferred.

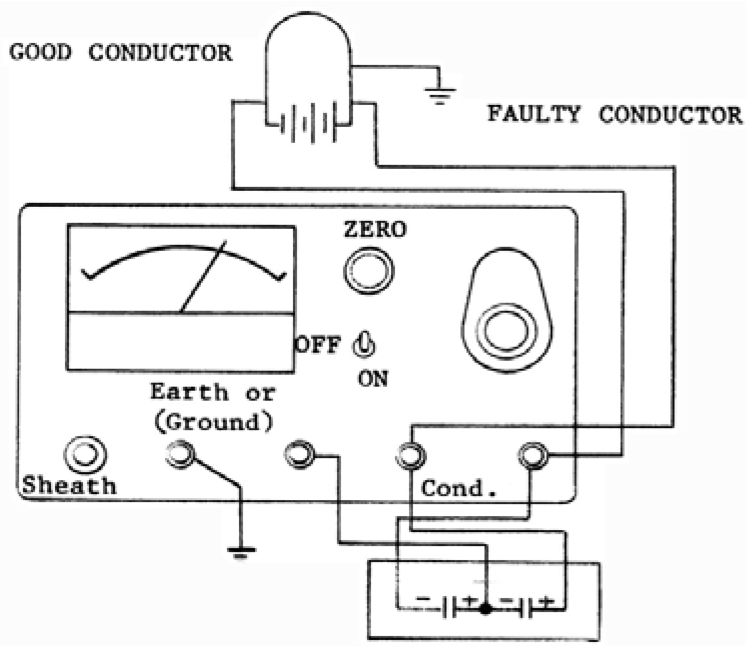


FIGURE 5: A method of overcoming electrostatic charges

VI. Cable Repair

Moisture and dirt are enemies to a successful field splice. A splice should be made under reasonably dry conditions. Do not let moisture get on Magnesium oxide.
Do not get flux on the Magnesium oxide.

To prepare cable for splicing, use a tubing cutter and nick the sheath at a distance 3/8" from the end. A slight bend will break the sheath. Crush end with linesmans pliers, slip off the cut end and remove the magnesia insulation squarely with the cut. Cut conductors back to 3/16" from the end of sheath using pliers. This will leave an airspace of 3/8" after splice is made.

If an insert bead is supplied with the splice kit, ream out end of the hot section 1/8" and insert bead over the conductor and into sheath.

Check insulation value between conductors and sheath on both lengths of cable using a 5OOV D.C. megger. If reading is above 100 megohms proceed with the splice.

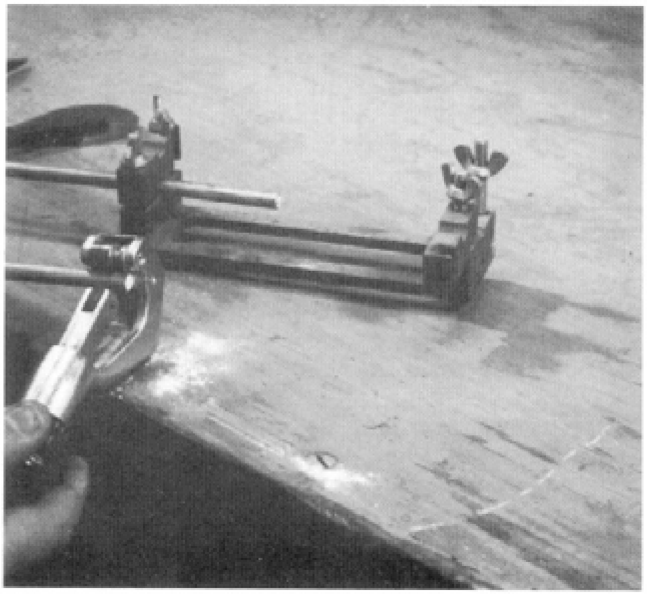
If the reading is lower, dry out cable by running the torch heat across cable starting about 12" from ends and heat to a dull red (about 1200 degrees F). Slowly move heat towards end. Check megger reading again, however it may exceed 100 megohms while cable is hot.

Brazing should be done with #1 tip or smaller with an oxyacetylene flame. Do Not use butane, propane, etc., as those gases will not produce enough heat.

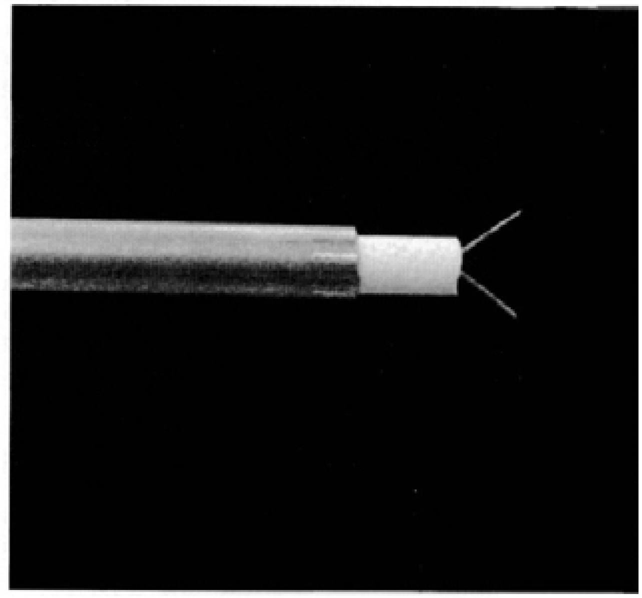
With conductor ends butted, apply a minimum amount of flux to each conductor joint and braze, leaving as small of a bead as possible. Remove hard flux with knife.

Slip the previously applied splice sleeve over brazed joint and center same. Sleeve is bored out to proper inside diameter for the size of cable being brazed. Apply a minimum amount of flux on the end of the sleeve, only enough to make a good seal. Do not saturate. Try to prevent flux from running into center conductor area. This work should be done in the vertical position. After silver soldering both ends, quench with water soaked rag and retest with megger. If reading is above 20 megohms the cable is acceptable for reinstallation.

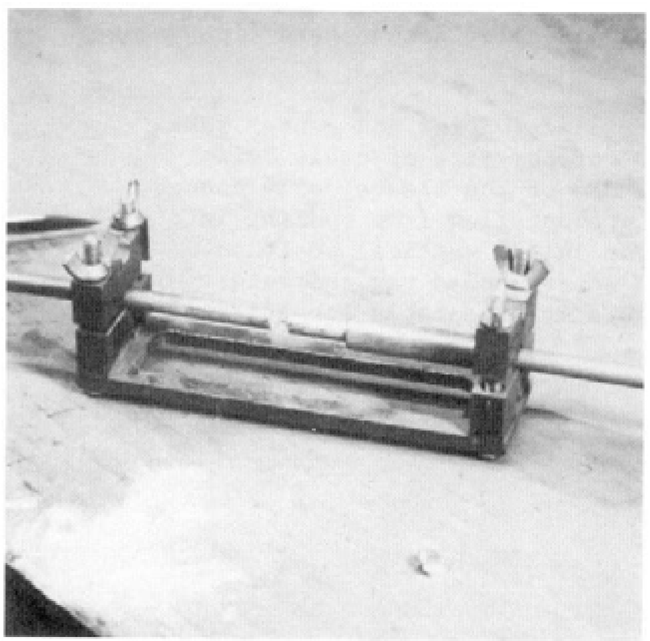
Pictorial Field Splice Instruction Sheet for Stainless Cable



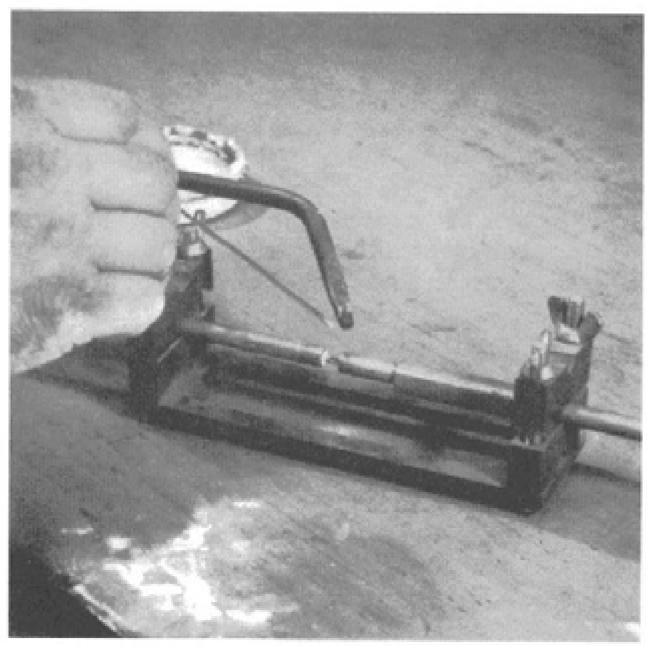
<u>Step 1</u>
Cut cable with tubing cutter approx. 90% through. The remains break off with linesmans pliers



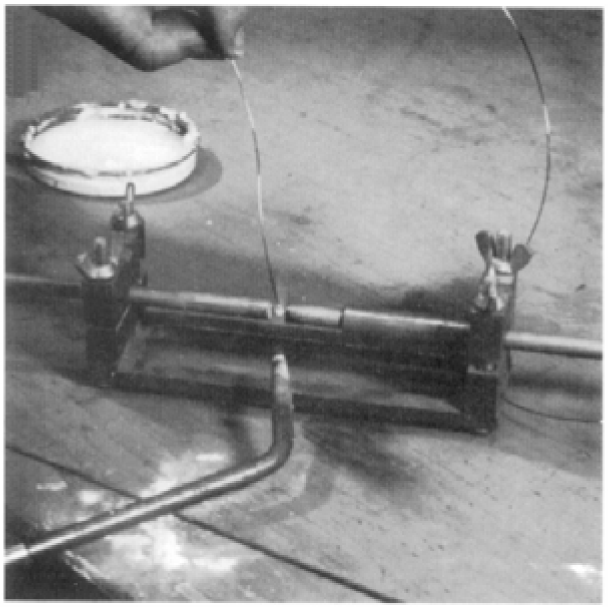
<u>Step 2</u>
If an insert bead is supplied with the splice kit, ream out end of hot section 1/8” and insert bead over conductor and into sheath



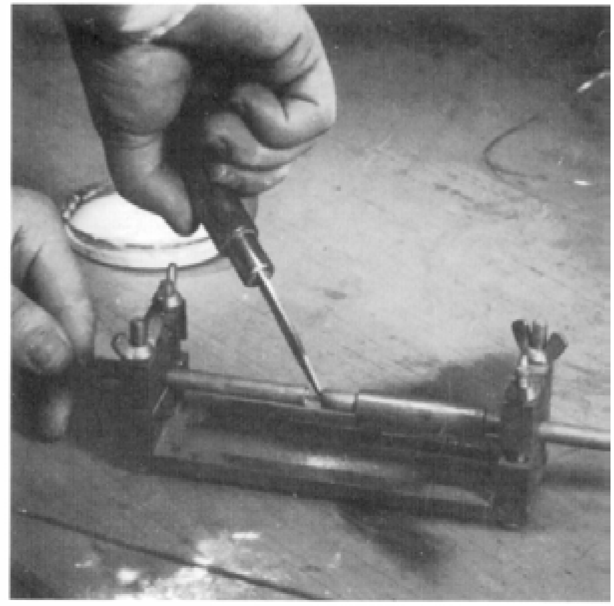
<u>Step 3</u>
Repeat procedure with the other half of cable and butt ends together. Hold together in splice vise, slipping sleeve over one end. Void area should not exceed 3/8”



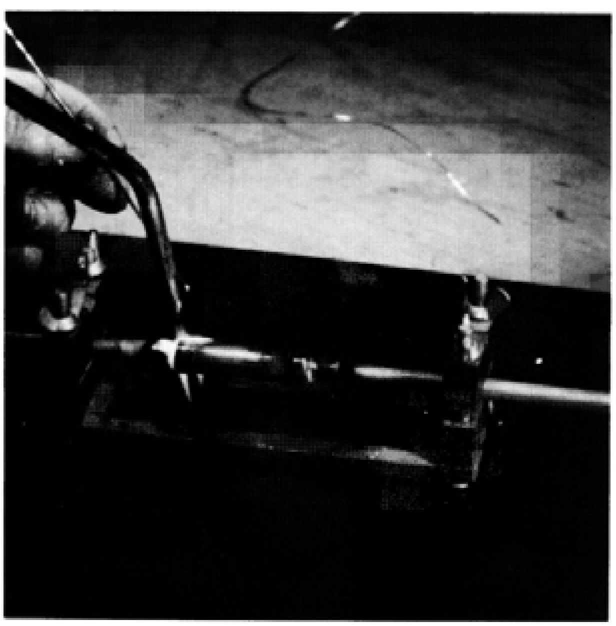
<u>Step 4</u>
Apply small amount of flux on butt splice of conductor(s).



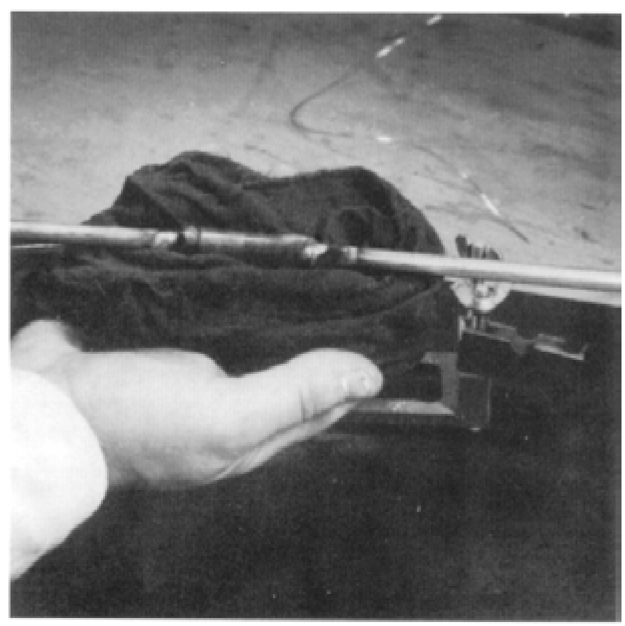
<u>Step 5</u>
Adjust oxy-acetelyne torch No. 0 or 1 tip to proper flame mixture and braze conductors together



<u>Step 6</u>
After making solder connections on conductors, clean off all carbon and flux.



<u>Step 7</u>
Position sleeve, apply flux uniformly around the ends of the sleeve. Solder both ends without leaving any pinholes. This should be done in the vertical position, if possible.



<u>Step 8</u>
Soak entire splice in water, or use water soaked rag. Megger after splice has cooled off. Minimum reading should be 20 megohms.

NELSON M. I. SPLICE KITS AND END CAP KITS APPLICATION

DETERMINING THE CATALOG NO.:
Sample Cat. No. = SI - BA

S = Sleeve
E = End Cap
P = Pulling Eye

I = Inconel
C = Copper

A = 5/16" O.D.
B = 3/16" O.D.

For End Cap or Pulling Eye Omit Second Digit

How to Apply:		Cat. No.
3/16" "K" Cable	Hot-to-Hot Splice	SI - BB
3/16" "K" Cable	Hot-to-Cold Splice	SI - BA
3/16" "K" Cable	End Cap	EI - B
3/16" "K" Cable	Pulling Eye	PI - B
5/16" "B" Cable	Hot-to-Hot Splice	SI - AA
Also	Hot-to-Cold Splice	
5/16" "B" Cable	End Cap	EI - A
5/16" "B" Cable	Pulling Eye	PI – A

For copper heaters, simply substitute "C" for "I" in the Catalog Numbers and use proper cable Size "A" or "B". Copper cable sizes are as follows:
12-2, 12-1, 14-2, 14-1, 16-2 and 17-2 are 5/16" O.D. - Use "A"
16-1, 17-1, 20-2, 22-1, 25-2 and 25-1 are 3/16" O.D. - Use "B"
SAMPLE: 17-1 Hot-to-Cold Splice Kit = SC – BA
NOTE: All Cold Sections are 5/16" O.D.
NOTE: For Stainless Steel Cables (Obsolete) use the Inconel Designation.

M. I. SPLICE KIT CONTENTS

Qty.	Description
2	Sleeves (Determined by Cat. No.)
4	FA-3229 Ceramic Insert
4	FA-3230 Ceramic Insert
1 Oz.	Bottle of Handy Flux
12"	Silver Solder 1/16" O.D.
1	Instruction Sheet

M. I. END CAP KIT CONTENTS

Qty.	Description
2	End Caps (Determined by Cat. No.)
6"	Silver Solder 1/16" O.D.
1 Oz.	Bottle of Handy Flux
1	Instruction Sheet

NOTE: In Pulling Eye Kits, puller eyes will be used in place of end caps.

Kits contain enough material to make two splices or two end terminations.

Nelson **does not** recommend making hot-to-hot **field splices** on the following cables: 25-2, 21-2, 20-2 or any 2/C "K" cable due to its difficulty.
NOTE: Previous to approximately mid 1980, each copper size had a different cable O.D. and, therefore, a different size sleeve. To be sure whether your copper cable is the new or the old, measure its O.D. Remember, all post 1980 copper cable is either 5/16" or 3/16" O.D.
For any other M.I. field splicing application problems, consult factory.