920.0 CORROSION CONTROL - CATHODIC PROTECTION

920.0 CATHODIC PROTECTION

921.0 CODES AND STANDARDS

922.0 EQUIPMENT AND MATERIAL SPECIFICATIONS

922.1 Rectifiers

The rectifier transformer shall be designed for continuous operation and will be oil cooled. It shall convert 380 volt 3-phase 50 cycle per second power to 220 volt single phase power. Voltages may vary ±10%.

The rectifier shall be of selenium type and the unit supply voltage variation must be rated at maximum ambient shade temperature of 50°C. The DC volt and ammeter and also output control knobs must be kept behind lockable dustproof and weatherproof cover. The transformer rectifier tank must be weatherproof and filled to the cold oil level with Class B 30 oil complying with B.S. Specification No. 148.1. All internal wiring shall have P.V.C. insulation to the relevant British Standard. The Transformer Rectifier shall be equipped with a suitably rated dustproof-weatherproof A.C. switch fuse mounted on the tank and fitted with HRC fuses of suitable rate and in accordance with the relevant British Standard. The switch fuse shall be capable of being locked in "ON" & "OFF" position and having bottom cable entry.

Output regulation equipment must be immersed in the oil. The DC output of transformer rectifier should be regulated by 3 tapping switches, coarse, medium and fine. Each switch should have four position, control of DC output should be made in 63 steps. The transformer/rectifier may have constant current characteristic depending on operation requirement. Surge arrester shall be provided for all transformer/rectifier units.

922.2 Ground Beds

922.2.1 Impressed Current Anodes

Graphite or high silicon cast iron rods shall be used. Both types require a backfill. Use of graphite anodes shall be limited in soil with resistivity higher than 1000 ohm-cm.

Graphite anodes shall be linseed oil impregnated and pressure treated.

Total encapsulation shall be used on the graphite-to-wire junction. Wire lead shall be attached to the anode, giving a pull strength exceeding #4, #6 or #8 cable and shall have a low resistance contact. The lead connection shall be connected at one end and centered in the anode.

922.2.2 Cable

The conductor shall be No. 8AWG or larger and shall meet the requirements of ASTM B8 or ASTM B231.

The conductor shall be insulated with high density polyethylene and shall meet the requirements of ASTM-D1248.

922.2.3 Backfill for Groundbed

Graphite and high silicon cast iron anodes shall be surrounded by a metallurgical coal coke breeze of low resistivity and low ash content. The resistivity of backfill material shall not exceed 50 ohm-cm. Maximum particle size of coke to be 3/16 inch (0.5 cm) without additional lime. Maximum particle size of coke to be 3/16 inch (0.5 cm). Dust percentage shall not be more than 10%. This backfill shall extend one foot (30 cm) below the bottom, six inches (15 cm) around the circumference, and one foot (30 cm) above the top of the anode. Two feet (60 cm) of gravel shall top the backfill. Backfill shall be firmly tamped during installation. Minimum diameter of hole for anode shall be 8 in. (20 cm). For deep well groundbeds calcined petroleum coke should be specified in the form of rounded granules or beads to prevent gas blocking.

922.3 Galvanic Anodes

High potential magnesium anodes (galvomag) shall be used where impressed current systems are not practical. For 10 year life expectancy, the following maximum milliampere current drains shall be observed:

32 lb. (14.5 kg) anode - 160 ma.
17 lb. (7.7 kg) anode - 85 ma.
9 lb. (4.1 kg) anode - 45 ma.

Anodes shall be surrounded by a suitable backfill (75% gypsum, 20% bentonite, 5% sodium sulfate) and packed in a cloth container.

922.4 Insulated Fittings

a. Insulated Compression Couplings

This is a compression type coupling which contains a gasket and insulated sleeve arrangement which will not allow two pipes joined together.

b. Flange Insulators

This type of insulated fitting consists of a neoprene faced phenolic full-faced insulating gasket, insulating washers with back-up steel washers and insulated sleeves to cover each flange bolt.

c. Weld-In Type Insulated Coupling

This type fitting is a prefabricated insulated coupling with a short length of pipe on either side of fitting. This fitting is welded directly into the pipeline to achieve electric isolation. The length of pipe on either side of the fitting shall be long enough to prevent heat distortion of the flange.

d. Insulated Stop Cock

This insulated fitting is used on all new domestic meter and regulator sets and when new service lines are installed to old meter sets.

e. Insulated Unions

This insulated fitting is used on old meter sets, where stop cock cannot be replaced with an insulated stopcock.

922.5 Power Source

Where electrical power is not readily available, other power sources may be utilized. Included in these:

a. Thermo-electric generators.
b. Sealed Rankine cycle turbo-alternators.
c. Solar cell battery systems.
d. Isotopic fueled generators.

923.0 DESIGN CRITERIA

923.1 Impressed Current Cathodic Protection

A coated pipeline is under cathodic protection when a pipe to soil potential of -0.85 volts is attained using a Cu-$CuSO_4$ half-cell. This potential is measured at soil near the pipe surface.

The amount of current required to attain protection is determined by the Current Requirement Test (Sec. 925.4). Results of a Soil Resistivity Test (Sec. 925.3) and a Current Requirement Test will provide the information necessary to design a ground bed according to Manufacturer's directions.

Soil Resistivity Tests are also necessary to locate the ground bed in an area of low soil resistivity.

The ground bed shall be installed at right angles to and more than one hundred feet (30 m) from the pipeline. The anodes shall be spaced at least 15 feet (4.5 m) apart.

923.2 Galvanic Anode Cathodic Protection

Galvanic anodes are used where relatively small increments of current are required in areas with low soil resistivity.

a. On bare or very poorly coated systems where complete cathodic protection may not be feasible from a cost standpoint.

b. On well coated pipelines having overall impressed current cathodic protection systems, where additional small amounts of current are needed.

c. To correct stray current interference.

d. On short increments of well coated pipe such as distribution and service lines.

923.3 Insulated Fittings

a. Sections of pipelines under cathodic protection must be insulated from other metal objects.

b. Pipes of different metals must be insulated from each other.

c. Meters must be insulated from the service pipe.

923.4 Cased Crossings

Casing pipe used at road and railroad crossings shall be electrically insulated from the carrier pipe. A test for electrical shorts shall be made at the time of installation both before and after welding of the pipe to existing pipe.

923.5 Test Stations

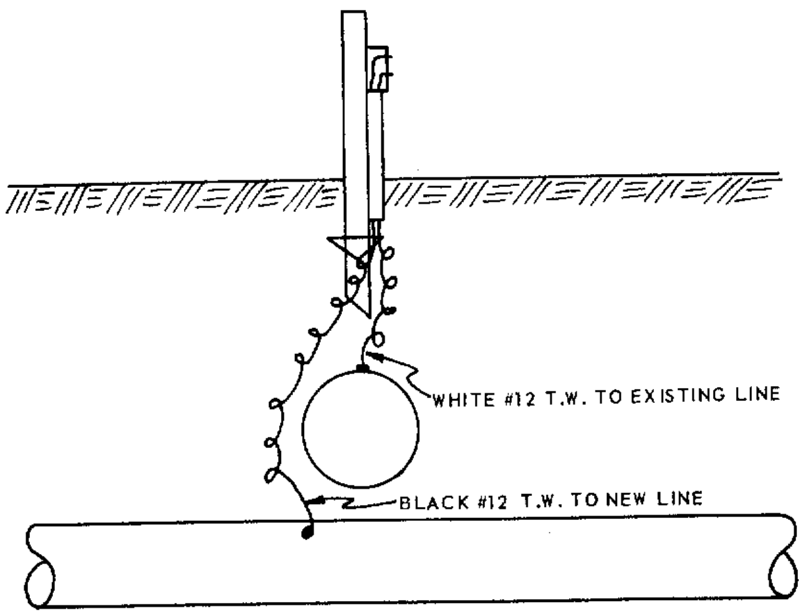
Test stations allow aboveground test points for the purpose of cathodic protection testing. A typical sketch of a test-wire tie-in for future cathodic installation (Standard 923.5.1) and typical sketch of a cathodic test station assembly (Standard 923.5.2) are in the Typicals and Drawings Section.

923.5.3 Single Line Test Station

This type test station shall be installed along a transmission or distribution line where there are no aboveground facilities to obtain a pipe-to-soil potential of the pipeline. Approximate interval between test stations should be 0.3 mile (0.5 Km). A typical sketch of a test point for urban areas (Standard 923.5.3) is in the Typicals and Drawings Section.

923.5.4 Line Crossing Test Station

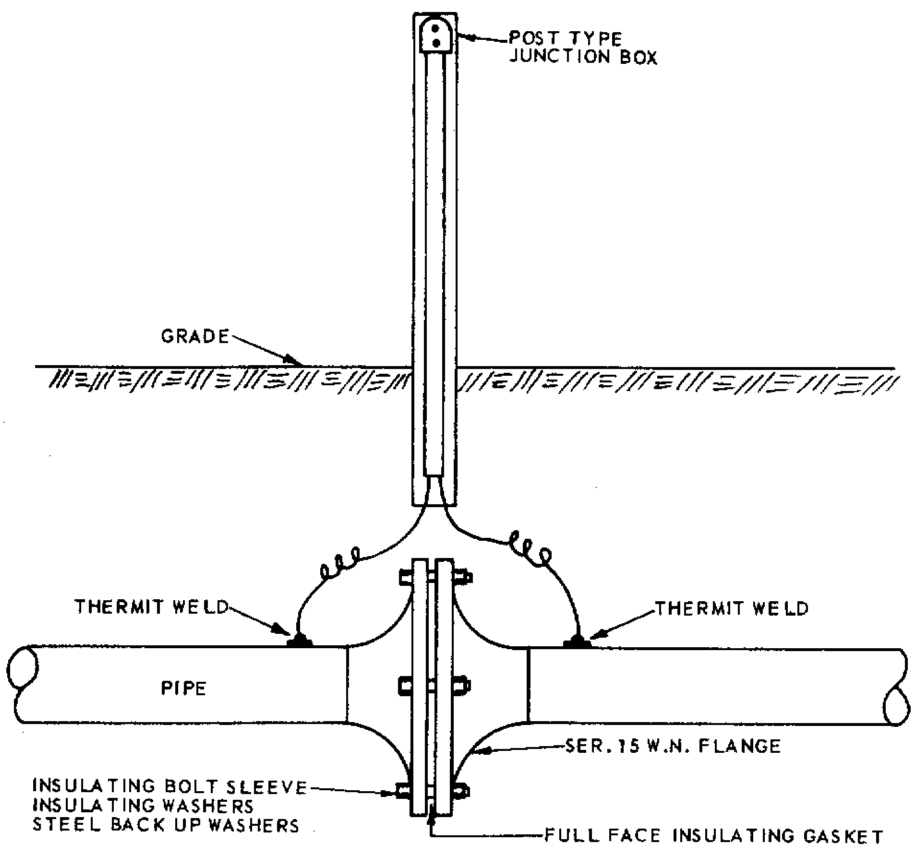
The pipeline crossing test station shall be installed at locations where representatives of both pipeline companies are mutually clearing any interference problems on their respective pipelines. If stray current is found, a resistance bond wire can be installed.



TYPICAL LINE CROSSING TEST STATION

923.5.5 Insulated Fitting Test Station

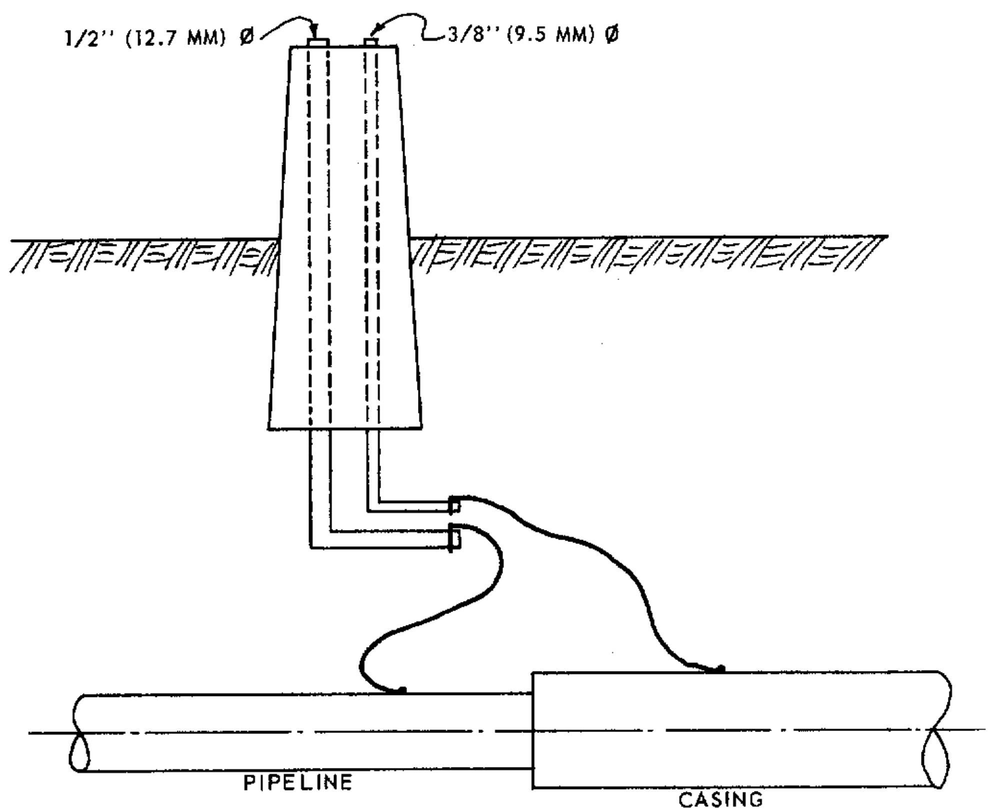
All underground insulated fittings must have test stations installed to allow a periodic check of the effectiveness of the insulator.



FLANGE TYPE INSULATION

923.5.6 Cased Crossing Test Station

All road and railroad crossings must have test stations installed to allow a periodic check for shorts between the carrier pipe and the casing or the vent pipe.



CASED CROSSING TEST STATION

924.0 INSTALLATION AND CONSTRUCTION

924.1 Rectifiers

Oil immersed rectifiers shall be installed in the shade and away from any equipment which creates heat.

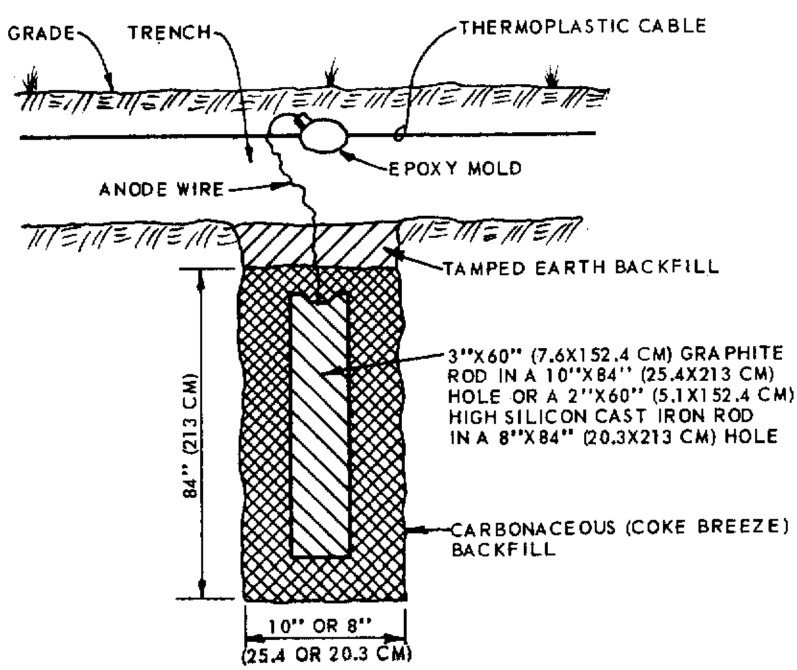
The rectifier cabinet must not be coated with mastics, tars, or any other insulating materials.

Rectifier cabinets shall be connected to a ground rod.

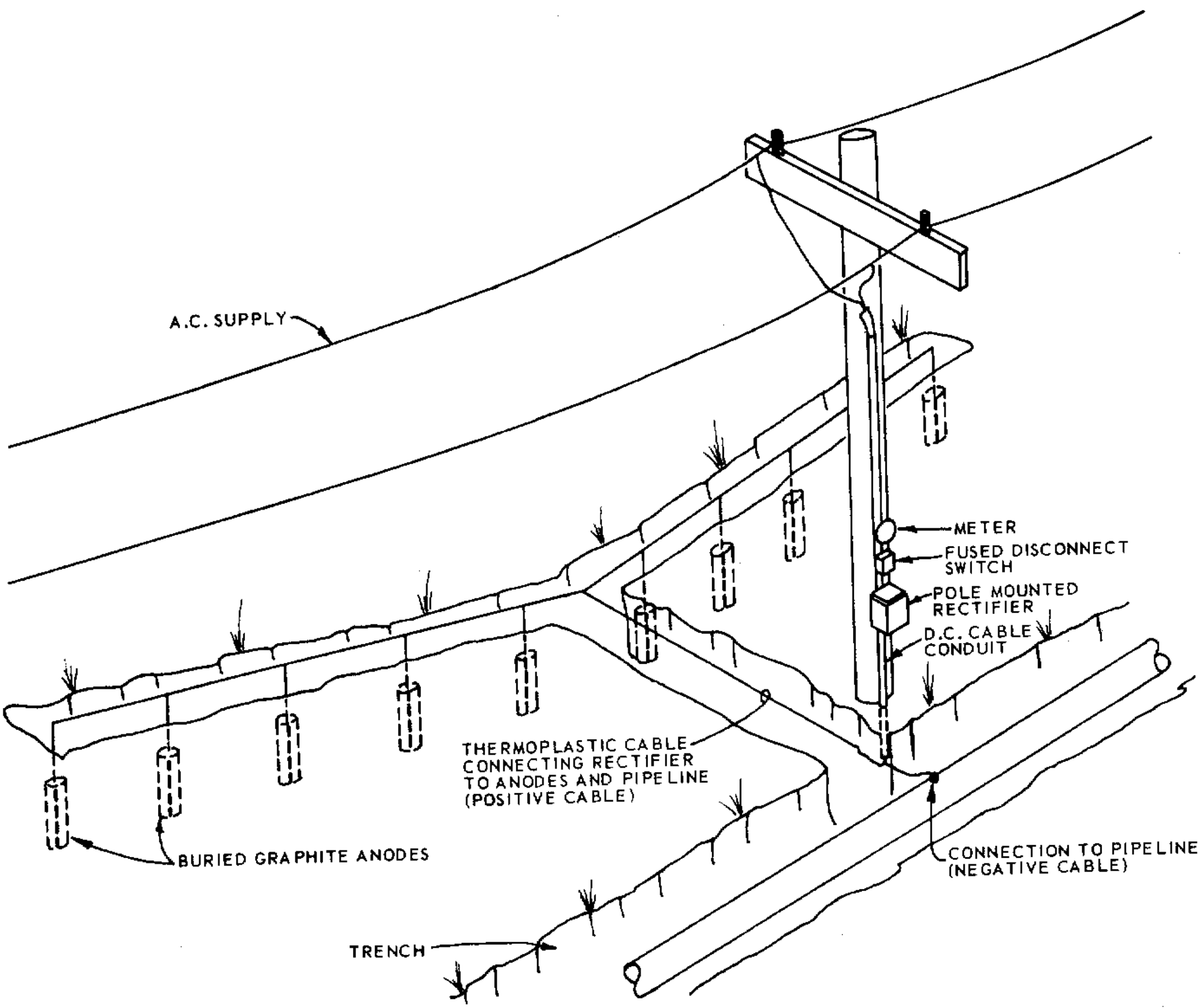
Verify that the structure potential shifts negatively when the rectifier is energized.

924.2 Ground Beds

The hole for an anode shall be augered 4 foot (130 cm) deeper than the length of the rod and 7 inches (3.8 cm) more in diameter than the rod.



One foot (30 cm) of coke-breeze backfill is poured into the hole and tamped. The rod is centered in the hole and surrounded by backfill which is thoroughly tamped. The rod cable is spliced, taped, and coated to the positive header cable. See Section 924.3.1. One foot (30 cm) of backfill is tamped in above the rod and covered with two feet (60 cm) of gravel. See the following diagram of entire setup.

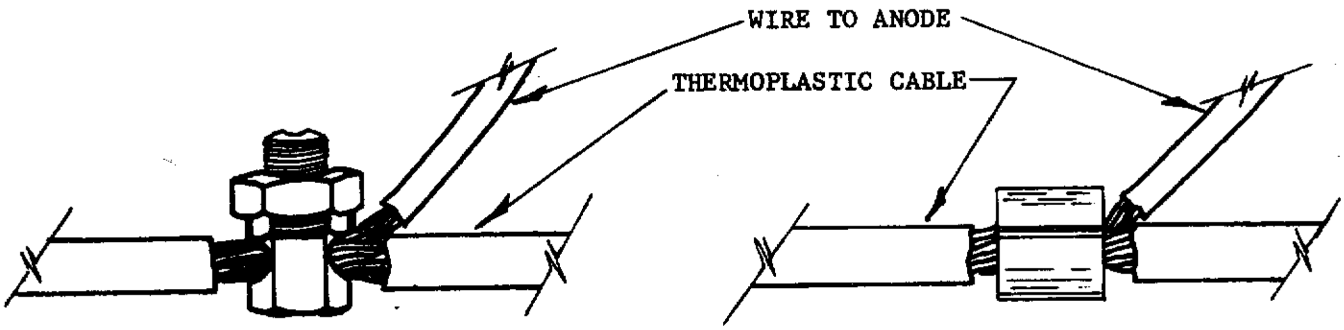


924.2.1 Splicing Instructions

a. Remove sufficient insulation to permit proper installation of the connector.

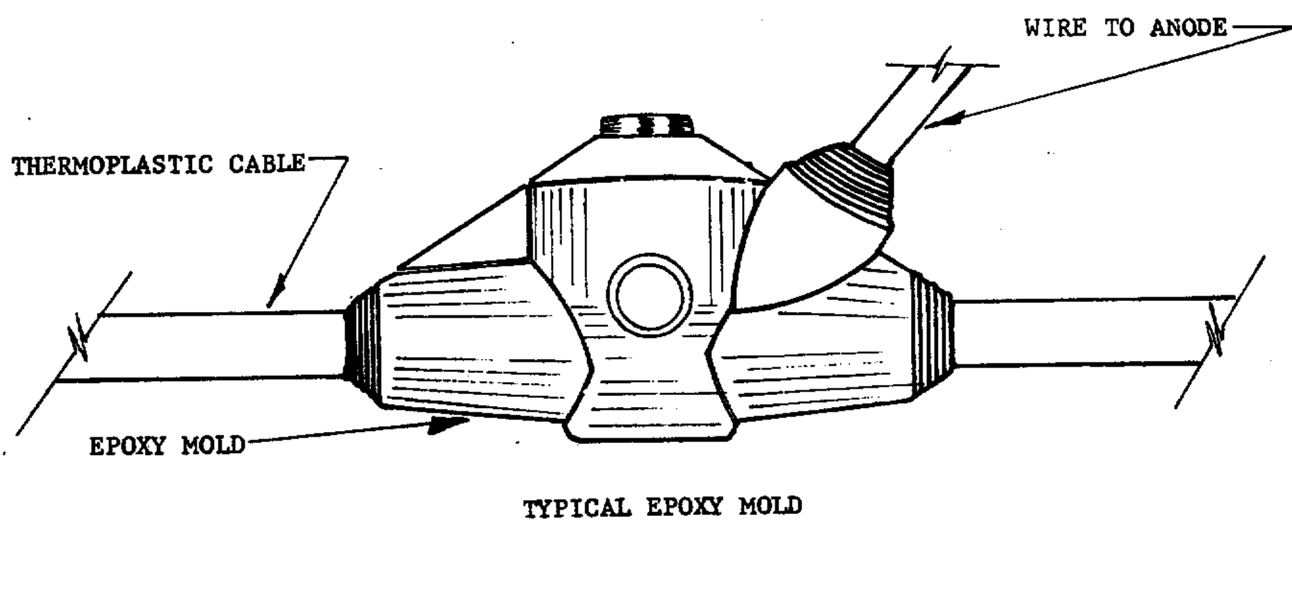
b. Attach the connector to the conductors by using either a split-bolt or compression-type connector.

c. Install an epoxy resin splicing kit over connection in accordance with manufacturer's recommendations.



SPLIT-BOLT CONNECTOR

COMPRESSION FITTING



TYPICAL EPOXY MOLD

924.3 Galvanic Anodes

Anodes should be located in areas having high subsoil moisture such as creek beds or drainage ditches.

Anodes shall be installed three to five feet (1 to 1-1/2 m) away from the pipeline and at least one foot (30 cm) deeper than the pipeline.

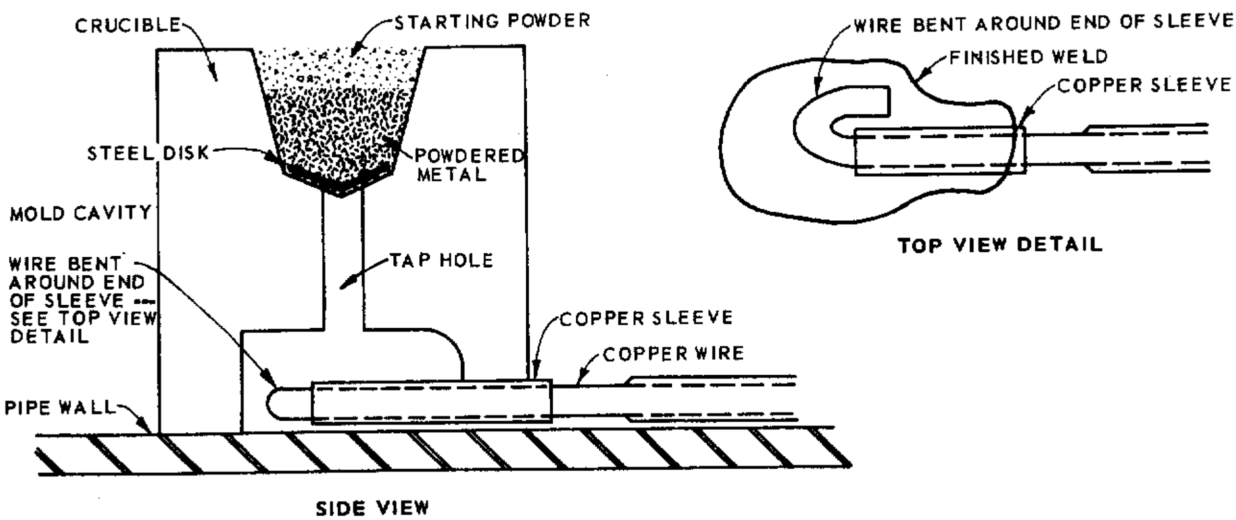
The earth should be thoroughly tamped around the anode, watered, then backfilled to the surface.

Thermit welding (924.4) shall be used to connect the anode lead wire to the pipeline.

924.4 Thermit Welding

For distribution systems and pipelines the thermit weld process (cad-welding) should be used for attaching test leads, anode leads and bonding lead wires to pipelines with the following restrictions:

1. Use only the No. 15 gram F-33 alloy charge or equivalent.
2. Never shall more than one charge be used in attaching one lead wire.
3. The thermit weld process should only be applied by field personnel who have been instructed in the proper use and who have been informed and understand the above restrictions.
4. After completion of the thermit weld, it shall be protected by use of a plastic thermit cap filled with mastic.



DETAIL OF THERMIT WELD PROCEDURE

2. All thermit charges should be limited to 15 grams.

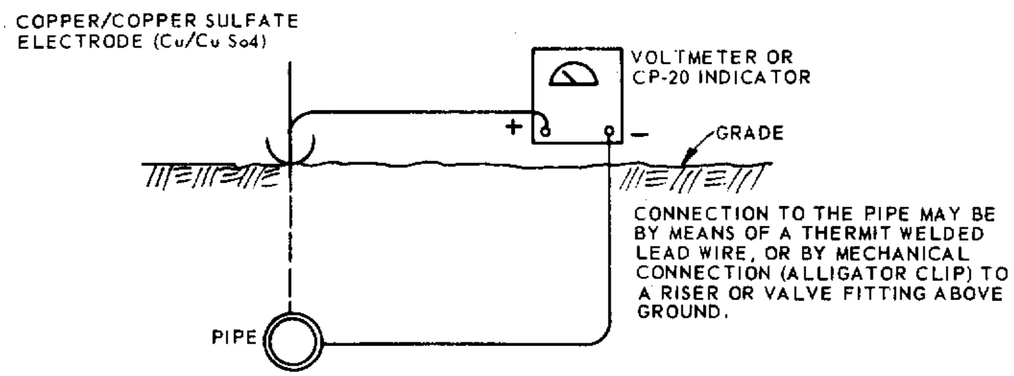
3. The use of thermit welds should be avoided in high stress areas such as elbows, tees, etc.

4. If more than one thermit weld is required, the minimum spacing between welds should be four inches.

925.0 INSPECTION AND TESTS

925.1 Pipe-to-Soil Potential

Pipe-to-soil potential measurements are made of the electrical potential surrounding environment (earth). These potential readings are taken through the use of a high resistance voltmeter or potentiometer voltmeter (usually 50,000 ohms per volt or higher) and a copper/copper sulfate electrode.



TYPICAL P/S SURVEY HOOK-UP

These measurements are taken at the surface of the ground at test locations. For most accurate results, the copper/copper sulfate should be placed directly over the pipeline at the ground level. To improve the accuracy of the millivolt readings, the copper/copper sulfate should be placed in moist earth. This sometimes requires digging a small hole below the sod of a yard or adding water to the earth at the copper/copper sulfate location. This type measurement is most commonly used on a coated pipeline system.

If an aboveground test station is not available, contacting the coated pipeline with a probe bar for the purpose of obtaining pipe-to-soil (P/S) potentials may be done but it is not recommended. If the coating is brittle, it could disbond quite a sizable surface area on the pipeline and increase your total current requirements.

The electrical potential measurements can indicate several things. Among these are:

a. Indicating the extent of the corroding area.

b. Locating areas where corrosion is most severe.

c. Locating areas that are subject to stray current interference. (electrolysis)

d. Indicating whether the underground structure being tested is under the influence of cathodic protection.

e. To establish potential mv difference readings across insulators.

925.2 Surface to Surface Potential Survey

a. Purpose of the Surface to Surface Potential Survey

This type of survey is best utilized on underground pipelines which are bare or considered bare lines which were installed before coatings were used to insulate a pipeline from the surrounding earth.

Past experience of our systems indicates that normally not more than 10 percent to 15 percent of a given bare line is subject to failure due to galvanic corrosion. These small, highly localized corrosion cells will be distributed erratically along the entire length of this line.

b. Locating Lines

In conducting a surface potential survey, the pipeline must first be accurately located. This is especially important on small diameter piping. Most of the new transistorized, inductive pipe locators work well for this purpose, either connected together by the special handle provided by most manufacturers, or operated separately with one man carrying the transmitter and another the receiver.

On distribution systems, the conductive type locator can best be utilized by connecting the transmitter to a meter set riser and tracing the service line and main with the receiver.

c. (S/S) Procedure

The mechanics of a surface potential survey on a bare line are relatively a simple operation. It involves the use of two copper/copper sulfate reference electrodes or (half cells) connected to a high resistance voltmeter or potentiometer. The interval between electrodes is governed by the situation at hand; however, we find that 20 feet (6 m) between electrodes should be used on transmission piping (not to be exceeded). It is advisable to use 10 foot (3 m) intervals on bare distribution piping.

The rear electrode is placed directly over the pipeline and the lead electrode is placed directly over the pipeline 10 or 20 feet (3 to 6 m) from the rear electrode dependent upon the type line surveyed and extended in the direction desired. With the electrodes so located, the difference in potential between the reference electrode locations, caused by current flowing in the soil, is measured. This reading will be reflected in millivolts. It should be remembered that the polarity or direction of current flow as shown on the meter is the opposite of the direction of current flow in the pipeline.

Once the reading has been taken and noted, the rear electrode is moved forward to the spot formerly occupied by the lead electrode. The lead electrode progresses along the line another 10 or 20 foot (3 to 6 m) interval where another reading is taken. By moving along the line in this manner, it is possible to locate the corroding (current discharge) sections of the pipeline by noting the changes of polarity or direction of flow as indicated by the meter.

When a current reversal is encountered, the survey is stopped and the distance between electrodes is halved successively until the exact location is pin-pointed or defined.

Since, at a true reversal, galvanic current will always be leaving the pipeline, side drain readings are required to define anodic areas. Side drain measurements consist of placing one electrode directly over the pipe at the point of reversal and the other electrode about 3 to 5 feet (1 to 1-1/2 m) perpendicular from the pipeline and in line with the other electrode. The relative magnitude of current flowing from the line at this point, based on the numerical value of the acquired millivolt measurement, can then be determined.

In addition, soil resistivity values are obtained at pipe depth where each reversal (current discharge) is found along the pipeline. This information is used for a constant correlation with the surface potential data being acquired.

A bar hole and gas leak detection survey shall also be taken at each corrosion cell to determine if any gas leakage is present. This is a very effective way of locating gas leaks which are caused by corrosion.

Interpretation of the acquired surface data, with respect to determining physical condition of the buried pipeline, can become somewhat complex. It is governed by the types of corrosion patterns encountered, the characteristics of soils traversed, type and age of pipe, and other conditions which vary by area and location. However, the correlation of the acquired potential and soil resistivity data with visual inspection of the pipe at several "hot spots" of graduated severity makes it possible to evaluate the condition of the line surveyed with a high degree of accuracy. Also, one can design a protective system with a minimum of wasted time, labor, and materials.

925.3 Soil Resistivity Measurements

a. Purpose of Soil Resistivity Measurements

When a pipe-to-soil (P/S) or surface-to-surface (S/S) potential survey is made at predetermined intervals, the soil resistivity can be measured and recorded at each location where a corrosive environment is encountered.

The soil resistivity survey along a pipeline route will provide the following information:

1. Areas where you can anticipate corrosion because of the variation in soil resistance.

2. Areas to locate anode beds (impressed current type or galvanic anodes).

3. Helps to determine size and amount of cathodic protection material needed for a given life.

b. Soil Resistivity Mechanics

Soil resistivity is usually expressed in ohm centimeter or ohms per centimeter cubed, which is equivalent to the resistivity of a cube of soil with the dimensions of one centimeter. Resistivity is generally inversely proportional to the amount of dissolved chemicals and moisture content. That is, with an increase in dissolved chemicals or an increase in soil moisture, the resistivity is lowered.

c. Soil Classifications

Soils can be classified into resistivity ranges in ohm-cm, such as shown below:

Soil Corrosivity vs. Resistivity

Ohm-Cm	Description
Below 500	Very Corrosive
500 - 1,000	Corrosive
1,000 - 2,000	Moderately Corrosive
2,000 - 10,000	Mildly Corrosive
Above 10,000	Progressively Less Corrosive

d. Methods of Measuring Soil Resistivity for Survey Purposes

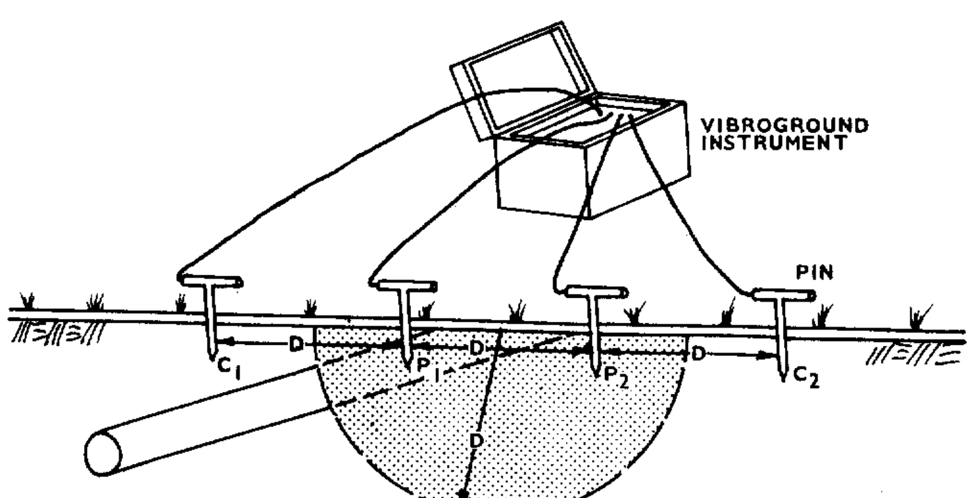
The most common methods for obtaining resistivity measurements along an underground pipeline are the four pin Wenner and the A-C bridge type single rod methods.

Some judgment must be exercised in interpreting the results from these two methods of measuring soil resistivity. Soil resistivity not only varies with depth, but can also vary considerably with short horizontal distances. Resistivities can also vary throughout the year. Soils have a range from about 15 to over one million ohm centimeter. Following is a short dissertation on each method.

e. Wenner Four Pin Method

This method is recommended over the single rod because it measures resistivity over a considerably larger volume of earth and therefore, more accurate reading relative to the pipeline.

Resistivities made by the Wenner four pin method represents average values to a depth equal to the spacing between the pins as shown in the figure below:



FOUR PIN METHOD

When evaluating resistivities for several depths and the measurements indicate significant variances, it must be remembered that each increased depth is averaged with all of the soils above. If a bare pipeline, fence or other metallic structure closely parallels the line of probes, the indicated resistivity would be lower than the actual. If this is suspected, the line of probes (pins) may be rotated ninety degrees or moved a greater distance away from the underground metal. In extremely dry soils, there may be a high resistance contact between the probe and the earth. A small amount of water poured around the soil pin contact will correct this condition and will not materially affect the measurement.

The four pin Wenner method can also be used to locate low resistance soil for the purpose of installing a deep rod ground bed. The pin spacings are placed farther apart, but equi-distance between the pins is maintained. If the pins were placed 100 feet (30 m) apart, a 100 foot (30 m) depth soil resistivity measurement can be obtained.

f. Minimum Level of Cathodic Protection

The minimum level of cathodic protection shall be 4 negative (cathodic) voltage of at least 0.85 volts, pipe to soil, with reference to a saturated copper-copper sulfate half cell.

The maximum allowable potential for different coats shall be a negative voltage of 1.6 volts, polarized at the negative tie-in for sacrificial anodes and 2.0 volts for rectifiers.

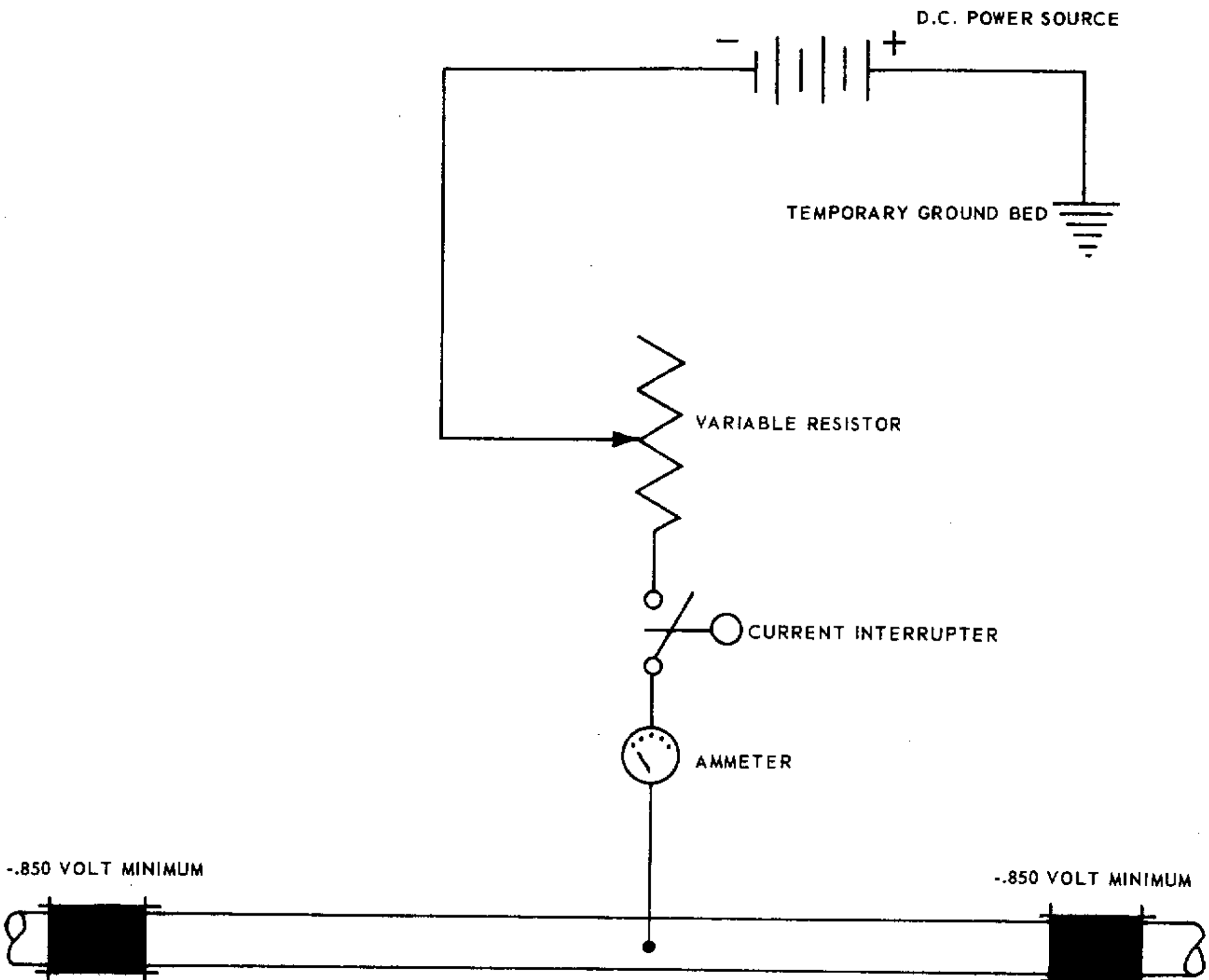
925.4 Current Requirement Tests

a. Purpose of Current Requirement

This test is made to determine the amount of current required to place a given segment of pipeline under the influence of cathodic protection.

b. Method of Obtaining Current Requirement

For this test, a direct current source (rectifier, DC generator, welding machine or a car battery) is connected to a temporary ground bed (galvanized culvert, chain link fence, steel fence, aluminum foil or steel rods driven into the earth) and to the pipe to be tested. A variable resistor (large enough to handle the current load) should also be placed in the circuit to control the amount of current desired. Reference figure below for schematic diagram of this test setup. If it is possible, the temporary ground bed should be positioned as close as possible to the actual ground bed or anode bed you intend to use to cathodically protect this pipeline. This will give a much more accurate total current requirement.



CURRENT REQUIREMENT TEST CONFIGURATION - COATED PIPELINES

The variable resistor, ammeter and automatically operated current interrupter (for opening and closing the circuit on a predetermined time cycle) are connected in series with the DC current source.

c. Sufficient Current Determination

With this temporary source established and the current interrupter in operation, pipe-to-soil potential measurements are made at intervals in each direction from the point where the current is being introduced to the outer extremities of the pipeline. The current required to bring a given segment of pipeline up to a cathodic protection level is a minimum of -.850 volt at the outer extremities. When you are completely satisfied that the entire pipeline system is under the influence of cathodic protection, the total amount of current required can be determined from the ammeter in temporary source hook-up.

d. Excessive Voltage

If an impressed current unit (rectifier and ground bed) is installed to protect a coated line, do not exceed 2.5 volts protective level at the negative tie-in on the pipeline. Higher voltages could disbond the coating.

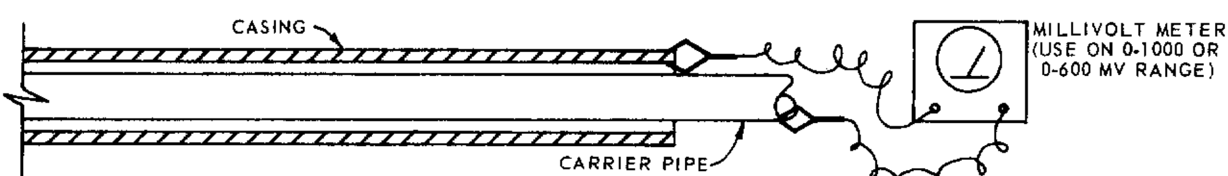
925.5 Cased Crossings

The Inspector shall be required to make the following necessary tests during and after the installation of a cased railroad or highway undergrade crossing. Tests are made during the installation to assure proper insulation between the casing and carrier pipe upon completion. If tests are not done during, but are done after the installation and a short occurs, it might be necessary to excavate the line again and make the required corrections.

925.5.1 Testing

Cased railroads and highways shall be tested:

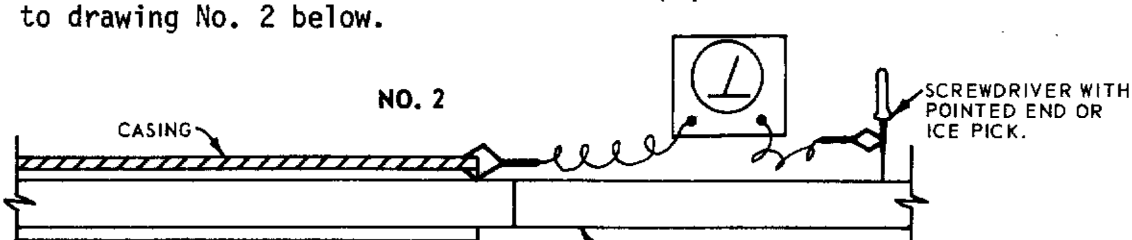
a. Immediately following installation of carrier pipe and before this carrier pipe is welded into existing pipe on either end of the casing. By using a milli-volt meter (Robertshaw, General Controls or Sun) you will be able to determine whether the carrier pipe is electrically insulated from the casing. If the carrier pipe is electrically insulated from the casing, you will get a milli-volt reading on the milli-volt meter. This will be somewhere between the range of 0-1,000 milli-volts. If carrier pipe is shortened to the casing, there will be zero reading on the milli-volt meter. Refer to drawing No. 1 below.



NO. 1

b. Follow same procedure after the carrier pipe is welded in. Refer to drawing No. 2 below.

NO. 2



c. Install the permanent test station per 923.5.6.

d. Check again after the backfilling is completed.

e. Final check after pressure testing of line. (Could shift carrier pipe in casing.)

925.6 Electrical Insulations

All underground insulated fittings shall have test leads installed so that the junction may be checked for shorts. See Test Stations (Section 923.5).

925.7 Commissioning Test Stations

925.7.1 With the potentiometer measure pipe to soil potential at all test stations. Readings should be at least -0.85 volts. If readings are not sufficiently negative or are zero the system must be thoroughly examined.

925.7.2 A zero potential would indicate a faulty rectifier. Using the manufacturers drawings the output of rectifiers must be checked for voltage and current delivered. If the problem is in the rectifier it is always desirable to have the manufacturers representative present when troubleshooting.

After the rectifier is repaired the test site voltages should be re-measured.

925.7.3 If voltages are found to be insufficiently negative at any site, and the rectifiers are operating properly, a complete system examination must be made.

a. For transmission lines potential shorts locations are at casings, crossings of other pipelines, and insulated joints where distribution systems are connected. Casing shorts may be easily determined by taking measurements at the test connections shown in Section 923.5.6.

b. For distribution systems potential shorts locations are at casings, other pipeline crossings, and particularly at service risers.

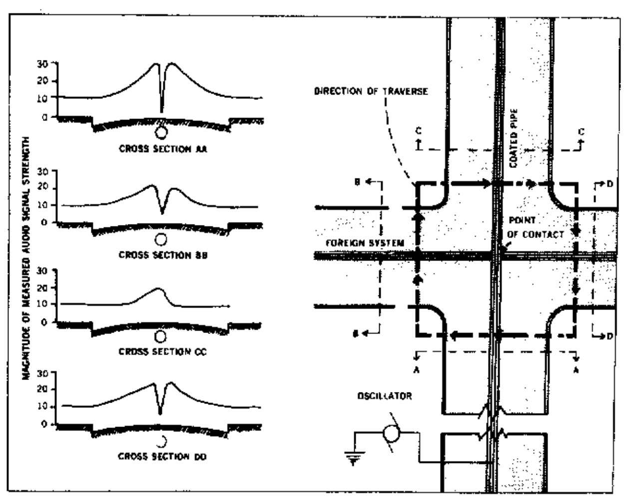
c. The "null" method of locating shorts has proven satisfactory. This method requires:

Audio generator, 10-15 watts output
Output voltage selector
Interrupter
Receiver with filters resonant to the generator frequency.

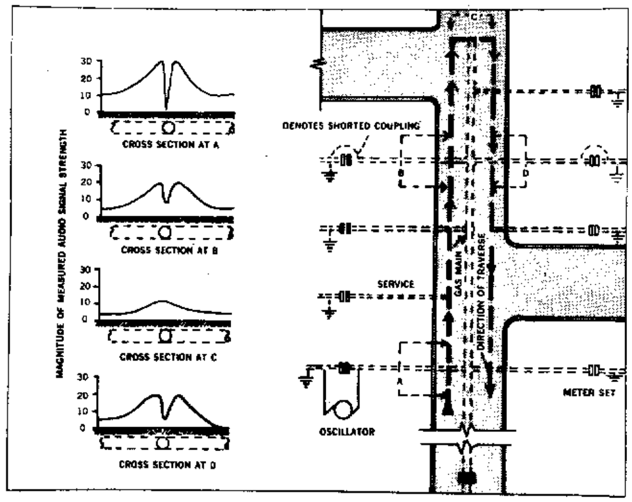
The audio generator is electrically connected to the pipe being investigated and is also earthed. Output voltage is selected to give maximum audio signal on the receiver.

The receiver picks up the audio signal in the pipe. By crossing at right angles to the pipeline, the audio signal should drop sharply when directly over the pipe, or a "null" is found. Shorts in the system disturb the "null" point.

For instance, at a foreign pipeline crossing, there should be no "null" in the signal over the foreign pipeline. If there is electrical contact at the crossing the audio signal will travel in the foreign pipeline and a "null" will be found when crossing the foreign pipeline. Refer to the example below.



For locating shorts at meter sets a traverse can be made as shown below. A shorted insulator at a meter set will allow the audio signal to flow into the piping beyond.



925.7.4 Interferences

Rectifiers feeding nearby foreign pipelines can cause current to enter the pipeline being commissioned. Erratic voltage measurements at the commissioned pipeline test sites are an indication of interference. If unexpectedly high or low voltages are found interference may be suspected.

The operator of the foreign pipeline must be contacted. By shutting off the foreign pipeline rectifier and retaking voltagemeasurements at the newly commissioned line, it may be determined if interference is the problem.

If both lines are coated the problem may be solved by electrically bonding both lines together. Or a rectifier may be placed on the newly commissioned line in the problem area.

If the foreign line is bare the only solution is to add a rectifier for the newly commissioned line.