APPENDIX E

FEDERAL REQUIREMENTS FOR CORROSION CONTROL

This appendix contains a simplified breakdown of the pipeline safety code corrosion control requirements as they would normally apply to operators of small natural and LP-Gas systems. The complete text of the corrosion control requirements can be found in 49 CFR Part 192, Subpart I.

Procedures and Qualifications

Operators must establish procedures to implement a corrosion control program for their piping system. These procedures should include the design, installation, operation, and maintenance of a cathodic protection system. These procedures must be carried out by, or be under the direction of, a person qualified by experience and training in pipeline corrosion control method (49 CFR 192.453).

Techniques for Compliance

The following is a list of sources where small operators can find qualified personnel to develop and carry out a corrosion control program:

- There are many consultants and consulting firms which specialize in the cathodic protection field. Many advertise in gas trade journals.
- Another source, especially for master meter operators, is an experienced corrosion engineer or experienced technician working for a local gas utility company. These people may be able to implement the cathodic protection for you, or may be able to refer you to some local qualified corrosion engineer(s).
- Operators of small municipal systems can contact the transmission company which supplies their gas. Their corrosion engineer, or technician, may be able to supply information as to where to find a local qualified corrosion engineer(s).

Corrosion Control Requirements for Pipelines Installed After July 31, 1971

All buried metallic pipe installed after July 31, 1971, must be properly coated and have a cathodic protection system designed to protect the pipe in its entirety (49 CFR 192.445(a)).

Rule for newly constructed metallic pipelines: each coated pipeline installed must have a cathodic protection system installed and placed in operation in its entirety within one year after completion of construction of the pipeline (49 CFR 192.455(a)). If the operator can demonstrate by tests, investigation, or experience that a corrosive environment does not exist, he is not required to coat and cathodically protect the pipeline. However, no later than 6 months after installation the operator must make tests to prove that no corrosion control measures were necessary. If tests indicate that corrosion control is necessary, cathodically protect (49 CFR 192.455(b)).

Recommend that all small operators coat and cathodically protect all new metallic pipe. It is extremely difficult and costly to prove that a noncorrosive environment exists.

Cathodic protection requirements do not apply to electrically isolated, metal alloy fittings in plastic pipelines, (a) if the alloyage (such as stainless steel) of the fitting provides corrosion control, and (b) if corrosion pitting of the fitting will not cause leakage.

Corrosion Control Requirements for Gas Distribution Pipelines Installed Before August 1, 1971

For master meter and small municipal gas distribution systems the pipeline safety code requires that bare or coated distribution pipelines, regulating, and measuring stations be cathodically protected in areas of active corrosion (49 CFR 192.457 (c)).

The operator must determine areas of active corrosion by, (a) electrical survey, or (b) where electrical survey is impractical, by the study of corrosion and leak history records, or (c) by leak detection surveys.

Active corrosion by federal definition means continuing corrosion which, unless controlled, could result in a condition that is detrimental to public safety (49 CFR 192.457(c)).

As a guideline for when an operator should consider continuing corrosion to be detrimental to public safety (active corrosion), Recommend the following:

- For master meter operators, all continuing corrosion occurring on metallic pipes (other than cast iron or ductile iron pipes) in a mobile home park or a housing complex, should be considered active and pipes should be cathodically protected, repaired, or replaced.
- For operators of small municipal gas systems, all continuing corrosion occurring on the distribution system in city limits (within 100 yards of a building intended for human occupancy, regulator stations, and at highway and railroad crossings) should be considered active and pipes should be cathodically, repaired, protected or replaced.
- Recommend that operators of small gas systems and their consultants use these following guidelines in determining where it is impractical to run electrical surveys to find areas of active corrosion:

  (a) Areas of fluctuating stray D.C. currents, such as those caused by telluric currents and electrical railway systems.

  (b) Where the pipeline is more than 2 feet in from and generally parallel to the edge of a paved street or within wall to wall pavement areas.

  (c) Pipelines in common trench with other metallic structures.

Extreme hardship and expense may render an electrical survey impractical for a given pipeline for conditions other than listed above. The operator, and/or his consultant, must demonstrate with written documentation of test studies, or past experience with electrical surveys for pipelines in a similar environment, the impracticability of the electrical survey.

In areas where electrical surveys cannot be run to determine corrosion, the operator should run leakage surveys on a more frequent basis. (Recommend that these surveys be run at a minimum of each calendar year with intervals not exceeding 15 months).

The electrical surveys conducted to find active corrosion must be run by a person qualified by experience and training in pipeline corrosion control methods.

Coating Requirements

All metallic pipe installed below ground as a new piping system or a replacement system should be coated in its entirety (49 CFR 192.455).

Examination of Exposed Pipe

Whenever buried pipe is exposed or dug up, the operator is required to examine any exposed portion of the pipe for evidence of corrosion on bare pipe or for deterioration of the coating on coated pipe. A record of this examination must be maintained. If the coating has deteriorated or the bare pipe has evidence of corrosion, remedial action must be taken (40 CFR 192.459).

Criteria for Cathodic Protection

The criteria that most small operators will choose to meet will be a (cathodic) voltage of at least -0.85. volts, with reference to a saturated copper-copper sulfate half cell.

Monitoring

A piping system which is under cathodic protection must be monitored systematically (49 CFR 192.465). Tests for effectiveness of cathodic protection must be done at least once each calendar year, at intervals not exceeding 15 months. Records of this monitoring must bed maintained.

If you use rectifiers to provide cathodic protection, each rectifier must be inspected six times each calendar year. The intervals must not exceed 2 ½ months, to insure that the rectifier(s) is operating. Records must be maintained.

Operators must take prompt action to correct any deficiencies indicated by the monitoring.

Electrical Isolation

Pipelines must be electrically isolated from other underground metallic structures (unless electrically interconnected and cathodically protected as a signal unit). For illustrations of where meter sets are commonly electrically insulated, see Figures 8, 13, and 14.

Test Points

Each pipeline under cathodic protection must have sufficient test points for electrical measurement to determine the adequacy of cathodic protection (49 CFR 192.469, 192.471). Test points should be maintained on a cathodic protection system map.

Remedial Measures

All steel pipe used to replace an existing pipe must be coated and cathodically protected. Each segment of pipe which must be repaired because of corrosion leak must be cathodically protected (49 CFR 192.483).

Internal Corrosion Inspection

Whenever a section of pipe is removed from system, the internal surface must be inspected for evidence of corrosion. Remedial steps must be taken if internal corrosion is found. Be sure to keep records of this inspection. (49 CFR 192.475).

Atmospheric Corrosion

Portions of newly installed above ground pipelines must be cleaned and coated or jacketed with a material suitable for the prevention of atmospheric corrosion (49 CFR 192.479). Above ground pipe, including meter, regulators, and measuring stations, must be inspected for atmospheric corrosion once each calendar year, but with intervals not exceeding 3 years. Remedial action must be taken if atmospheric corrosion is found (49 CFR 192.481).

Basic Terms

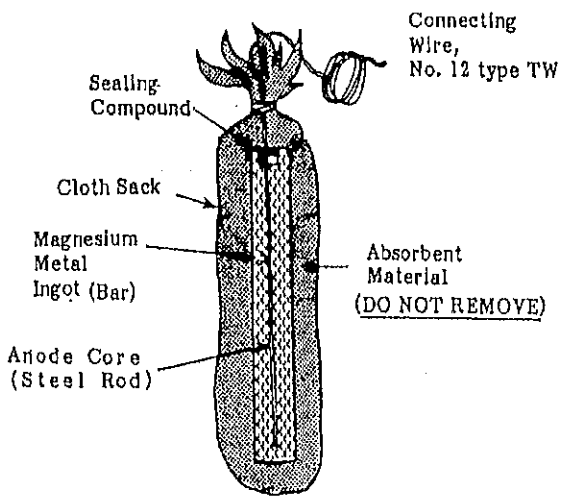
Corrosion is the deterioration of a metal pipe. The corrosion is caused by a reaction that takes place between the metallic pipe and its surroundings. As a result, the pipe deteriorates and may eventually leak. The corrosion can be retarded or stopped with cathodic protection.

Operators should use either PE pipe manufactured according to ASTM D2513 or coated steel pipe as new or replacement pipe. If steel pipe is installed, that pipe must be coated and cathodically protected.

Cathodic protection is a procedure by which an underground metallic pipe is protected against corrosion. A direct current is impressed onto the pipe by means of either a sacrificial anode or a rectifier. Pipe will not corrode where sufficient current flows onto the pipe.

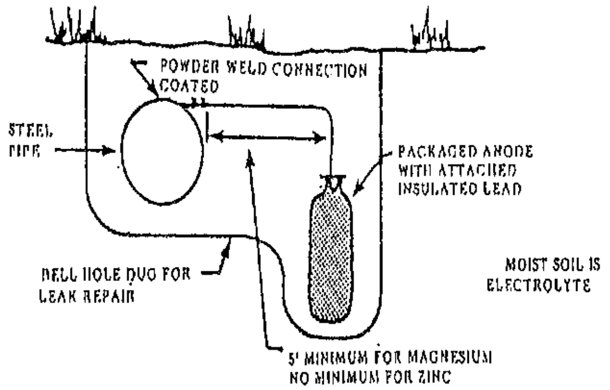
Anode (sacrificial) is an assembly consisting of a bag usually containing a magnesium or zinc ingot and other chemicals which is connected by wire to an underground metal piping system. It serves essentially as a battery which impresses a direct current on the piping system to retard corrosion. (See Figure F-2).

Figure F-2 – Typical Magnesium (Mg) Anode



Sacrificial protection means the reduction or prevention of corrosion of a metal (usually steel in a gas system) in an electrolyte (soil) by galvanically coupling the metal (steel) to a more anodic metal (magnesium or zinc). (See Figure F-3). The magnesium or zinc will sacrifice itself (corrode) and prevent the steel pipe from corroding.

Figure F-3

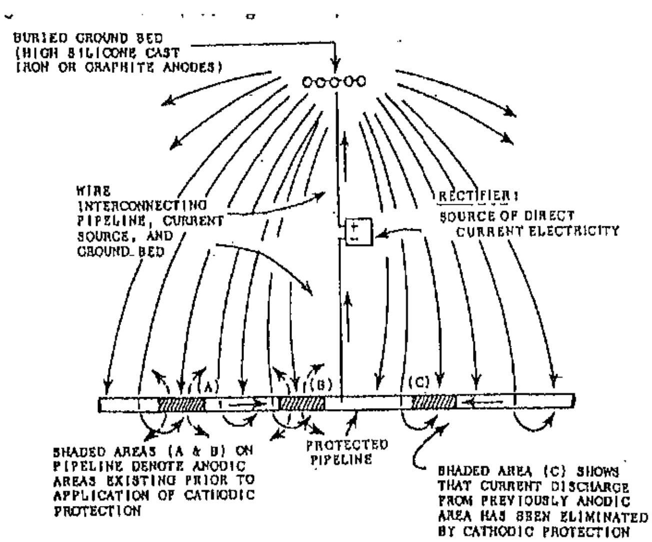


SINGLE PACKAGED ANODE INSTALLATION

Zinc and magnesium are more anodic than steel. Therefore, they will corrode, and provide cathodic protection for the steel pipe to which it is connected.

Rectifier is an electrical device which changes alternating current (A.C.) into direct current (D.C.). This current is then impressed on an underground metallic piping system to protect it against corrosion. (See Figure F-4).

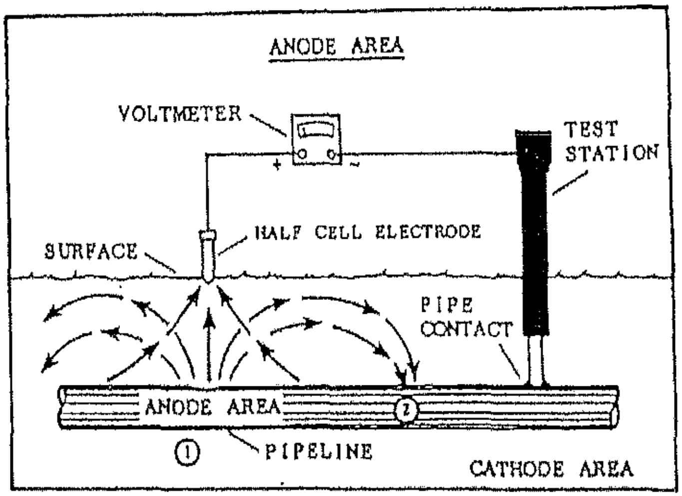
Figure F-4



This illustrates how cathodic protection can be achieved by use of a rectifier. Make certain the negative terminal of the rectifier is connected to the pipe. Note: If you do the reverse (positive terminal to pipe), you will corrode the pipe -- FAST.

Potential means the difference in voltage between two points of measurement. (See Figure F-5.)

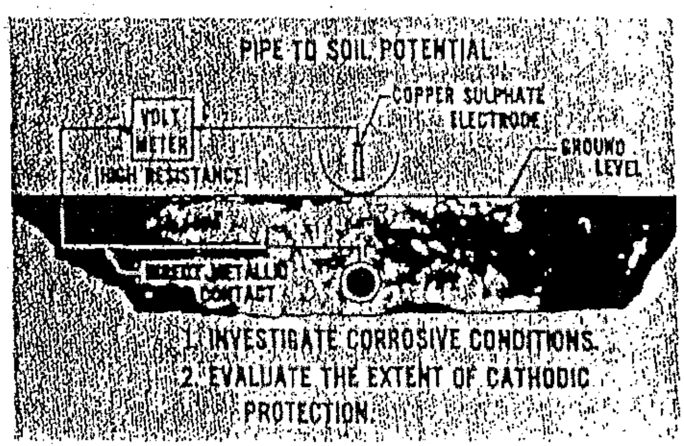
Figure F-5



The voltage potential in this case is the difference between points 1 and 2. Therefore, the current flow is from the anodic area (1) of the pipe to the cathodic area (2). The half cell is a copper-copper sulfate electrode ($Cu\text{-}CuSO_4$)

Pipe-to-soil potential means the potential difference between a buried metallic structure of piping system and the soil surface. The difference is measured with a half cell reference electrode (see definition of reference electrode which follows) in contact with the soil. (See Figure F-6.)

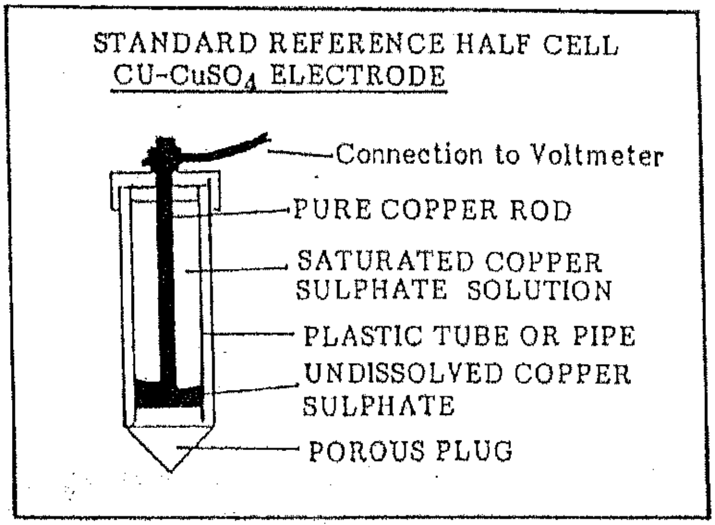
Figure F-6



If the volt meter shown reads at least -0.85 volts, the operator can usually consider that the steel pipe has cathodic protection. Note: Be sure to take into consideration the voltage (IR) drop which is the difference between the voltage at the top of the pipe and the voltage at the surface of the earth.

Reference electrode means a device which usually has copper immersed in copper sulfate solution. The open circuit potential is constant under similar conditions of measurement. (See Figure F-7.)

Figure F-7

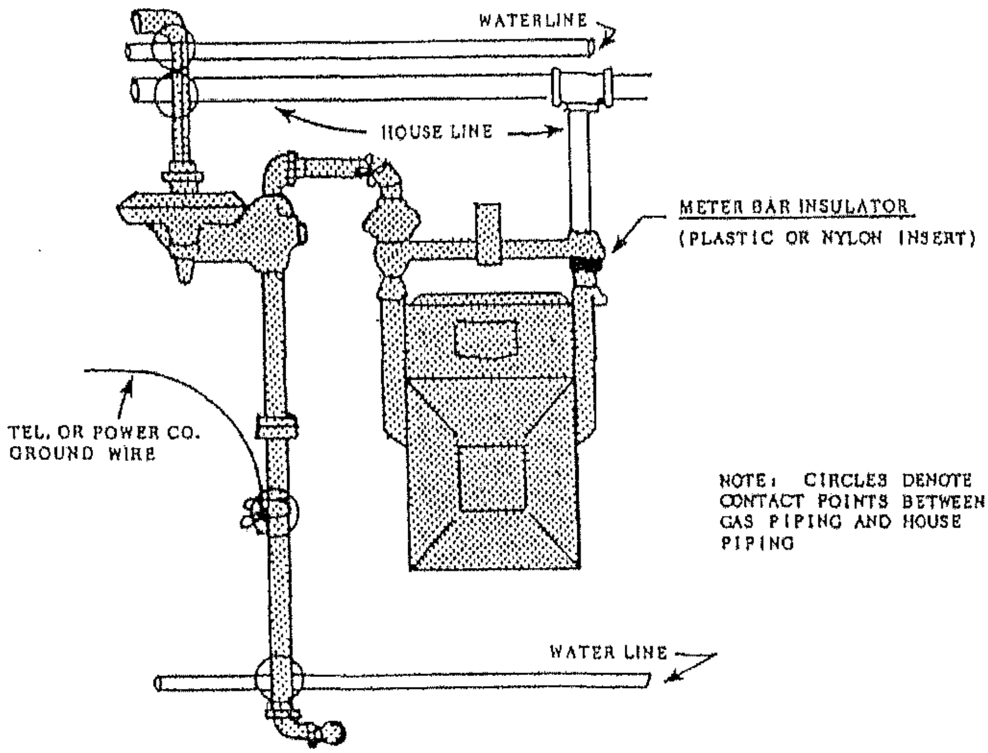


Reference Electrode - Saturated copper-copper sulfate half cell.

Short or corrosion fault means an accidental or incidental contact between a cathodically protected section of a piping system and other metal structures (water pipes, buried tanks, or unprotected section of a gas piping system.) (See Figure F-8.)

Figure F-8 - Typical Meter Installation Accidental Contacts

(Meter Insulator Shorted Out by House Piping, etc.)

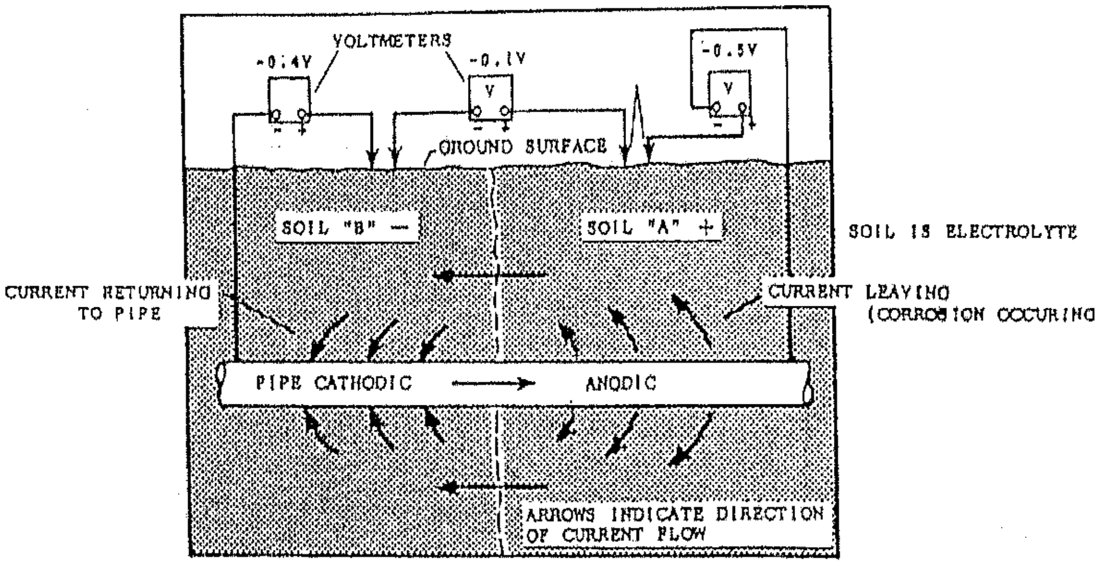


Shaded piping shows company piping from service entry to meter insulator at location shown on sketch above. Unshaded areas show house piping, BX cables, etc.

The locations that are circled are typical points at which the company piping (shaded) can come in metallic contact with house piping. This causes shorting out or "by-passing" the meter insulator.

The only way to clear these contacts permanently is to move the piping that is in contact. The use of wedges, etc., to separate the piping is not acceptable. If you cannot move the piping, install a new insulator between the accidental contact and the service entry.

Figure F-10



CORROSION FROM DISSIMILAR SOILS

A corrosion cell may be summed up as follows:

- Current flows through the electrolyte from the anode to the cathode. It returns to the anode through the return circuit.

- Corrosion occurs wherever current leaves the metal (pipe, fitting, etc.) and enters the soil (electrolyte.) The point where current leaves is called anodic. Corrosion, therefore, occurs in the anodic area.

- Current is picked up at the cathode. No corrosion occurs here. The cathode is protected against corrosion. Polarization (hydrogen film buildup) occurs at the cathode. When the film of hydrogen remains on the cathode surface, it acts as an insulator and reduces the corrosion current flow.

- The flow of current is caused by a potential (voltage) difference between the anode and the cathode.

Table 1

METAL	Potentials VOLTS*	
Commercially pure magnesium	-1.75	Anodic
Magnesium alloy (6% Al, 3% Zn 0.15% Mn)	-1.6	
Zinc	-1.1	
Aluminum alloy (5% zinc)	-1.05	
Commercially pure aluminum	-0.8	
Mild steel (clean and shiny)	-0.5 to -0.8	
Mild steel (rusted)	-0.2 to -0.5	
Cast iron (not graphitized)	-0.5	
Lead	-0.5	
Mild steel in concrete	-0.2	
Copper, brass, bronze	-0.2	
High silicon cast iron	-0.2	
Mill scale on steel	-0.2	
Carbon, graphite, coke	+0.3	Cathodic

*Typical potential normally observed in natural soils and water, measured with respect to copper sulfate reference electrode.

When connected together in an electrolyte, any metal in the table will be anodic (corrode relative to) any metal below it. (That is, anode sacrifices itself to protect the metal (pipe) lower in the table.)

FUNDAMENTAL CORROSION THEORY

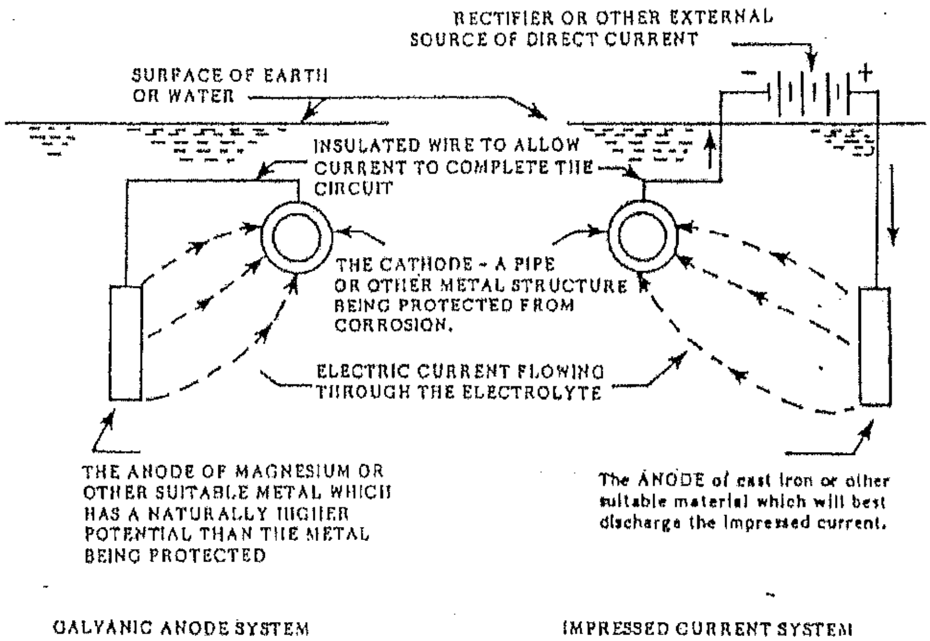
In order for corrosion to occur there must be four elements: electrolyte, anode, cathode, and a return circuit. A metal will corrode at the point where current leaves the structure. (See Figure F-10.)

TYPES OF CATHODIC PROTECTION

There are two basic methods of cathodic protection: the galvanic anode system and the impressed current system.

Galvanic anodes are commonly used to provide cathodic protection on gas distribution systems. Impressed current systems are normally used for transmission lines. However, if properly designed, impressed current can be used on distribution system. (See Figure F-11.)

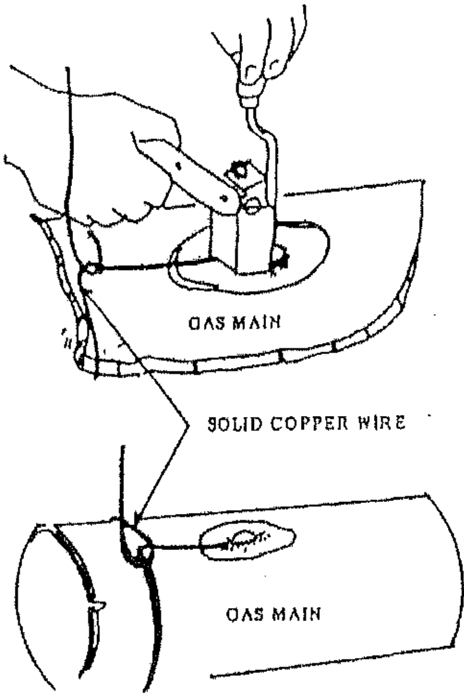
Figure F-11



Any current, whether galvanic or stray, that leaves the pipeline causes corrosion. In general, corrosion control is obtained as follows:

Galvanic Anodes System. Anodes are "sized" to meet current requirements of the resistivity of the environment (soil.) Anodes are made of materials such as magnesium, zinc, or aluminum. They are usually installed near the pipe and connected to the pipe with an insulated conductor. They are sacrificed (corroded) instead of the pipe. (See Figures F-3, F-11, and F-12.)

Figure F-12 - Typical procedure for installing a Mg Anode



Impressed Current Systems. These systems are normally used along transmission pipelines where there is less likelihood of interference with other pipelines. The principle is the same except that the anodes are made of corrosion resistant material such as graphite, high silicon cast iron, lead-silver alloy, platinum, or scrap steel. The anodes are connected to a direct current source, such as a rectifier or generator.

INITIAL STEPS IN DETERMINING THE NEED TO CATHODICALLY PROTECT A SMALL GAS DISTRIBUTION SYSTEM

1. Determine type(s) of pipe in system: ___bare steel, ___coated steel, ___cast iron, ___plastic, ___ galvanized steel, ___ductile iron, or ___other.

2. Date gas system was installed:

   __________ Year pipe was installed (steel pipe installed after July 1, 1971, must be cathodically protected in its entirety.)

_______ Who installed pipe. (By contacting the contractor and other operators who had pipe installed by same contractor, operators may be able to obtain valuable information as:

- o Type of pipe in ground.
- o If pipe is electrically isolated.
- o If gas pipe is in common trench with other utilities.

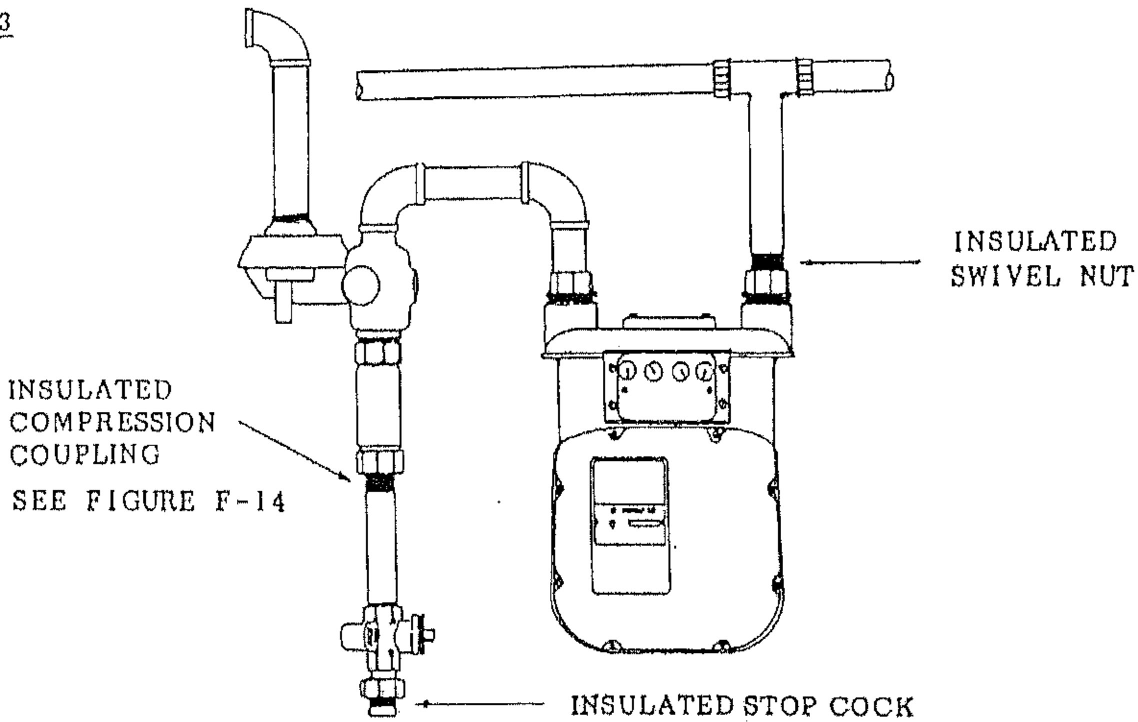
3. _______ Pipe location - map/drawing. Locate old construction drawings or current system maps. If no drawings are available, a metallic pipe locator may be used.

4. _______ Before the corrosion engineer arrives, it is a good idea to make sure that customer meters are electrically insulated. If system has no meter, check to see if gas pipe is electrically insulated from house or mobile home pipe. (See Figure F-13.)

5. _______ Contact an experienced corrosion engineer or consulting firm.

Try to complete steps 1 through 4 before you get a consultant.

Figure F-13



Places where a meter installation may be electrically isolated.

Figure F-14

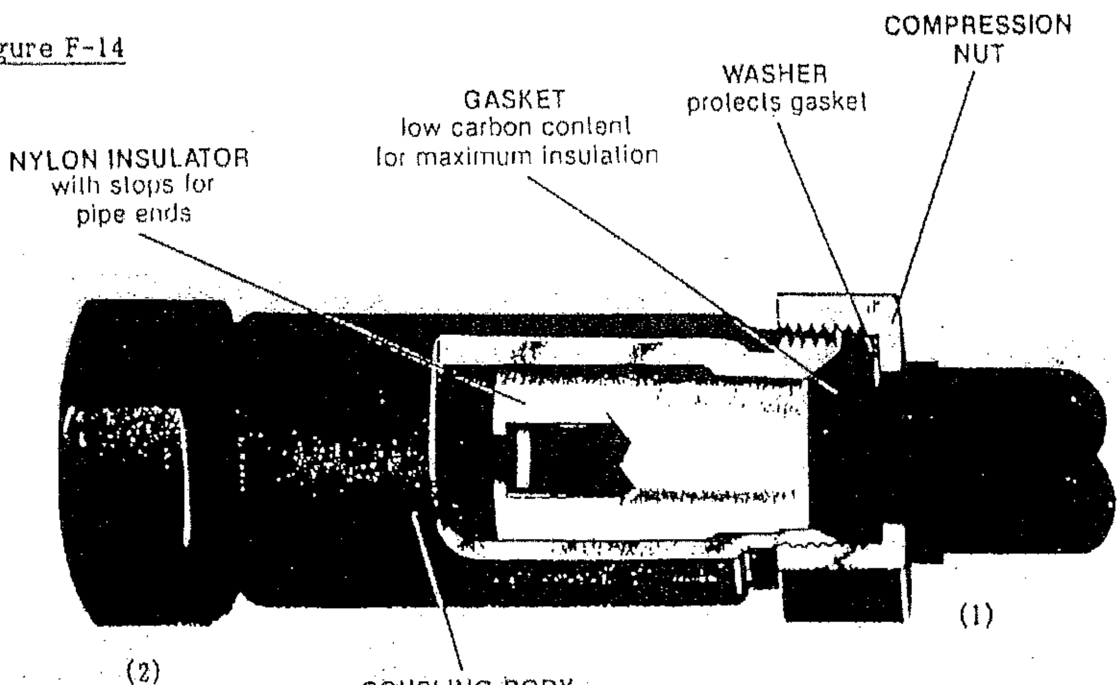
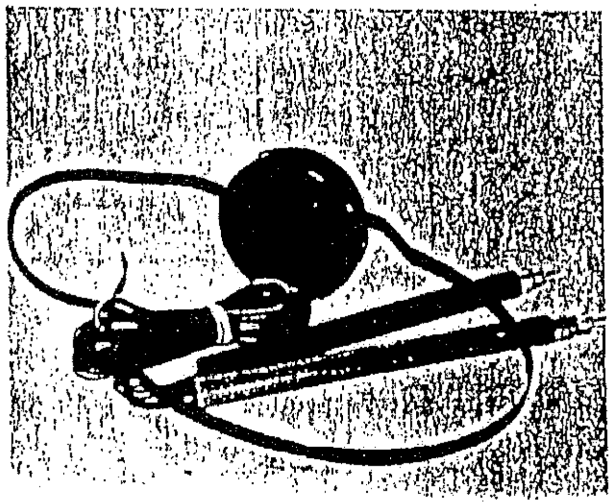


Illustration of an insulated compression coupling used on meter sets to protect against corrosion. Pipe connection by this union will be electrically insulated between the piping located on side one (1) and the piping located on side two (2).

Figure F-15

INSULATION TESTER



This Insulator Tester consists of a magnetic transducer mounted in a single earphone headset with connecting needle point contact probes. It is a "go" or "no go" type tester which operates from low voltage current present on all underground piping systems thus eliminating the necessity of outside power sources or costly instrumentation and complex connections.

By placing the test probes to metallic surface on either side of the insulator a distinct audible tone will be heard if the insulator is performing properly. Absence of audible tone indicates faulty insulator. Insulator effectiveness can be determined quickly using this simple, easy to operate tester.

6. Use of Consultant

A sample method which may be used by a consultant to determine cathodic protection needs is the following:

- An initial pipe-to-soil reading will be taken to determine whether the system is under cathodic protection.

- If the system is not under cathodic protection, the consultant should clear underground shorts, or any missed meter shorts. (He/she will probably use a tone test.)

- After the shorts are cleared, another pipe-to-soil test should be taken. If the system is not under cathodic protection, a current requirement test should be run to determine how much electrical current is needed to protect the system.

- Additional tests, such as a soil resistivity test, bar hole examination, and other electrical tests, may be needed. The types of tests needed to be run will vary by each specific gas system.

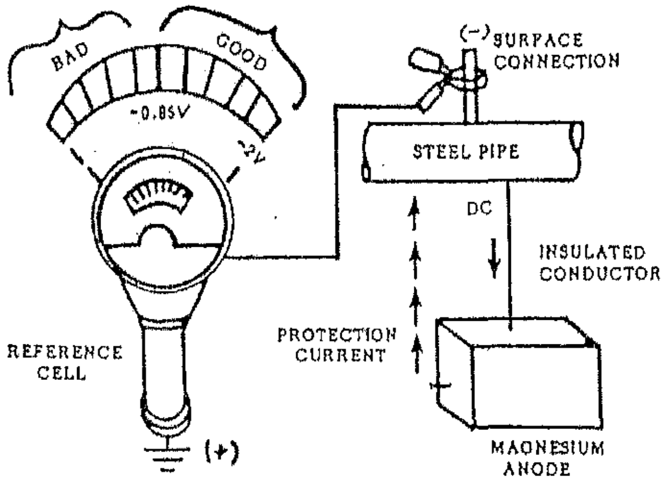
Remember to retain copies of all tests run by the corrosion engineer.

7. Cathodic Protection Design

The experienced corrosion engineer or gas consultant, based on the results of testing, will design a cathodic protection system that best suits your piping system.

Criteria - With the protective current applied, a voltage of at least -0.85 volts measured between the pipeline and a saturated copper-copper sulfate half cell. This measurement is called the pipe-to-soil potential reading. (See Figure F-16)

Figure F-16



This is a pipe-to-soil voltage meter with reference cell attached. This is a simple meter to use and is excellent for simple "go-no-go" type monitoring of a cathodic protection system. If meter reaches at least -0.85 volts, the operator knows that the steel pipe is under cathodic protection. If not, remedial action must be taken promptly. Note: Be sure to take into consideration the voltage (IR) drop which is the difference between the voltage at the top of the pipe and the voltage at the surface of the earth.

COATINGS

There are many different types of coating on the market. The better the coating application, the less amount of electrical current is needed to cathodically protect the pipe.

Mill Coated Pipe

When purchasing steel pipe for underground gas services, operators should purchase mill coated pipe. (i.e., pipe coated during manufacturing process.) Some examples of mill coatings are:

- Extruded polyethylene or polypropylene plastic coatings.
- Coal tar coatings.
- Enamels.
- Mastics.

Patching

Tape material is a good choice for external repair of mill coated pipe. Tape material is also a good coating for both welded and mechanical joints made in the field. One advantage is that these tapes may be applied cold. Some tapes in use today are:

- PE and PVC tapes with self-adhesive backing applied to a primed pipe surface.
- Plastic films with butyl rubber backing applied to a primed surface.
- Plastic films with various bituminous backings.

Consult your pipe supplier before purchasing tapes. Tapes must be compatible with the mill coating on the pipe.

Coating Application Procedures

When repairing and installing metal pipe, be sure to coat bare pipes, fittings, etc. It is absolutely essential that the instructions (supplied by the manufacturer of the coating) are followed precisely. Time and money is wasted if the instructions are not followed.

Some general guidelines for installation of pipe coatings:

- Properly clean pipe surface. (Remove soil, oil, grease, and any moisture.)

- Use careful priming techniques (avoid moisture, follow manufacturer's recommendations.)

- Proper application of coating materials (be sure pipe surface is dry - follow manufacturer's recommendations.) Make sure soil or other foreign material does not get under coating during installation.

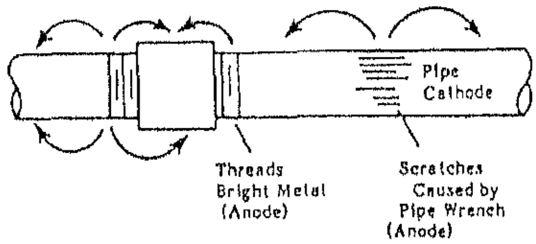
- Only backfill which is free of objects capable of damaging the coating should be allowed to strike the coated pipe directly. Severe coating damage can be caused by careless backfilling operations when rocks and debris strike and break the coating.

COMMON CAUSES OF CORROSION IN GAS PIPING SYSTEMS

Figure F-17

An example of a galvanic corrosion cell being set up. The tenants of this building have "shorted" out this meter by storing metallic objects on meter set. Never allow customers or tenants to store material on a meter installation.

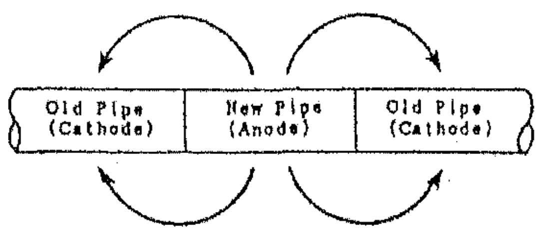
Figure F-18



Corrosion Caused by Dissimilarity of Surface Conditions

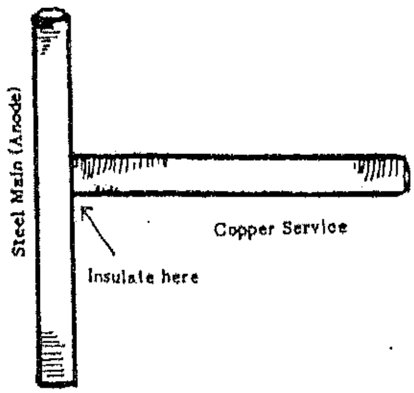
This pipe will corrode at the threads or where it is scratched. Remember to repair all cuts or scratches in the coating before burying the pipe. Always coat and/or wrap pipe at all threaded or weld connections before burying pipe.

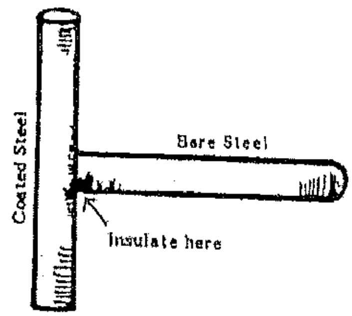
Figure F-19 - Galvanic Corrosion



Remember all new steel pipe must be coated and cathodically protected. The new pipe can either be electrically isolated from old pipe, or the new and old pipe must be cathodically protected as a unit.

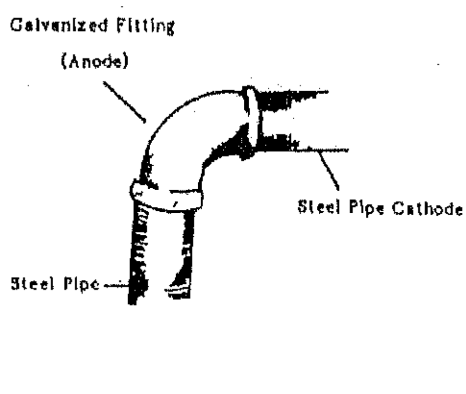
Figure F-20 - Galvanic Corrosion





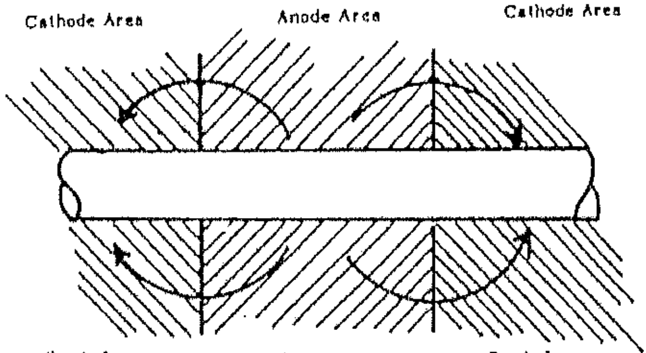
Steel is above copper in the galvanic series in Table 1 of this Appendix. Therefore, steel will be anodic to the copper service. That means, the steel pipe will corrode. The copper service should be electrically isolated from the steel main. Remember, steel and cast iron or ductile iron should not be tied in directly. Steel and cast iron should be electrically isolated. Also, coated steel pipe should be electrically isolated from bare steel pipe.

Figure F-21 - Galvanic Corrosion



The galvanized elbow will act as an anode to the steel and will corrode. Do not install galvanized pipe or fittings in system, if possible. However, if you use galvanized fittings, you must electrically isolate the fittings.

Figure F-22 - Galvanic Corrosion



A corrosion cell can be set up when pipe is in contact with dissimilar soils. This problem can be avoided by the installation of a well coated pipe under cathodic protection.

Figure F-23 - Poor Construction Practice

This is an example of a main which was buried without a coating or wrapping at the service connection. Also, you can see (at the bottom of the photo) that the main was not coated. Note that corrosion has occurred at both locations. There are repair clamps at bottom of the photo. This corrosion problem could have been avoided by properly coating and cathodically protecting the pipe.

GUIDELINE FOR MAGNESIUM ANODE INSTALLATIONS

The following information is a guideline only. There may be situations whereby magnesium anodes are not an effective means for the application of cathodic protection. Such situations would include soils with a high electrical resistance, piping that is not coated, or installed in a common trench and contacting other metallic facilities. When soil characteristics, coating condition or possible presence of numerous metallic contacts with other facilities are not known it may be desirable to engage persons that are qualified to make the necessary investigation.

Magnesium anodes can provide economical protection from corrosion on buried steel piping. They are most effective when the pipeline is relatively well coated and not in contact with other metallic facilities. Except for relative short sections of pipe (50' or less) it may not be effective or economical to protect bare (uncoated) piping using magnesium anodes. The presence or condition of the coating (if any) can be estimated by excavating the piping at several places. Suggested excavation locations might be piping "T's" and valve locations.

GENERAL INSTALLATION GUIDELINES

1. Above ground piping and all buried metallic piping must be electrically isolated from the piping planned for cathodic protection. This may be accomplished by installing dielectric unions or other fittings that have the capability to electrically isolate piping. All underground contacts with other metallic facilities must be eliminated for cathodic protection to be effective. Protective current intended for your facility will be received by the facility in contact with your line. This will result in unnecessary costs to protect your line. Underground contacts can be "cleared" by placing thick rubber gasket material, sections of a rubber tire or thick plastic materials between the two facilities to eliminate metal to metal contact.

2. Magnesium anodes are commonly packaged in a prepared backfill material and have 10' of # 12 insulated lead wire.

3. Long lengths of pipe (approximately 300' or more) will require multiple anodes. When possible it is desirable to install the anodes away from the ends of piping and equally spaced from each other when more than one is required.

4. Anodes may be positioned either vertically or horizontally however they should always be at least 1' from the piping and at or below the bottom of the piping. Prompt operation may be assisted by flooding the anodes with water prior to backfilling.

5. Thermite (cadweld) connections are strongly recommended to attach

the anode lead wire to the piping. The use of underground pipe clamps to attach anode leads may result in ineffective connections.

All anode lead connections and other damaged coating should be repaired prior to backfilling. A common method to coat anode lead connections and repair the pipe coating is use a plastic pipe wrapping tape. The procedure is to clean the pipe surface throughly, prime it with the recommended primer for that particular pipe wrap and then to securely wrap the pipe avoiding wrinkles and voids as much as possible.

The anode lead wire must have sufficient slack to protect it from soil settlement stress and other damage during backfilling.

6. Suggested anode spacing and sizes for <u>coated pipe</u> is:

0 to 5' lengths of 3/4" thru 4" pipe (Such as steel risers in plastic pipe systems)	1-1 lb. anode
0 to 300' lengths of 3/4" thru 4" pipe (position anode as near to pipe segment mid-point as is possible)	1-17 lb. anode

Lengths greater than 300' should have an anode for each 300' of piping and spaced approximately 300' apart.

Note: Other sizes of anodes may be used however their life expectancy will be increased or decreased depending upon their size. A larger anode will last longer than a smaller one. The average life will vary however a 10 to 20 year life can be expected for a correctly sized anode.

P/S potential measurements should be made at locations as far distant as possible from the anode. Otherwise the readings may indicate adequate protection when the pipe distant from the anode is not protected.

TYPICAL MAGNESIUM ANODE INSTALLATION

1. Anode may be installed either vertical or horizontal, however it should be as deep as the bottom of the pipe. Always remove anode from paper sack. Avoid handling by the lead wire as they are easily damaged.

2. It is recommended that the underground anode lead wire to pipe connection be made using the thermite process (Cadweld).

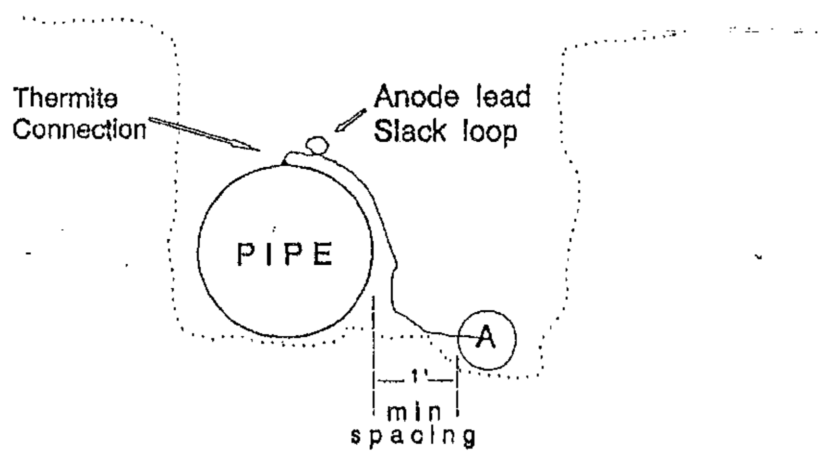
3. Coat the anode lead connection and repair any coating damage present in the excavation. Use an approved pipe coating material such as plastic pipe wrap and the primer supplied with it.

4. Care should be taken to prevent the anode lead wire from being stressed or broken during backfilling operations.

5. The anode may be flooded with water prior to backfilling to help it begin operating.

6. Backfill anode with native soil, not sand or rocks.

Typical Anode Installation



TROUBLESHOOTING A CP SYSTEM

GALVANIC SYSTEM

A. IF PREVIOUSLY OPERATED SATISFACTORILY

1. TEST ALL INSULATORS

2. INVESTIGATE FOR FOREIGN CONTACTS
    - A. UNDERGROUND WATER LINES
    - B. UNDERGROUND CABLES
    - C. GROUND CONNECTIONS TO POWER/TELEPHONE/TV CABLES

3. DISCONNECTED OR DEPLETED ANODES
    - A. CHECK ABOVE GROUND CONNECTIONS

4. POSSIBILITY OF ABNORMAL DRY SOIL CONDITIONS

B. IF NEVER OPERATED SATISFACTORILY

1. VERIFY ALL REQUIRED INSULATORS WERE INSTALLED

2. VERIFY ALL POSSIBLE UNDERGROUND CONTACTS HAVE BEEN REMOVED

3. REVIEW COATING QUALITY
   - A. IS COATING OF POOR QUALITY?
   - B. IF POOR QUALITY COATING, ADDITIONAL ANODES MAY BE REQUIRED
   - C. POOR QUALITY COATING MAY MAKE IT IMPRACTICAL TO USE GALVANIC ANODES

4. REVIEW ANODE INSTALLATION
   - A. ANODES PROPERLY SIZED, INSTALLED AND CONNECTED?
   - B. SUFFICIENT ANODES INSTALLED?