CHAPTER VIII
CORROSION CONTROL

FEDERAL REQUIREMENTS

This chapter contains a basic description of the corrosion control requirements contained in the pipeline safety regulations. 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 and maintain a corrosion control program for their piping system. These procedures should include design, installation, operation and maintenance activities on a cathodic protection system. A person qualified in pipeline corrosion control methods must carry out these procedures.

Techniques for Compliance

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

- There are many consultants and experts who specialize in cathodic protection. Many advertise in gas trade journals.
- Another source, for LP operators, is an experienced corrosion engineer or technician working for a local gas utility company. Such experts may be able to implement cathodic protection for LP gas operators or refer them to local qualified corrosion engineers.
- OPS suggests that operators of LP gas systems encourage their respective trade associations such as (The National Propane Gas Association) to gather and maintain records of available consultants or contractors who are qualified in their specific region.
- The local chapter of the National Association of Corrosion Engineers (NACE) may be able to provide useful information.
- Operators who are unsure of a consultant's qualification in corrosion control should contact operators who have hired the consultant in the past.

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.

Newly constructed metallic pipelines must be coated before installation and must have a cathodic protection system installed and placed in operation in its entirety within one year after construction of the pipeline.

Cathodic protection requirements do not apply to electrically isolated, metal alloy fittings in plastic pipelines if the alloyage of the fitting provides corrosion control and if corrosion pitting will not cause leakage.

Corrosion Control Requirements for Pipelines Installed Before August 1, 1971

For LP gas systems, the pipeline safety regulations require that underground bare or ineffectively coated distribution pipelines and underground tanks be cathodically protected in areas of active corrosion.

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

Active corrosion means continuing corrosion, which, unless controlled, could result in a condition that is detrimental to public safety.

As a guideline for operators when determining corrosion to be detrimental to public safety (active corrosion), OPS recommends the following:

- For LP gas operators, all continuing corrosion occurring on underground metallic pipes and tanks should be considered active and pipes should be cathodically protected, repaired or replaced.
- OPS recommends that operators of LP gas systems and their consultants use these following guidelines in determining where it is impractical to do electrical surveys to find areas of active corrosion:

  a. Areas of fluctuating stray dc currents, such as those caused by electrical railway systems
  b. Where the pipeline is more than 2 feet from the edge of and under a paved street or within wall to wall pavement areas.
  c. Pipelines in a common trench with other metallic structures.

Electrical surveys may prove to be impractical due to conditions other than those listed above. The operator must demonstrate the impracticability of an electrical survey.

In areas where electrical surveys cannot be run to determine corrosion, the operator should run leakage surveys on a more frequent basis. OPS recommends that these surveys be run at least once a year.

Electrical surveys to find active corrosion must be run by a person qualified in pipeline corrosion control methods.

Coating Requirements

All metallic pipe installed below ground, as a new or replacement pipeline system must be coated in its entirety. Types of coatings and handling practices are discussed later in this chapter.

Examination of Exposed Pipe

Whenever buried pipe is exposed or dug up, the operator is required to examine the 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.

Criteria for Cathodic Protection

Operators must meet one of five criteria listed in Appendix D of 49 CFR Part 192 to comply with the pipeline safety regulations for cathodic protection.

The criteria that most operators of LP gas systems choose is a (cathodic) voltage of at least -0.85 volt with reference to a saturated copper-copper sulfate half-cell. NOTE: IR drop must be considered. IR drop is the difference between the voltage at the top of the pipe and the voltage at the surface of the earth.

Monitoring

A piping system that is under cathodic protection must be systematically monitored. Tests for effectiveness of cathodic protection must be done at least once every year. Records of this monitoring must be maintained.

Short, separately protected service lines or short, protected mains may be surveyed on a sampling basis. At least 10 percent of these short sections and services must be checked each year so that all short sections in the system are tested in a 10-year period.

Examples of short, separately protected pipe in an LP gas system would be:

- Steel service lines connected to, but electrically isolated from, the main.
- Steel service risers that have cathodic protection provided by an anode attached to a riser that is installed on plastic service lines.

OPS recommends that if a small number of isolated protected sections of pipeline exist in the system, the operator include all sections in the annual survey.

When using rectifiers to provide cathodic protection, each rectifier must be inspected six times every year to ensure that the rectifier(s) is operating properly. The intervals must not exceed 2½ months. 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 single unit). For illustrations of where meter sets are commonly electrically insulated, see Figures VIII-8, VIII-13 and VIII-14 in this chapter.

Test Points

Each pipeline under cathodic protection must have sufficient test points for electrical measurement to determine the adequacy of cathodic protection. Test points should be shown on a cathodic protection system map.

Internal Corrosion Inspection

Whenever a section of pipe is removed from the 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.

Atmospheric Corrosion

Newly installed aboveground pipelines must be cleaned and coated or jacketed with a material suitable for the prevention of atmospheric corrosion. Aboveground pipe, including meters, regulators, and measuring stations, must be inspected for atmospheric corrosion. It is recommended that this be done on an annual basis during other annual maintenance. Remedial action must be taken if atmospheric corrosion is found.

Remedial Measures

All steel pipe used to replace an existing pipe must be coated and cathodically protected. Each segment of pipe that is repaired because of corrosion leaks must be cathodically protected.

Records

Operators must maintain records or maps of their cathodic protection system. Records of all tests, surveys, or inspections required by the pipeline safety code must be maintained.

SOME PRINCIPLES AND PRACTICES OF CATHODIC PROTECTION

This section gives operators with little or no experience in cathodic protection, a review of the general principles and practices of cathodic protection. Common causes of corrosion, types of pipe coatings and criteria for cathodic protection are among the topics. A checklist of steps which an operator of an LP gas system may use to determine the need for cathodic protection is included. Basic definitions and illustrations are used to clarify the subject. This section does not go into great depth. Therefore, reading this section alone will not qualify an operator to design and implement cathodic protection systems.

Basic Terms

Corrosion - The deterioration of metal pipe. Corrosion is caused by a reaction between the metallic pipe and its surroundings. As a result, the pipe deteriorates and may eventually leak. Although corrosion cannot be eliminated, it can be substantially reduced with cathodic protection. (See Figure VIII-1.)

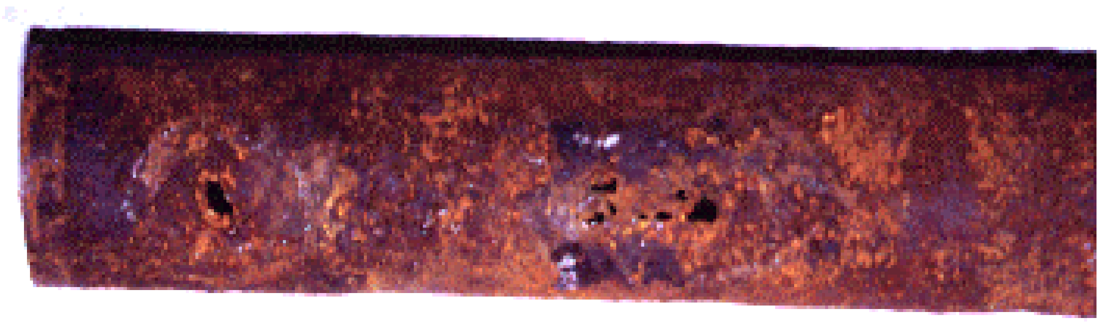


Figure VIII-1 Bare Pipe - not under cathodic protection

An example of bare steel pipe installed for gas service. Note the deep corrosion pits that have formed. Operators should never install bare steel pipe or bare tanks underground. Operators should use either polyethylene pipe manufactured according to ASTM D2513 or coated steel pipe as new or replacement pipe. If steel pipe is installed, it must be coated and cathodically protected.

Cathodic protection - A procedure by which an underground metallic pipe is protected against corrosion. A direct current is impressed onto the pipe by means of a sacrificial anode or a rectifier. Corrosion will be reduced where sufficient current flows onto the pipe.

Anode (sacrificial) - 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 functions as a battery that impresses a direct current on the piping system to retard corrosion. (See Figure VIII-2.)

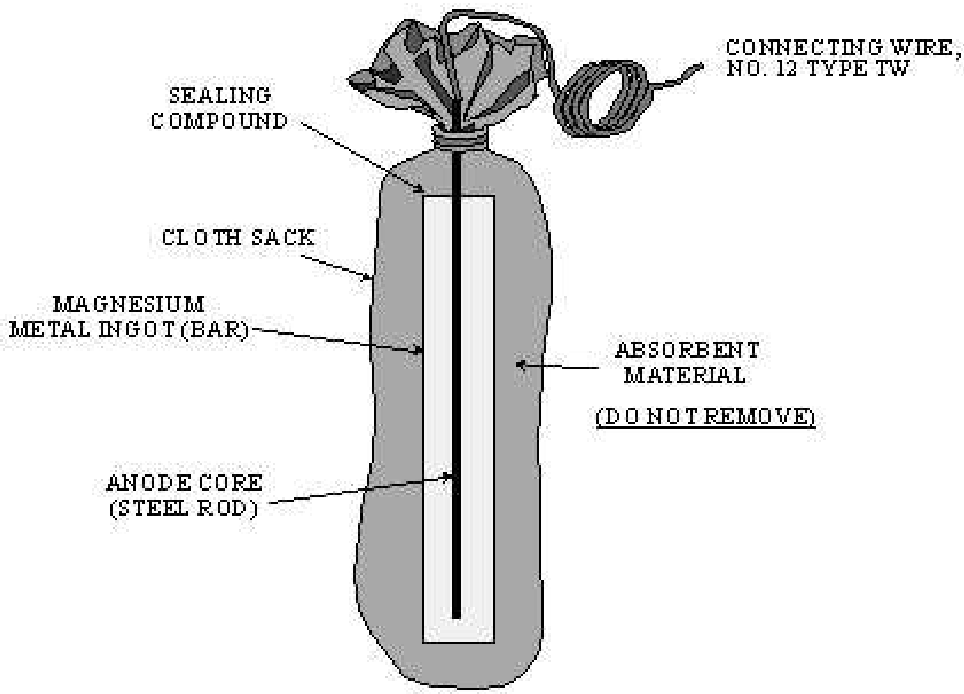


Figure VIII-2 Typical Magnesium (Mg) Anode

Sacrificial protection - The reduction 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 VIII-3.) The magnesium or zinc will sacrifice itself (corrode) to retard corrosion in the steel pipe.

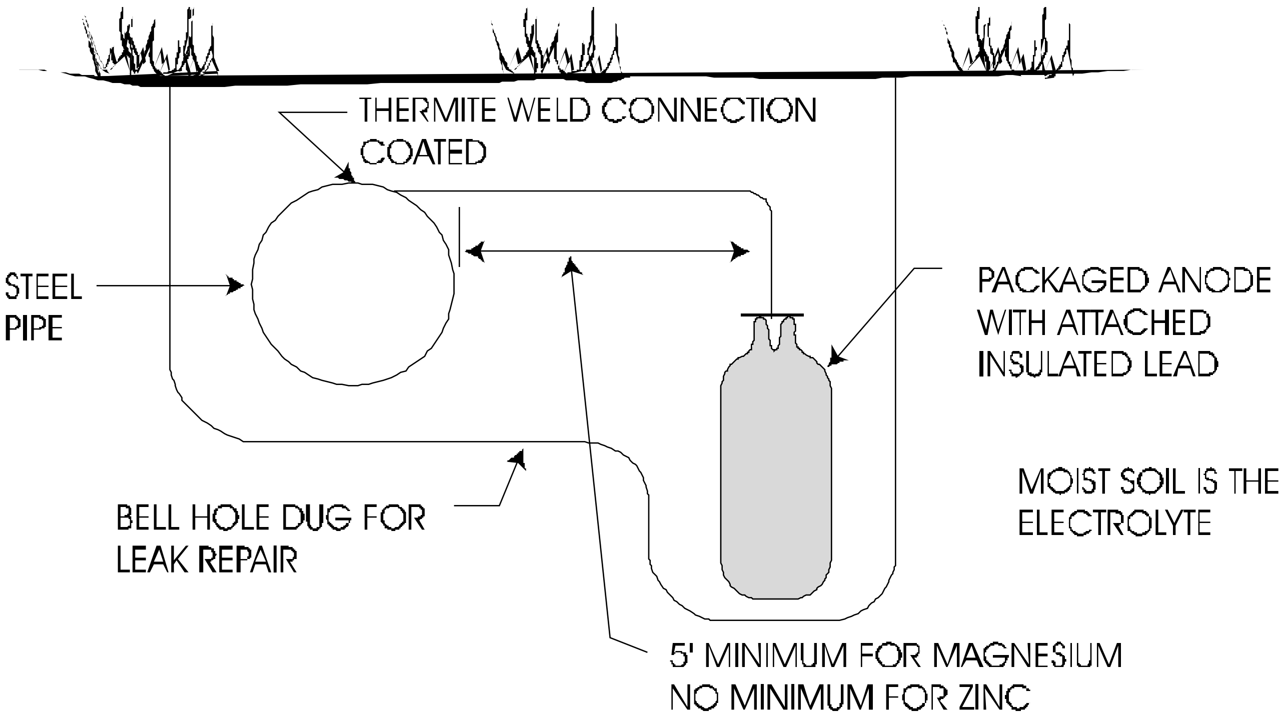


Figure VIII-3

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

Rectifier - An electrical device that changes alternating current (ac) into direct current (dc). This current is then impressed on an underground metallic piping system to protect it against corrosion. (See Figure VIII-4.)

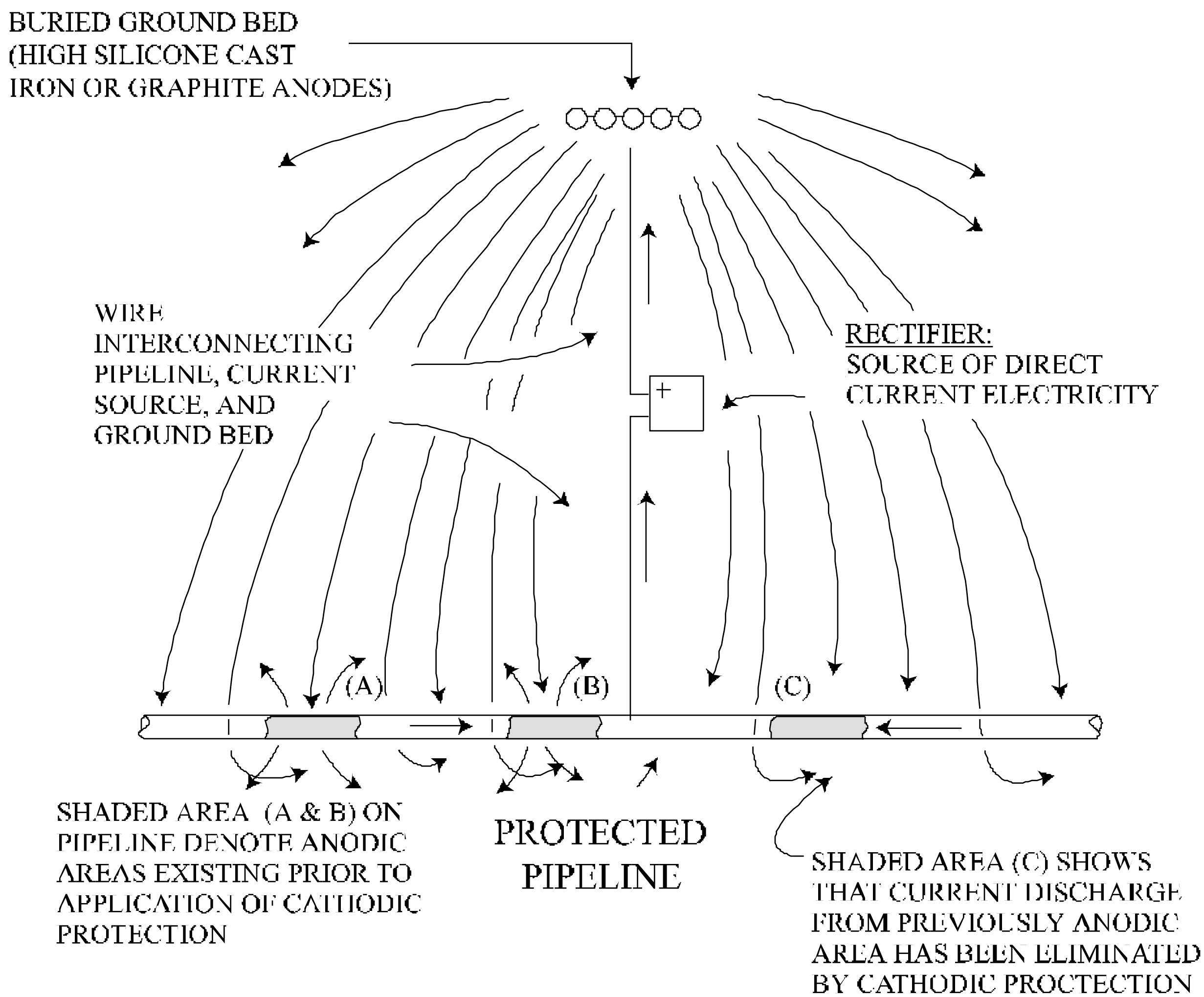


Figure VIII-4

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 the reverse occurs (positive terminal to pipe), the pipe will corrode much faster.

Potential - The difference in voltage between two points of measurement. (See Figure VIII-5.)

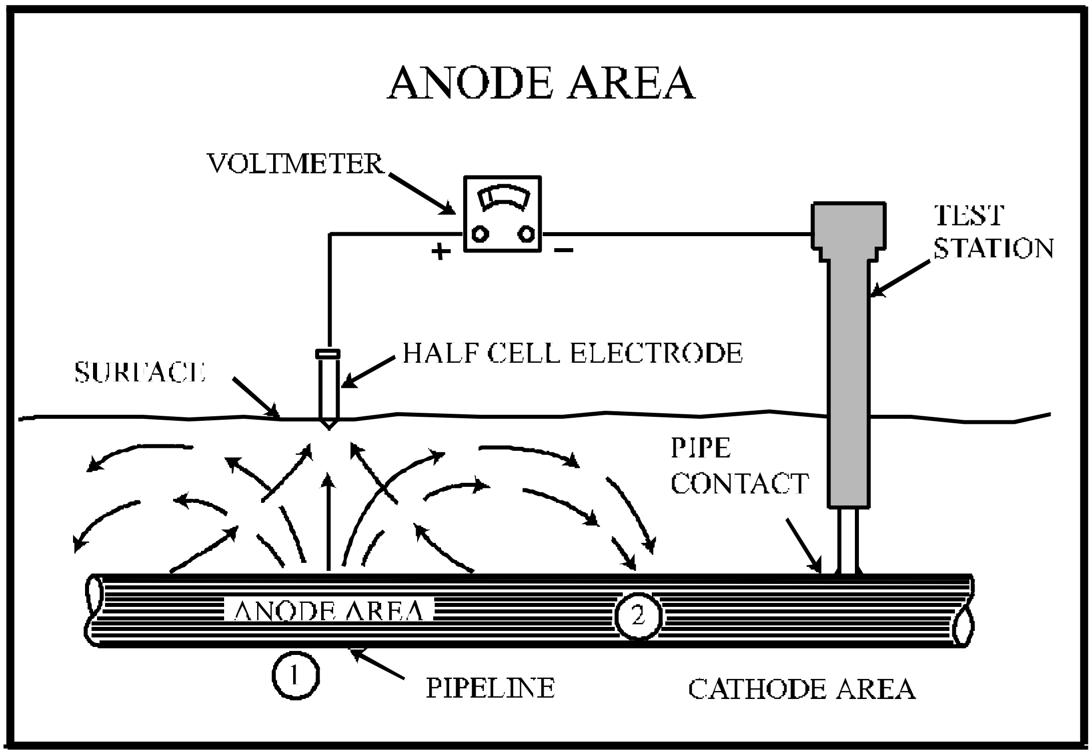


Figure VIII-5

The voltage potential in this example 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 an electrode made up of copper immersed in copper-copper sulfate ($CuCuSO_4$).

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

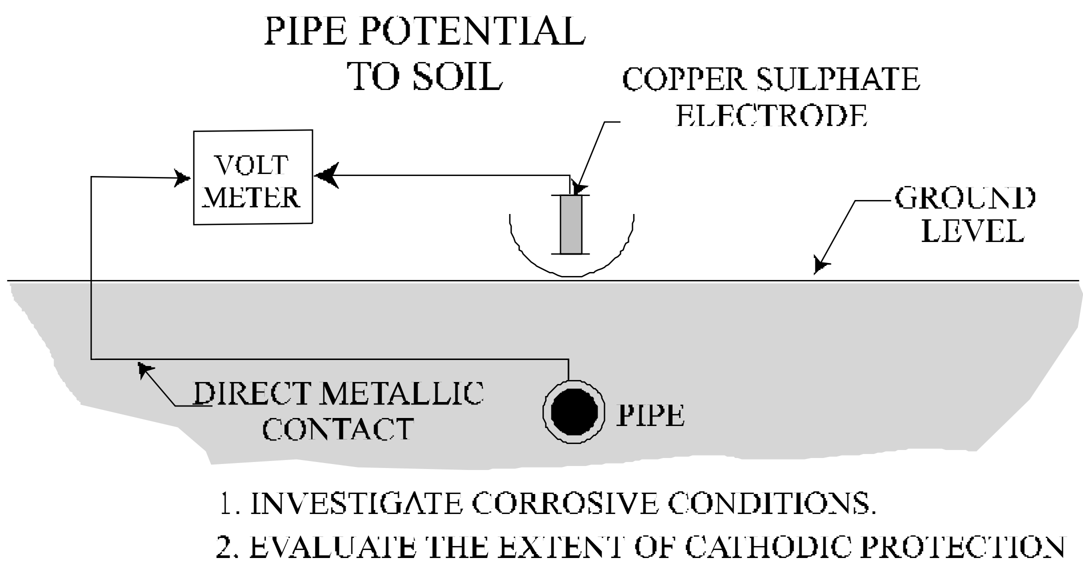
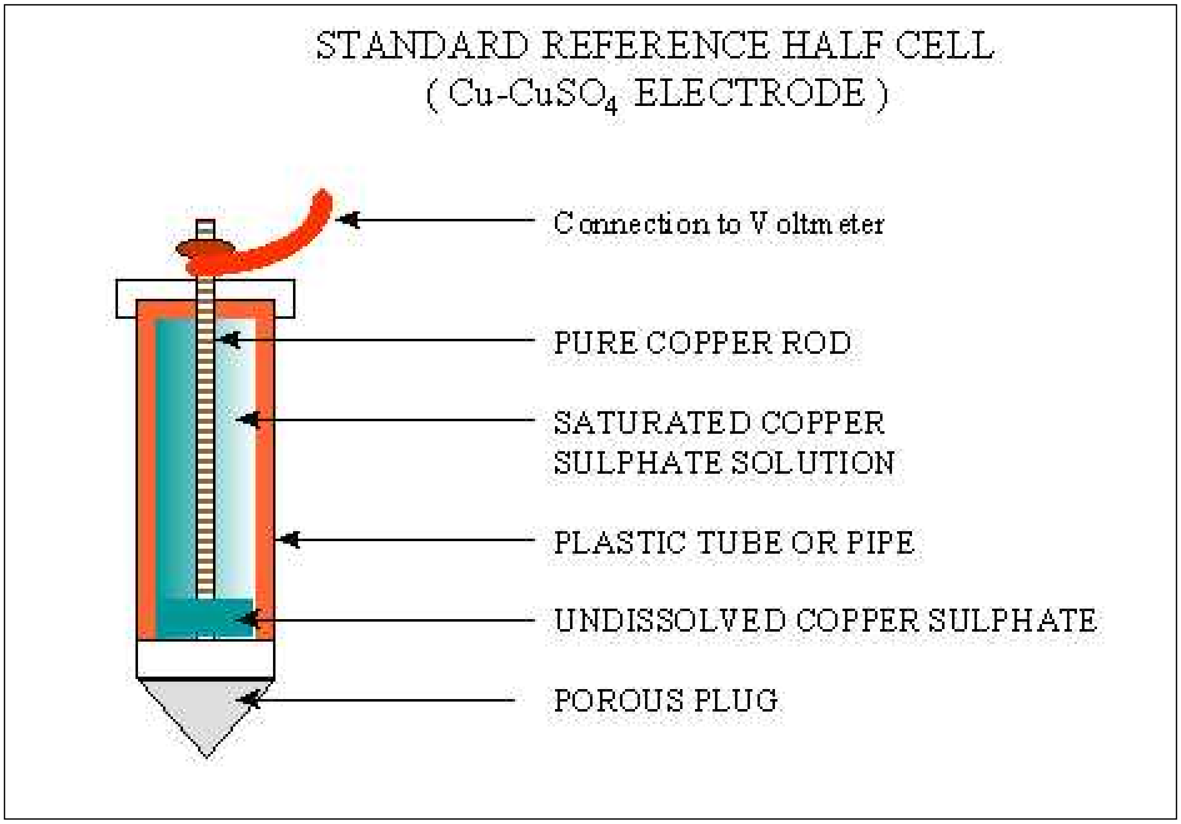


Figure VIII-6

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

Reference electrode (commonly called a half-cell) - A device which usually has copper immersed in a copper sulfate solution. The open circuit potential is constant under similar conditions of measurement. (See Figure VIII-7.)



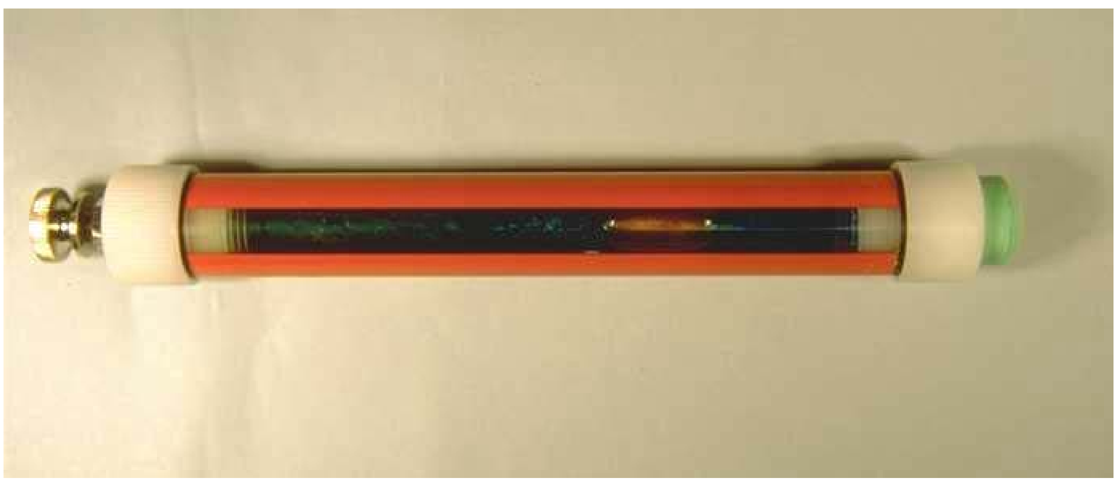


Figure VIII-7 Reference Electrode – A saturated copper-copper sulfate half-cell.

Short or **corrosion fault** - 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 VIII-8.)

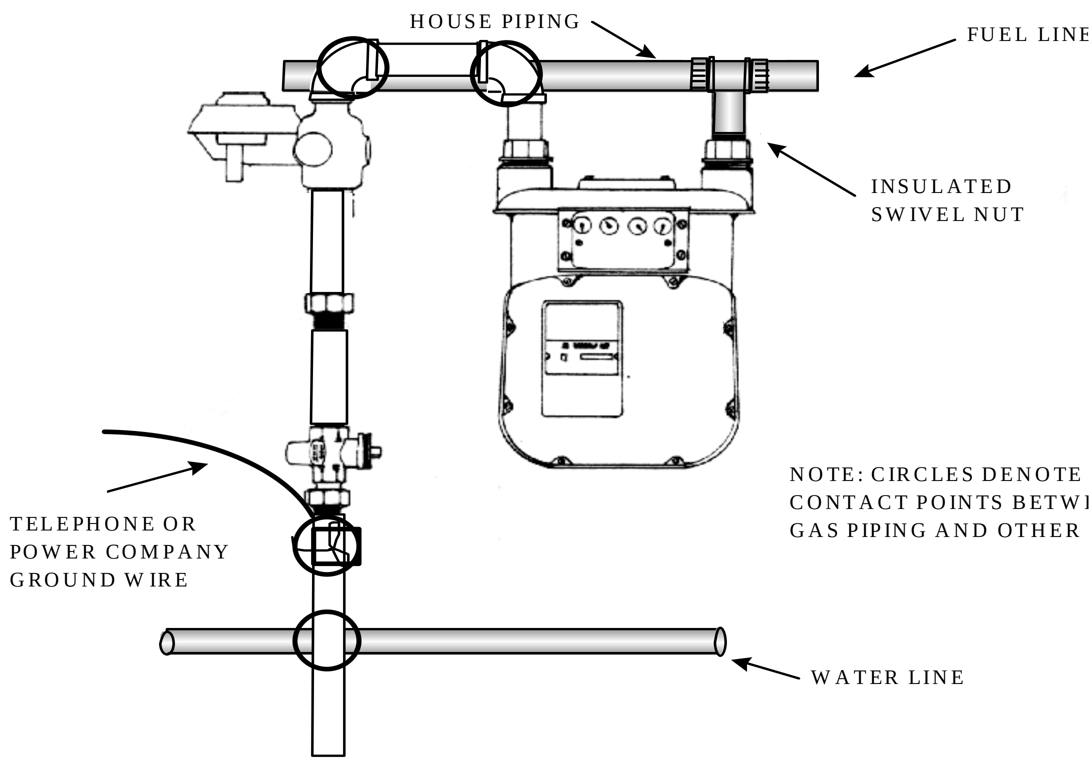


Figure VIII-8 Typical Meter Installation Accidental Contacts
(Meter Insulator Shorted Out by House Piping, etc.)

Unshaded piping shows company piping from service entry to meter insulator at location shown on sketch above. Shaded areas show house piping, electrical cables, etc. The circled locations are typical points where the company piping (unshaded) can come in metallic contact with house piping. This causes shorting out or "bypassing" of 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 the piping cannot be moved, install a new insulator between the accidental contact and the service entry.

Stray current - Current flowing through paths other than the intended circuit. (See Figure VIII-9.)

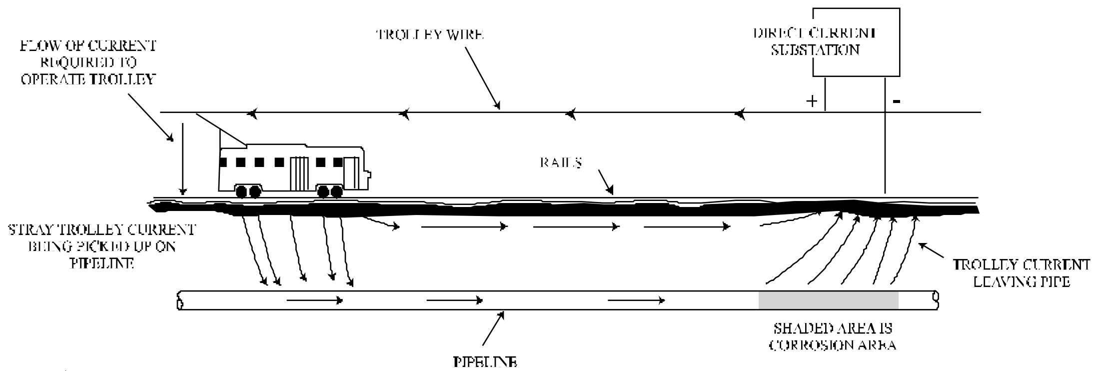


Figure VIII-9

This drawing illustrates an example of stray dc current getting onto a pipeline from an outside source. This can cause severe corrosion in the area where the current eventually leaves the pipe. Expert help is needed to correct this type of problem.

Stray current corrosion - Metal destruction or deterioration caused primarily by stray dc current in the soil around a pipeline.

Galvanic series - A list of metals and alloys arranged according to their relative potentials in a given environment. (See Table 1.)

Galvanic corrosion - Occurs when any two of the metals in Table 1 are connected in an electrolyte (soil). Galvanic corrosion is caused by the difference in the potentials of the two metals.

Table 1

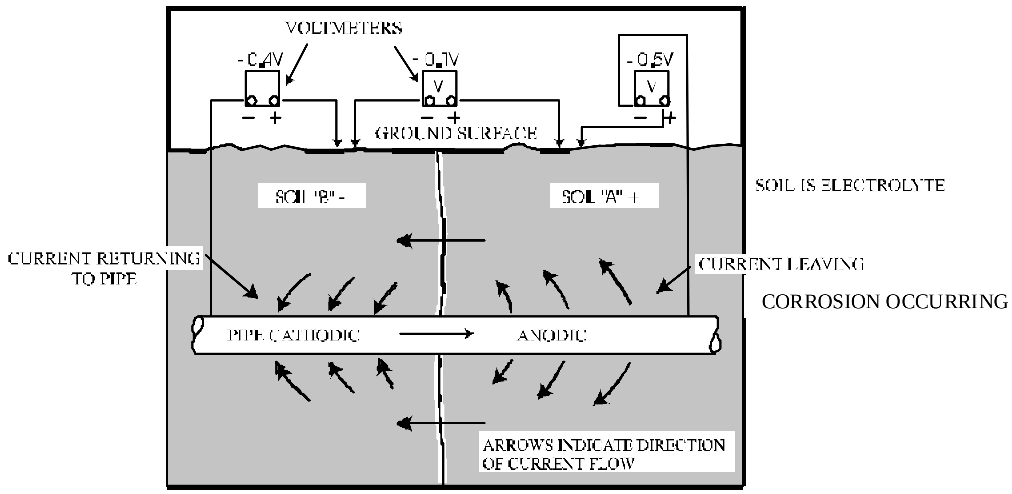
METAL	Potentials VOLTS*	
Commercially pure magnesium	-1.75	Anodic
Magnesium alloy (6% A1, 3% Zn, 0.15% Mn)	-1.6	
Zinc	-1.1	
Aluminum alloy (5% zinc)	-1.05	
Commercially pure aluminum	-0.8	
Mild steel (clean and shiny)	-0.5 to -0.8	
Mild steel (rusted)	-0.2 to -0.5	
Cast iron (not graphitized)	-0.5	
Lead	-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 in natural soils and water, measured with respect to a copper-copper sulfate reference electrode.

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

FUNDAMENTAL CORROSION THEORY

For corrosion to occur there must be four elements: electrolyte, anode, cathode and a metallic return circuit. A metal will corrode at the point where current leaves the anode. (See Figure VIII-10.) NOTE: Dissimilar soils may create an environment that enhances corrosion.



CORROSION FROM DISSIMILAR SOILS

Figure VIII-10

A corrosion cell may be described as follows:

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

- Corrosion occurs whenever current leaves the metal (pipe, fitting, etc.) and enters the soil (electrolyte). The area where current leaves is said to be 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.

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 a distribution system. (See Figure VIII-11.)

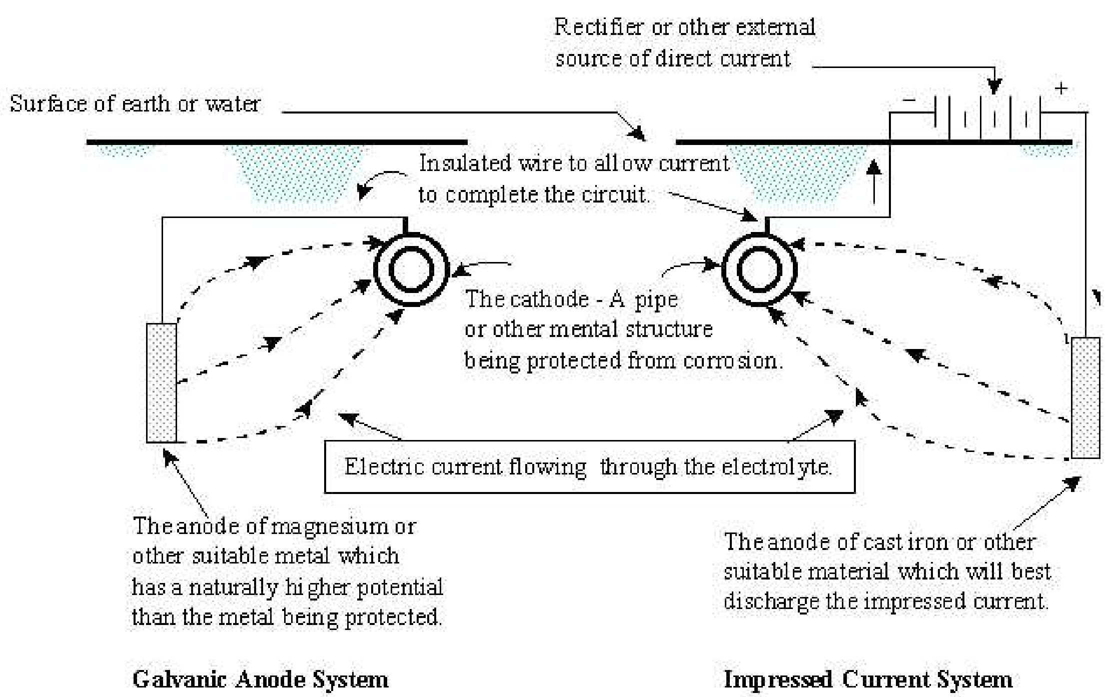


Figure VIII-11

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

Galvanic Anode Systems

Anodes are "sized" to meet current requirements of the resistivity of the environment (soil.) Anodes are made of materials such as magnesium (Mg), zinc (Zn) or aluminum (Al). 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 VIII-3, VIII-11 and VIII-12.)

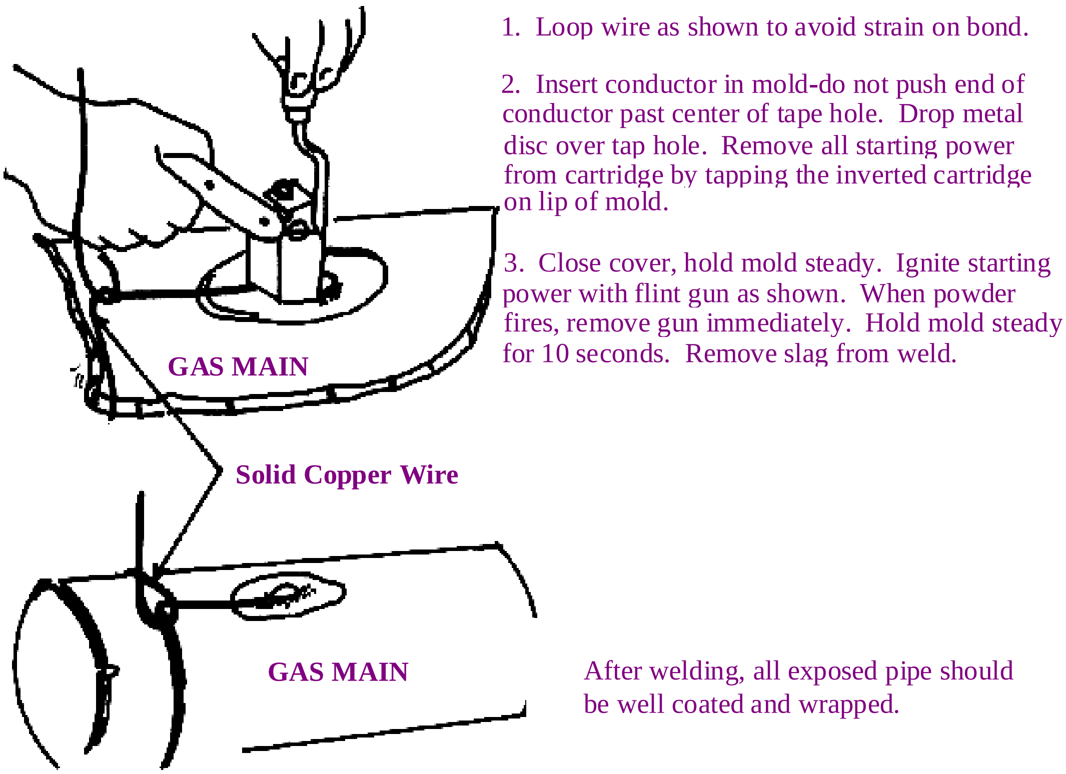


Figure VIII-12 Typical procedure for installing a Mg Anode

<u>Impressed Current Systems</u>

Anodes are connected to a direct current source, such as a rectifier or generator. 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.

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

1. Determine type(s) of pipe in the system: bare steel, coated steel, cast iron, plastic, galvanized steel, ductile iron or other.

2. Date the gas system was installed:

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

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

- Type of pipe in the ground.
- If pipe is electrically isolated.
- If the gas pipe is in a 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 customer meters are electrically insulated. If the system has no meter, check to see if the gas pipe is electrically insulated from house or mobile home piping. (See Figure VIII-13.)

5. Contact an experienced corrosion engineer or consulting firm. Try to complete steps 1 through 4 before contracting a consultant.

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 if 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. (The consultant 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 will vary for each 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 the gas piping system.

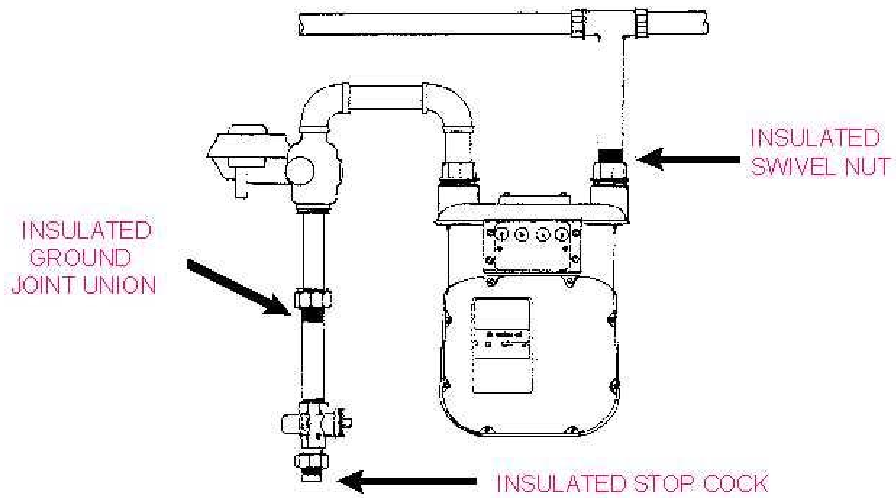


Figure VIII-13
Places where a meter installation may be electrically isolated.

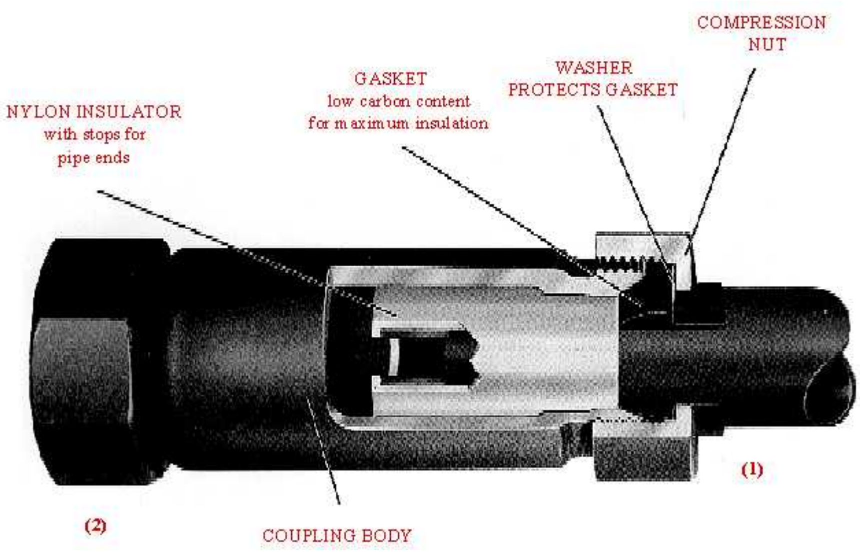
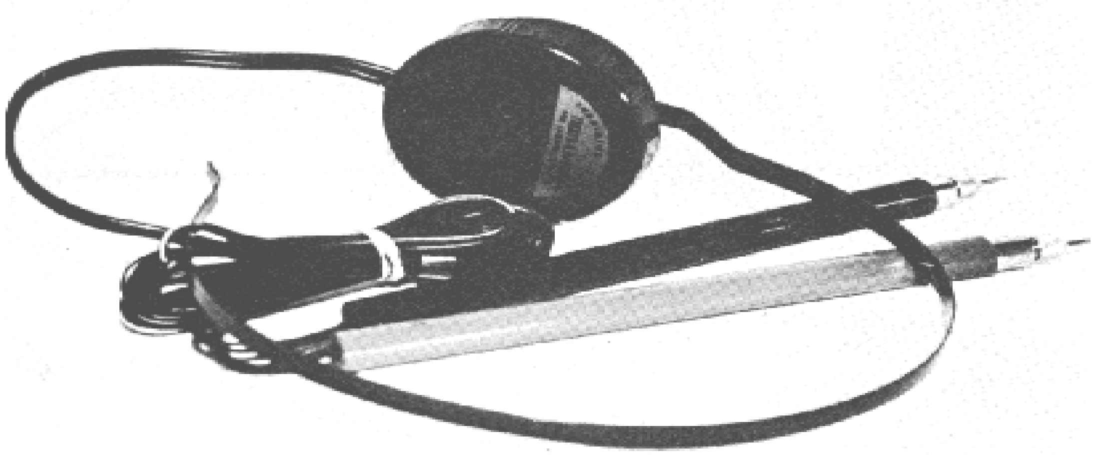


Figure VIII-14

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 VIII-15 Insulation tester



This insulation tester consists of a magnetic transducer mounted in a single earphone headset with connecting needlepoint 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 on the metallic surface on either side of the insulator a distinct audible tone will be heard if the insulator is performing properly. Absence of an audible tone indicates a faulty insulator. Insulator effectiveness can be determined quickly using this simple, easy-to-operate tester.

CRITERIA FOR CATHODIC PROTECTION

There are five criteria listed in Appendix D of Part 192, to qualify a pipeline as being cathodically protected. Operators can meet the requirements of any one of the five to be in compliance with the pipeline safety regulations. Most systems will be designed to Criterion 1.

Criterion 1: With the protective current applied, a voltage of at least -0.85 volt measured between the pipeline and a saturated copper-copper sulfate half-cell. This measurement is called the pipe-to-soil potential reading. (See Figure VIII-16)

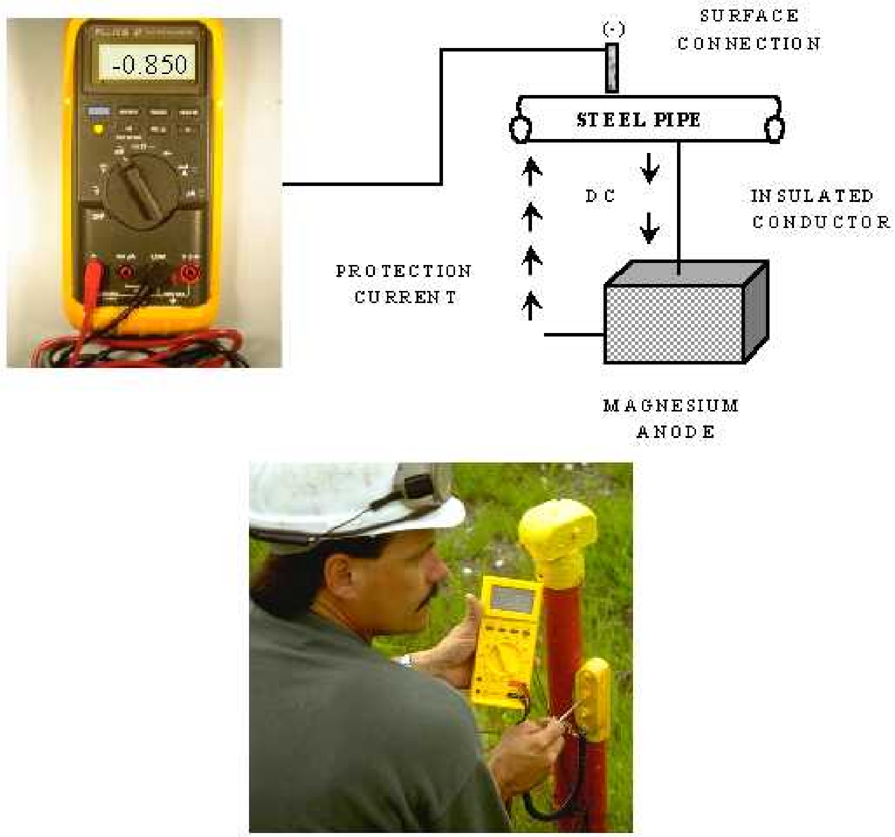


Figure VIII-16 Pipe to soil potential reading

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 volt*, 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 drop (IR drop) that 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 coatings on the market. The better the coating application, the less electrical current 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 the manufacturing process). Some examples of mill coatings are:

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

A qualified (corrosion) person can help select the best coating for an LP gas system. A coating consultant will be able to give master meter operators the names and locations of nearby suppliers of mill coated gas pipe. When purchasing steel pipe, remember to verify that the pipe was manufactured according to one of the specifications listed in Chapter III of this manual. This can be verified by a bill of lading or by the markings on mill coated pipe.

<u>Patching</u>

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 types 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 a pipe supplier before purchasing tapes. Tapes must be compatible with the mill coating on the pipe.

<u>Coating Application Procedures</u>

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 be followed <u>precisely</u>. Time and money is wasted if the instructions are not followed.

Some general guidelines for installation of pipe coatings:

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

- Use careful priming techniques. Avoid moisture and follow the manufacturer's recommendations.

Properly apply the coating materials (be sure pipe surface is dry - follow manufacturer's recommendations). <u>Make sure soil or other foreign material does not get under coating during installation</u>.

Backfill with material that is free of objects capable of damaging the coating. <u>Severe coating damage can be caused by careless backfilling when rocks and debris strike and break the coating</u>.

COMMON CAUSES OF CORROSION IN GAS PIPING SYSTEMS

Figure VIII-17 Shorted meter set

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

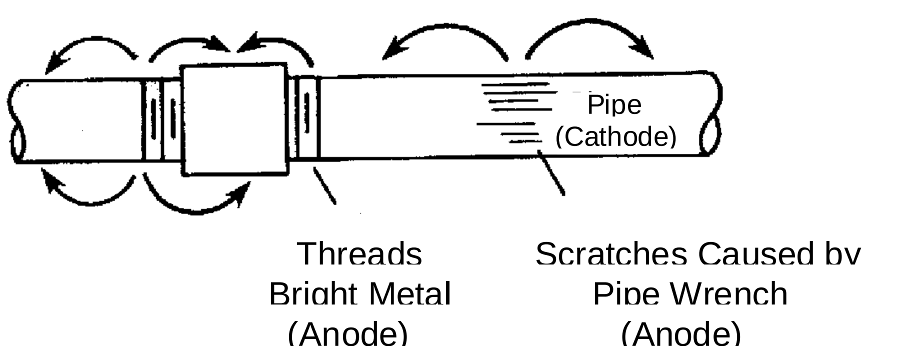


Figure VIII-18 Corrosion caused by dissimilar surface conditions.

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 the pipe.

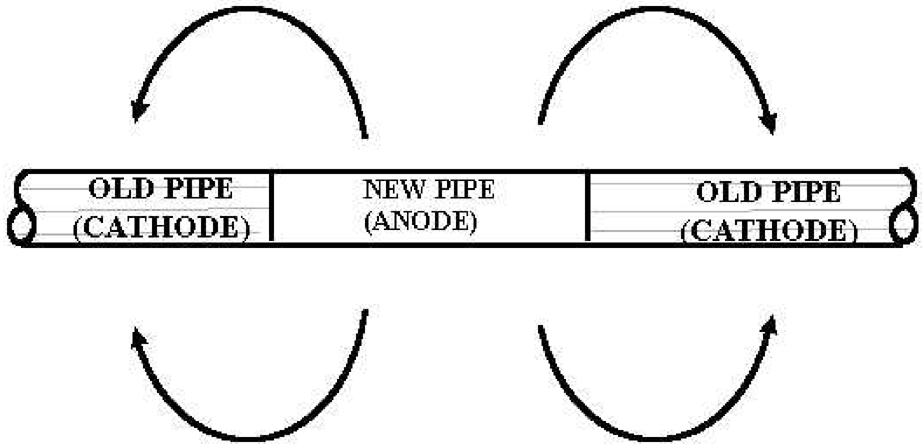


Figure VIII-19 Galvanic Corrosion

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.

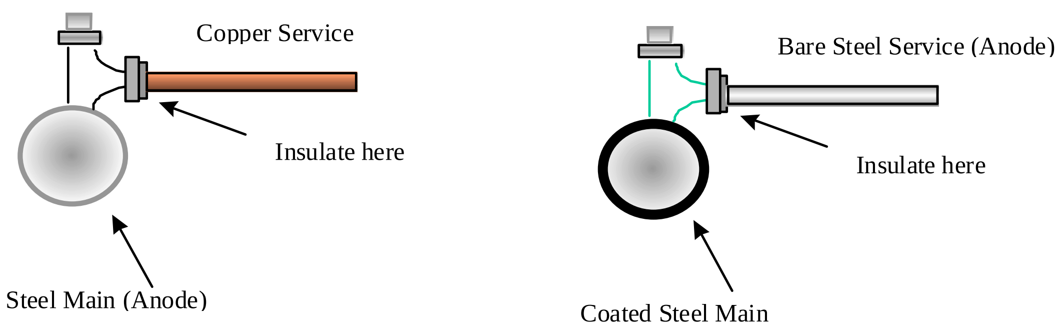


Figure VIII-20 Galvanic Corrosion caused by dissimilar metals.

Steel is above copper in the galvanic series in Table 1 of this chapter. 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.

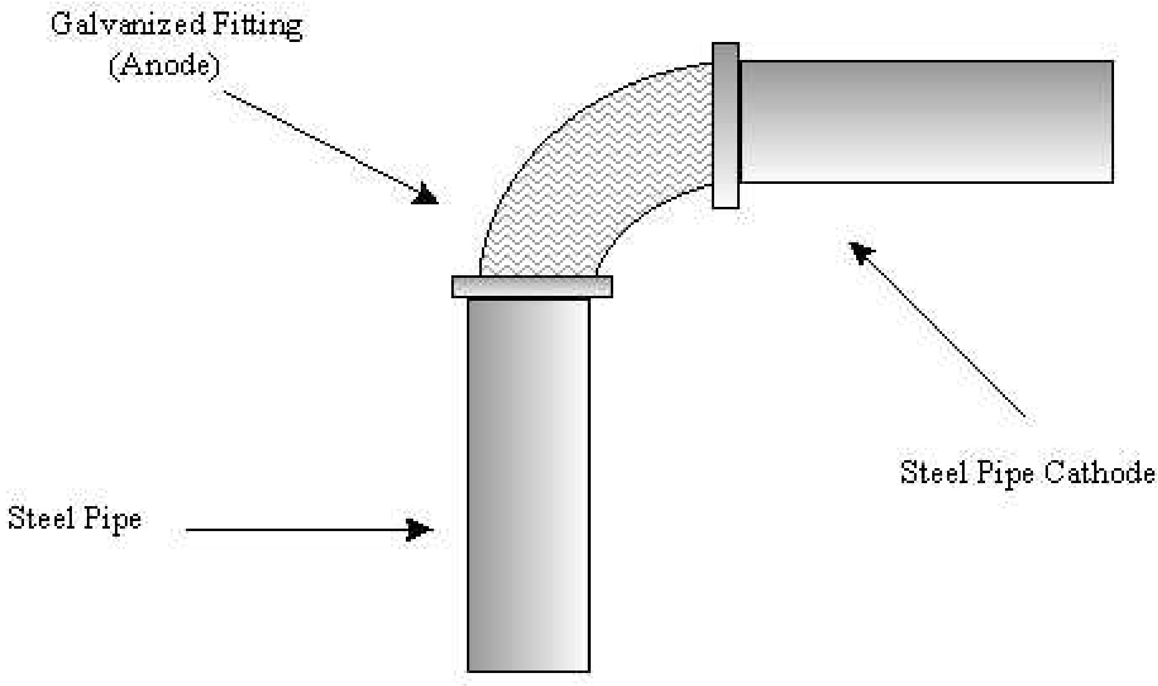


Figure VIII-21 Galvanic Corrosion

The galvanized elbow will act as an anode to steel and will corrode. Do not install galvanized pipe or fittings in a system, if possible. However, when using galvanized fittings, the fittings must be electrically isolated.

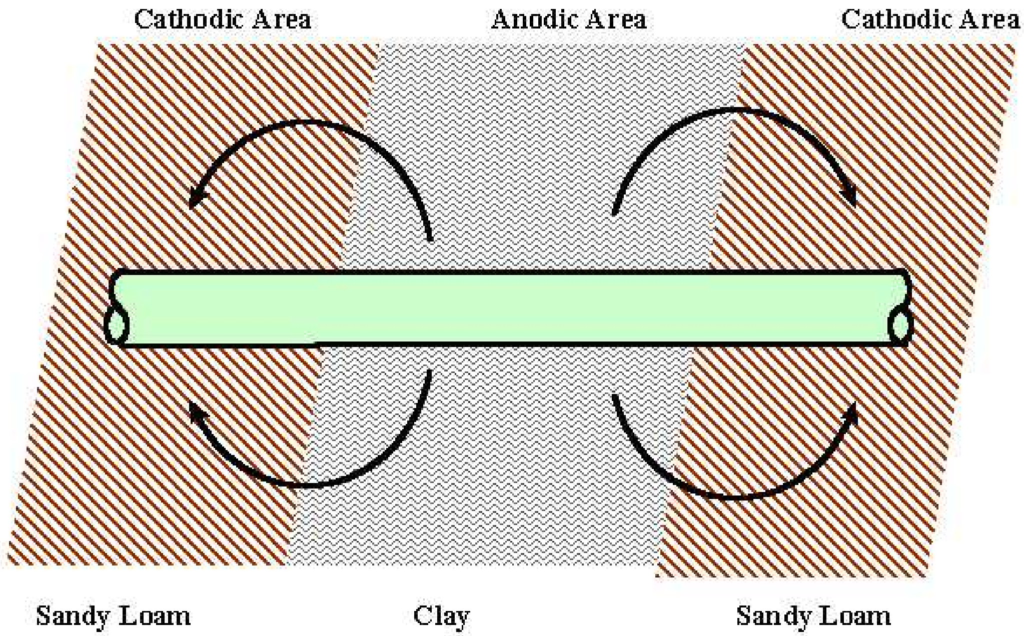


Figure VIII-22 Galvanic Corrosion

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 VIII-23 Poor Construction Practice

An example of a main which was buried without a coating or wrapping at the service connection. This corrosion problem could have been avoided with proper coating and cathodic protection.

Figure VIII-24 Atmospheric Corrosion

An example of atmospheric corrosion at a meter riser. This can be prevented by either jacketing the exposed pipe or by keeping it properly painted. Corrosion is usually more severe at the point the pipe comes out of the ground.