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# Process Piping Part 4 - Corrosion Protection and Lining of Piping Systems

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# Chapter 9
# Lined Piping Systems

## 9-1. General

When properly utilized, a lined piping system is an effective means by which to protect metallic piping from internal corrosion while maintaining system strength and external impact resistance. Cathodic protection is still required for buried applications to address external corrosion. Manufacturing standard options for the outer piping material are usually Schedule 40 or 80 carbon steel. Lined piping systems are not double containment piping systems.

a. Design Parameters

Design factors that must be taken into account for the engineering of lined piping systems include: pressure, temperature and flow considerations; liner selection factors of permeation, absorption, and stress cracking; and heat tracing, venting and other installation requirements.

b. Operating Pressures and Temperatures

The requirements for addressing pressure and temperature conditions for lined piping systems are summarized in the following paragraphs.

Lined piping systems are used primarily for handling corrosive fluids in applications where the operating pressures and temperatures require the mechanical strength of metallic pipe. Therefore, the determination of maximum steady state design pressure is based on the same procedure and requirements as metallic pipe shell, and the design temperature is based on similar procedures and requirements as thermoplastic pipe.

Table 9-1 lists recommended temperature limits of thermoplastic used as liners. The temperature limits are based on material tests and do not necessarily reflect evidence of successful use as piping component linings in specific fluid serviced at the temperatures listed. The manufacturer is consulted for specific application limitations.

c. Liner Selection

Liner selection for piping systems must consider the materials being carried (chemical types and concentrations, abrasives, flow rates), the operating conditions (flow, temperature, pressure), and external situations (high temperature potential).

For the material compatibility of metallic lined piping system with various chemicals, see Appendix B. As discussed in Chapter 4, metallic material compatibility should consider the type and concentration of chemicals

**Table 9-1**
**Thermoplastic Liner Temperature Limits (Continuous Duty)**

| | Recommended Temperature Limits | | | |
|---|---|---|---|---|
| | Minimum | | Maximum | |
| Materials | EF | EC | EF | EC |
| ECTFE | -325 | -198 | 340 | 171 |
| ETFE | -325 | -198 | 300 | 149 |
| FEP | -325 | -198 | 400 | 204 |
| PFA | -325 | -198 | 500 | 260 |
| PP | 0 | -18 | 225 | 107 |
| PTFE | -325 | -198 | 500 | 260 |
| PVDC | 0 | -18 | 175 | 79 |
| PFDF | 0 | -18 | 275 | 135 |

Note: Temperature compatibility should be confirmed with manufacturers before use is specified.
Source: ASME B31.3, p. 96, Reprinted by permission of ASME.

in the liquid, liquid temperature and total stress of the piping system. The selection of materials of construction should be made by an engineer experienced in corrosion or similar applications. See Appendix A, Paragraph A-4, for additional sources of corrosion data.

As discussed in Chapter 5, thermoplastic materials do not display corrosion rates and are, therefore, either completely resistant to a chemical or will rapidly deteriorate. Plastic lined piping system material failure occurs primarily by the following mechanisms: absorption, permeation, environmental-stress cracking, and combinations of the above mechanisms.

Permeation of chemicals may not affect the liner but may cause corrosion of the outer metallic piping. The main design factors that affect the rate of permeation include absorption, temperature, pressure, concentration, and liner density and thickness. As temperature, pressure, and concentration of the chemical in the liquid increase, the rate of permeation is likely to increase. On the other hand, as liner material density and thickness increase, permeation rates tend to decrease[1].

For plastic material compatibility with various chemicals, see Appendix B. See Appendix A, Paragraph A-4, for additional sources of corrosion data. For the material compatibility of elastomeric and rubber as well as other nonmetallic material lined piping systems with various chemicals, see appendix B.

Liners should not be affected by erosion with liquid velocities of less than or equal to 3.66 m/s (12 ft/s) when abrasives are not present. If slurries are to be handled, lined piping is best used with a 50% or greater solids content and liquid velocities in the range of 0.61 to 1.22 m/s (2 to 4 ft/s). Particle size also has an effect on erosion. Significant erosion occurs at >100 mesh; some erosion occurs at >250 but <100 mesh; and little erosion occurs at <250 mesh. Recommended liners for slurry applications are PVDF and PTFE, and soft rubber; by comparison, in a corrosive slurry application, PP erodes 2 times as fast and carbon steel erodes 6.5 times as fast[2].

d. Joining

Two available methods for joining lined pipe are flanged joints and mechanical couplings (in conjunction with heat fusion of the thermoplastic liners).

Thermoplastic spacers are used for making connections between lined steel pipe and other types of pipe and equipment. The spacer provides a positive seal. The bore of the spacer is the same as the internal diameter ($D_i$) of the lined pipe. Often, a gasket is added between the spacer and a dissimilar material to assist in providing a good seal and to protect the spacer.

When connecting lined pipe to an unlined flat face flange, a 12.7 mm (½ in) thick plastic spacer of the same material as the pipe liner is used. A gasket and a spacer will connect to an unlined raised face flange. Both a gasket and a spacer is recommended to connect to glass-lined equipment nozzles. Install a 12.7 mm (½ in) thick spacer between lined pipe or fittings and other plastic-lined components, particularly valves, if the diameters of the raised plastic faces are different.

For small angle direction changes, tapered face spacers may be used[3]. It is not recommended to exceed a five degree directional change using a tapered face spacer. For directional changes greater than five degrees, precision-bent fabricated pipe sections are available from lined pipe manufacturers.

Gaskets are not necessary to attain a good seal between sections of thermoplastic lined pipe, if recommended fabrication and installation practices are followed. Often, leaks result from using insufficient torque when trying to seal a joint. The addition of a gasket provides a softer material which seals under the lesser stress developed by low torque. When gaskets or any dissimilar materials are used in the pipe joint, the lowest recommended torque for the materials in the joint is always used.

Gaskets are put in when previously used lined pipe is reinstalled following maintenance. Gaskets are also used between plastic spacers and non-plastic-lined pipe, valves, or fittings.

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[1] Schweitzer, Corrosion-Resistant Piping Systems, pp.149-151.
[2] Ibid., p. 153.
[3] Crane/Resistoflex, "Plastic Lined Piping Products Engineering Manual," p. 41.

The recommended bolt torque values for thermoplastic lined piping systems are shown on Tables 9-2 through 9-5. Excessive torque causes damage to the plastic sealing surfaces. When bolting together dissimilar materials, the lowest recommended torque of the components in the joint is used.

Bolting torque is rechecked approximately 24 hours after the initial installation or after the first thermal cycle. This is required to reseat the plastic and allow for relaxation of the bolts. Bolting is performed only on the system in the ambient, cooled state, and never while the process is at elevated temperature or excessive force could result upon cooling.

e. Thermal Expansion

Thermal expansion design for lined piping systems can be handled in a similar manner as metallic piping. Expansion joints have been used to compensate for thermal expansion. However, expansion joints are usually considered the weakest component in a piping system and are usually eliminated through good engineering practices. Due to the bonding between the liner and the metallic pipe casing, pre-manufactured sections of pipe designed to allow for changes in movement of the piping system are available from manufacturers.

On long straight pipe runs, lined pipe is treated similarly to carbon steel piping. Changes in direction in pipe runs are introduced wherever possible to allow thermal expansion.

A common problem is the installation of lined piping between a pump and another piece of equipment. On new installations, equipment can be laid out such that there are no direct piping runs. Where a constricted layout is required or a piping loop would not be practical, the solution is to allow the pump to "float." The pump-motor base assemblies are mounted on a platform with legs. These bases are available from several manufacturers or can be constructed. These bases allow movement in order to relieve the stresses in the piping system.

f. Heat Tracing and Insulation

Heat tracing, insulation, and cladding can be installed on lined piping systems when required. The key for the design is to not exceed the maximum allowable temperature of the lining. Manufacturers recommendations on electrical heat tracing design should be followed to avoid localized hot spots. Steam heat tracing should not be used with most plastic lined piping systems due to the high temperature potential. Venting is required on many lined piping systems to allow for permeating vapor release. If insulation or cladding is to be mounted on the piping system, vent extenders should be specified to extend past the potential blockage.

g. Piping Support and Burial

Design of support systems for lined piping systems follows the same guidelines as for the outer piping material. Spans for systems consisting of the material used in the outer pipe may be used. Supports should permit the pipe to move freely with thermal expansion and contraction. The design requirements for buried lined piping systems are the same as those for the outer piping material. That is, a buried plastic lined carbon steel pipe should be treated the same way as a carbon steel pipe without a liner.

## 9-2. Plastic Lined Piping Systems

Thermoplastic lined piping systems are commonly used and widely available commercially under a variety of trade names. Table 9-6 presents a summary of some of the material properties for plastic liners, and Table 9-7 lists some of the liner thicknesses used for the protection of oil production equipment when applied as a liquid coating. Standard liner thicknesses are 3.3 to 8.6 mm (0.130 to 0.340 inches).

a. Common Plastic Liners

Most thermoplastics can be used as liner material. However, the more common and commercially available plastic liners include polyvinylidene chloride, perfluoroalkoxyl, polypropylene, polytetrafluoroethylene, and polyvinylidene fluoride.

**Table 9-2**
**ANSI Class 125 and Class 150 Systems**
**(Lightly Oiled Bolting)**

| Pipe Size, mm (in) | Number of Bolts | Bolt Diameter mm (in) | Bolt Torque, N-m (ft-lb) | | | |
|---|---|---|---|---|---|---|
| | | | PVDC | PP | PVDF | PTFE |
| 25 (1) | 4 | 14 (½) | 41 (30) | 37 (35) | 75 (55) | 34 (25) |
| 40 (1½) | 4 | 14 (½) | 54 (40) | 102 (75) | 81 (60) | 75 (55) |
| 50 (2) | 4 | 16 (5/8) | 61 (45) | 149 (110) | 169 (125) | 102 (75) |
| 65 (2½) | 4 | 16 (5/8) | 75 (55) | 169 (125) | N.A. | N.A. |
| 80 (3) | 4 | 16 (5/8) | 95 (70) | 169 (125) | 169 (125) | 149 (110) |
| 100 (4) | 8 | 16 (5/8) | 68 (50) | 190 (140) | 169 (125) | 129 (95) |
| 150 (6) | 8 | 20 (3/4) | 129 (95) | 305 (225) | 305 (225) | 169 (125) |
| 200 (8) | 8 | 20 (3/4) | 217 (160) | 305 (225) | 305 (225) | 258 (190) |
| 250 (10) | 12 | 24 (7/8) | N.A. | 468 (345) | N.A. | 271 (200) |

Notes: These torques are only valid for lightly oiled ASTM A 193 bolts and nuts. Lightly oiled is considered WD-40 (WD-40 is a registered trademark of WD-40 Company, San Diego, CA) or equivalent.
N.A. = Part is not available from source.

Source: Crane/Resistoflex, “Plastic Lined Piping Products Engineering Manual,” p. 54.

**TABLE 9-3**
**ANSI Class 300 Systems**
**(Lightly Oiled Bolting)**

| Pipe Size mm (in) | Number of Bolts | Bolt Diameter mm (in) | Bolt Torque, N-m (ft-lb) | | | |
|---|---|---|---|---|---|---|
| | | | PVDC | PP | PVDF | PTFE |
| 25 (1) | 4 | 16 (5/8) | 37 (35) | 61 (45) | 95 (70) | 41 (30) |
| 40 (1½) | 4 | 16 (5/8) | 81 (60) | 149 (110) | 230 (170) | 108 (80) |
| 50 (2) | 8 | 16 (5/8) | 34 (25) | 75 (55) | 115 (85) | 54 (40) |
| 80 (3) | 8 | 20 (3/4) | 54 (40) | 136 (100) | 210 (155) | 88 (65) |
| 100 (4) | 8 | 20 (3/4) | 81 (60) | 230 (170) | 305 (225) | 149 (110) |
| 150 (6) | 12 | 20 (3/4) | 88 (65) | 224 (165) | 305 (225) | 115 (85) |
| 200 (8) | 12 | 24 (7/8) | 169 (125) | 441 (325) | 495 (365) | 203 (150) |

Note: These torques are only valid for lightly oiled ASTM A 193, B7 bolts and ASTM A 194, 2H nuts. Lightly oiled is considered WD-40 (WD-40 is a registered trademark of WD-40 Company, San Diego, CA) or equivalent.

Source: Crane/Resistoflex, “Plastic Lined Piping Products Engineering Manual,” p. 54.

**Table 9-4**
**ANSI Class 125 and Class 150 Systems**
**(Teflon - Coated Bolting)**

| Pipe Size, mm (in) | Number of Bolts | Bolt Diameter mm (in) | Bolt Torque N-m (ft-lb) | | | |
|---|---|---|---|---|---|---|
| | | | PVDC | PP | PVDF | PTFE |
| 25 (1) | 4 | 14 (½) | 27 (20) | 34 (25) | 54 (40) | 20 (15) |
| 40 (1½) | 4 | 14 (½) | 41 (30) | 75 (55) | 61 (45) | 54 (40) |
| 50 (2) | 4 | 16 (5/8) | 41 (30) | 95 (70) | 122 (90) | 68 (50) |
| 65 (2½) | 4 | 16 (5/8) | 37 (35) | 122 (90) | N.A. | N.A. |
| 80 (3) | 4 | 16 (5/8) | 68 (50) | 122 (90) | 122 (90) | 95 (70) |
| 100 (4) | 8 | 16 (5/8) | 37 (35) | 122 (90) | 122 (90) | 81 (60) |
| 150 (6) | 8 | 20 (3/4) | 41 (30) | 102 (75) | 102 (75) | 68 (50) |
| 200 (8) | 8 | 20 (3/4) | 75 (55) | 102 (75) | 102 (75) | 102 (75) |
| 250 (10) | 12 | 24 (7/8) | N.A. | 339 (250) | N.A. | 203 (150) |
| 300 (12) | 12 | 24 (7/8) | N.A. | 339 (250) | N.A. | 271 (200) |

Notes: These torques are valid only for Teflon-coated ASTM A 193, B7 bolts and ASTM A 194, 2H nuts.
N.A. = Part is not available from source.

Source: Crane/Resistoflex, “Plastic Lined Piping Products Engineering Manual,” p. 55.

**TABLE 9-5**
**ANSI Class 300 Systems**
**(Teflon - Coated Bolting)**

| Pipe Size mm (in) | Number of Bolts | Bolt Diameter mm (in) | Bolt Torque N-m (ft-lb) | | | |
|---|---|---|---|---|---|---|
| | | | PVDC | PP | PVDF | PTFE |
| 25 (1) | 4 | 16 (5/8) | 41 (30) | 37 (35) | 61 (45) | 27 (20) |
| 40 (1½) | 4 | 20 (3/4) | 34 (25) | 61 (45) | 95 (70) | 41 (30) |
| 50 (2) | 8 | 16 (5/8) | 27 (20) | 61 (45) | 95 (70) | 41 (30) |
| 80 (3) | 8 | 20 (3/4) | 34 (25) | 61 (45) | 81 (60) | 34 (25) |
| 100 (4) | 8 | 20 (3/4) | 41 (30) | 95 (70) | 102 (75) | 61 (45) |
| 150 (6) | 12 | 20 (3/4) | 41 (30) | 95 (70) | 102 (75) | 37 (35) |
| 200 (8) | 12 | 24 (7/8) | 129 (95) | 312 (230) | 346 (255) | 163 (120) |

Notes: These torques are valid only for Teflon-coated ASTM A 193, B7 bolts and ASTM A 194, 2H nuts.

Source: Crane/Resistoflex, “Plastic Lined Piping Products Engineering Manual,” p. 55.

**Table 9-6**
**Plastic Liner Material Properties**

| Liner Material | Shell Material | Specific Gravity | Tensile Strength, MPa (psi) | Available Size Range, mm (in) | Maximum Temperature, EC (EF) |
|---|---|---|---|---|---|
| PVC | - - | 1.45 | 41.4 (6,000) | - - | 82 (180) |
| PVDC | carbon steel | 1.75 | 18.6 (2,700) | 25 to 200 (1 to 8) | 79 (175) |
| PE | carbon steel, aluminum | 0.94 | 8.27 (1,200) | 50 to 200 (2 to 8) | 66 (150) |
| PP | carbon steel | 0.91 | 31.0 (4,500) | 25 to 300 (1 to 12) | 107 (225) |
| PTFE | carbon steel, TP304L stainless steel | 2.17 | 17.2 (2,500) | 25 to 300 (1 to 12) | 232 (450) |
| FEP | carbon steel | 2.15 | 23.4 (3,400) | 25 to 750 (1 to 30) | 204 (400) |
| PFA | carbon steel | 2.15 | 24.8 (3,600) | 25 to 750 (1 to 30) | 260 (500) |
| ETFE | carbon steel | 1.7 | 44.8 (6,500) | as required* | 150 (300) |
| PVDF | carbon steel | 1.78 | 31.0 (4,500) | 25 to 200 (1 to 8) | 135 (275) |
| ECTFE | carbon steel, stainless steel | 1.68 | 48.3 (7,000) | 25 to 200 (1 to 8) | 150 (300) |

Note: *Typically liquid applied; availability based upon shell piping availability.
Source: Compiled by SAIC, 1998; note that confirmation is required from the specific vendor for a selected product.

**Table 9-7**
**Liquid-Applied Coating Thickness**

| Material | Total Dry Film Thickness Range |
|---|---|
| Fluoropolymers (ETFE, ECTFE) | 50 to 125 µm (2 to 5 mils) |
| PVDF | 500 to 1,500 µm (20 to 60 mils) |

Source: NACE, RP 0181-94, p. 3.

Polytetrafluoroethylene (PTFE) is a fully fluorinated polymer. Although PTFE is chemically inert to most materials, some chemicals will permeate through the liner. Therefore, venting of the joint area between the liner and outer casing is required[4]. PTFE materials are produced in accordance with ASTM D 1457 with material parameters specified by the designation of type (I through VIII) and class (specific to each type). The manufacture of PTFE lined pipe and materials are in accordance with ASTM F 423.

Polyvinylidene fluoride (PVDF) is similar to PTFE but is not fully fluorinated. PVDF liners can be produced with sufficient thickness to prevent permeation of gases (seeTable 9-8) so that liner venting is not required[5]. PVDF resins are produced in accordance with ASTM D 3222 with material parameters specified by the designation of either type 1 (class 1 or 2) or type 2. PVDF lined pipe and fittings are manufactured to conform to ASTM F 491.

Polyvinylidene chloride (PVDC) is a proprietary product of Dow Chemical (trade name Saran). PVDC is often used in applications where purity protection is critical. PFA resins are manufactured according to ASTM D 729, and lined piping and fittings are manufactured to conform to ASTM F 599.

Polypropylene (PP) lined pipe is typically inexpensive compared to other lined plastic piping systems. In addition, PP does not allow permeation; therefore, liner venting is not required[6]. Physical parameters (e.g., density, tensile strength, flexural modulus) of PP materials are specified by cell classification pursuant to ASTM D 4101. Additional material requirements may be added using the ASTM D 4000 suffixes; for example, W = weather resistant. The manufacture of PP lined pipe and materials are in accordance with ASTM F 492.

Perfluoroalkoxyl (PFA) is a fully fluorinated polymer that is not affected by chemicals commonly found in chemical processes. Depending upon process conditions PFA will absorb some liquids, however, including benzaldehyde, carbon tetrachloride, toluene, ferric chloride, hydrochloric acid, and other liquids. PFA lacks the physical strength of PTFE at higher temperatures and fails at 1/4 of the life of PTFE under flexibility tests[7]. PFA resins are manufactured according to ASTM D 3307, and lined piping and fittings are manufactured to conform to ASTM F 781.

**Table 9-8**
**Typical PVDF Liner Thickness**
**Required to Prevent Permeation**

| Nominal Pipe Size, mm (in) | Liner Thickness, mm (in) |
|---|---|
| 25 (1) | 3.81 (0.150) |
| 40 (1 ½) | 4.07 (0.160) |
| 50 (2) | 4.37 (0.172) |
| 80 (3) | 4.45 (0.175) |
| 100 (4) | 5.26 (0.207) |
| 150 (6) | 5.54 (0.218) |
| 200 (8) | 5.54 (0.218) |

Source: Reprinted from Schweitzer, Corrosion-Resistant Piping Systems, p. 182, by courtesy of Marcel Dekker, Inc.

b. Plastic Lined Piping Construction

As discussed in Paragraph 9-1d, plastic lined pipe piping is joined using flanges or mechanical couplings and fittings that are normally flanged. Some manufacturers can provide pre-bent pipe sections to avoid the use of flanged elbows. Use of pre-bent pipe sections requires

4 Schweitzer, Corrosion-Resistant Piping Systems, pp. 161-162.
5 Ibid., p. 165.
6 Ibid., p. 166.
7 Ibid., p. 164.

that the design take into account the manufacturer's standard bend radius which is often larger than the bend radius for conventional elbows.

**9-3. Other Lined Piping Systems**

The elastomer and rubber materials most commonly used as liner materials include natural rubber, neoprene, butyl, chlorobutyl, nitrile, and EPDM, which tend to be less expensive than other liners. Design criteria that need to be considered before selecting elastomeric and rubber lined piping systems include: corrosion resistance, abrasion resistance, maximum operating temperature, and potential contamination of conveyed material.

Elastomeric and rubber linings vary in thickness from 3.2 to 6.4 mm (1/8 to 1/4 in). Lined pipe is available from 40 to 250 mm (1½ to 10 in), standard, at ratings of 1.03 MPa (150 psi) or 2.06 MPa (300 psi). Joining is typically accomplished through the use of flanges.

Glass-lined piping systems are commercially available with carbon steel outer piping in sizes of 25 to 300 mm (1 to 12 in), standard. Joining is accomplished using class 150 split flanges, although class 300 split flanges are also available as options. A PTFE envelope gasket is recommended[8]. Stress is to be avoided; expansion joints should be used to isolate vibration and other stresses from the piping system. Sudden changes in process temperatures should also be avoided.

Nickel-lined piping systems are available in sizes from 40 to 600 mm (1½ to 24 in) with liner thickness of 0.0008 to 0.015 inches. Joining is accomplished either by welding or flanging, with welding the preferred method[9].

[8] Schweitzer, Corrosion-Resistant Piping Systems, p. 198.
[9] Ibid., p. 199.

# Chapter 12
# Corrosion Protection

## 12-1. Corrosion Protection

Among other factors, the integrity and life of a piping system is dependent upon corrosion control. As discussed in previous chapters of this manual, internal corrosion of piping systems is controlled by the selection of appropriate materials of construction, wall thickness, linings and by the addition of treatment chemicals. External corrosion can also be addressed through materials of construction. However, other methods may be required when metallic piping systems are applied.

a. Buried Installations

In buried installations, leaks due to corrosion in metallic piping systems can cause environmental damage. Furthermore, certain types of processes pose safety problems if cathodic protection is not properly installed and maintained. The design and installation of the piping system without consideration of cathodic protection is not acceptable.

b. Above Grade Installations

The external surfaces of metallic piping installed above grade will also exhibit electrochemical corrosion. The corrosion rate in air is controlled by the development of surface-insoluble films. This development is, in turn, affected by the presence of moisture, particulates, sulfur compounds, nitrogen-based compounds, and salt. This corrosion is typically uniform, although pitting and crevice corrosion are also common. Besides selecting a material of construction that is appropriate for the ambient environment, the primary method of corrosion control in above grade piping system is the application of protective coatings. However, a stray current survey must be performed to ensure that electrical currents have not been created through the piping support system.

## 12-2 Cathodic Protection

Cathodic protection and protective coatings shall both be provided for the following buried/submerged ferrous metallic structures, regardless of soil or water resistivity:

- natural gas propane piping;
- liquid fuel piping;
- oxygen piping;
- underground storage tanks;
- fire protection piping;
- ductile iron pressurized piping under floor (slab on grade) in soil;
- underground heat distribution and chilled water piping in ferrous metallic conduit in soils with resistivity of 30,000 ohm-cm or less; and
- other structures with hazardous products as identified by the user of the facility.

a. Cathodic Protection Requirements

The results of an economic analysis and the recommendation by a "corrosion expert" shall govern the application of cathodic protection and protective coatings for buried piping systems, regardless of soil resistivity. In addition, cathodic protection for metallic piping supported above ground may be warranted. TM 5-811-7, Electrical Design, Cathodic Protection, provides criteria for the design of cathodic protection for aboveground, buried, and submerged metallic structures including piping. Cathodic protection is mandatory for underground gas distribution lines, 946 $m^3$ (250,000 gal) or greater water storage tanks and underground piping systems located within 3 m (10 ft) of steel reinforced concrete.[1]

For ductile iron piping systems, the results of an analysis by a "corrosion expert," as defined in Paragraph 12-2b, shall govern the application of cathodic protection and/or bonded and unbonded coatings. Unbonded coatings are defined in AWWA C105.

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[1] TM 5-811-7, p. 2-2.

b. Cathodic Protection Designer

All pre-design surveys, cathodic protection designs, and acceptance surveys must be performed by a "corrosion expert." A corrosion expert is defined as a person who, by reason of thorough knowledge of the physical sciences and the principles of engineering and mathematics acquired by a professional education and related practical experience, is qualified to engage in the practice of corrosion control of buried or submerged metallic piping and tank systems. Such a person must be accredited or certified by the National Association of Corrosion Engineers (NACE) as a NACE Accredited Corrosion Specialist, or a NACE Certified Cathodic Protection Specialist licensing that includes education and experience in corrosion control of buried or submerged metallic piping and tank systems. The "corrosion expert" designing the system must have a minimum of five years experience in the design of cathodic protection systems, and the design experience must be type specific. For instance, a cathodic protection engineer who only has experience designing water tank systems should not design the cathodic protection system for an underground gas line.

The design of the cathodic protection system shall be completed prior to construction contract advertisement except for design-construct projects and pre-approved underground distribution systems. The liquid process piping specification section shall be coordinated with CEGS 13110, Cathodic Protection System (Sacrificial Anode); CEGS 13111, Cathodic Protection System (Steel Water Tanks); and CEGS 13112, Cathodic Protection System (Impressed Current) as required.

c. Cathodic Protection Methods

As previously discussed, galvanic corrosion is an electrochemical process in which a current leaves the pipe at the anode site, passes through an electrolyte, and re-enters the pipe at the cathode site. Cathodic protection reduces corrosion by minimizing the difference in potential between the anode and cathode. The two main types of cathodic protection systems, galvanic (or sacrificial) and impressed current, are depicted in Figure 12-1. A galvanic system makes use of the different corrosive potentials that are exhibited by different materials, whereas an external current is applied in an impressed current system. The difference between the two methods is that the galvanic system relies on the difference in potential between the anode and the pipe, and the impressed current system uses an external power source to drive the electrical cell.

d. Cathodic Protection Design

The design of a cathodic protection system must conform to the guidance contained in TM 5-811-7 (Army), and MIL-HDBK-1004/10 (Air Force). Field surveys and other information gathering procedures are available in TM 5-811-7. The following steps and information is required to ensure a cathodic protection system will perform as designed:

Step 1. Collect data:
- corrosion history of similar piping in the area;
- drawings;
- tests to include current requirement, potential survey, and soil resistivity survey;
- life of structures to be protected;
- coatings; and
- short circuits.

Step 2. Calculate the surface area to be protected and determine the current requirement.

Step 3. Select the anode type and calculate the number of anodes required.

Step 4. Calculate circuit resistance, required voltage, and current.

Step 5. Prepare life cycle cost analyses.

Step 6. Prepare plans and specifications.

## 12-3. Isolation Joints

When piping components, such as pipe segments, fittings, valves or other equipment, of dissimilar materials are connected, an electrical insulator must be used between the components to eliminate electrical current flow. Complete prevention of metal-to-metal contact must be achieved. Specification is made for dielectric unions between threaded dissimilar metallic components; isolation flanged joints between non-threaded dissimilar metallic components; flexible (sleeve-type) couplings for

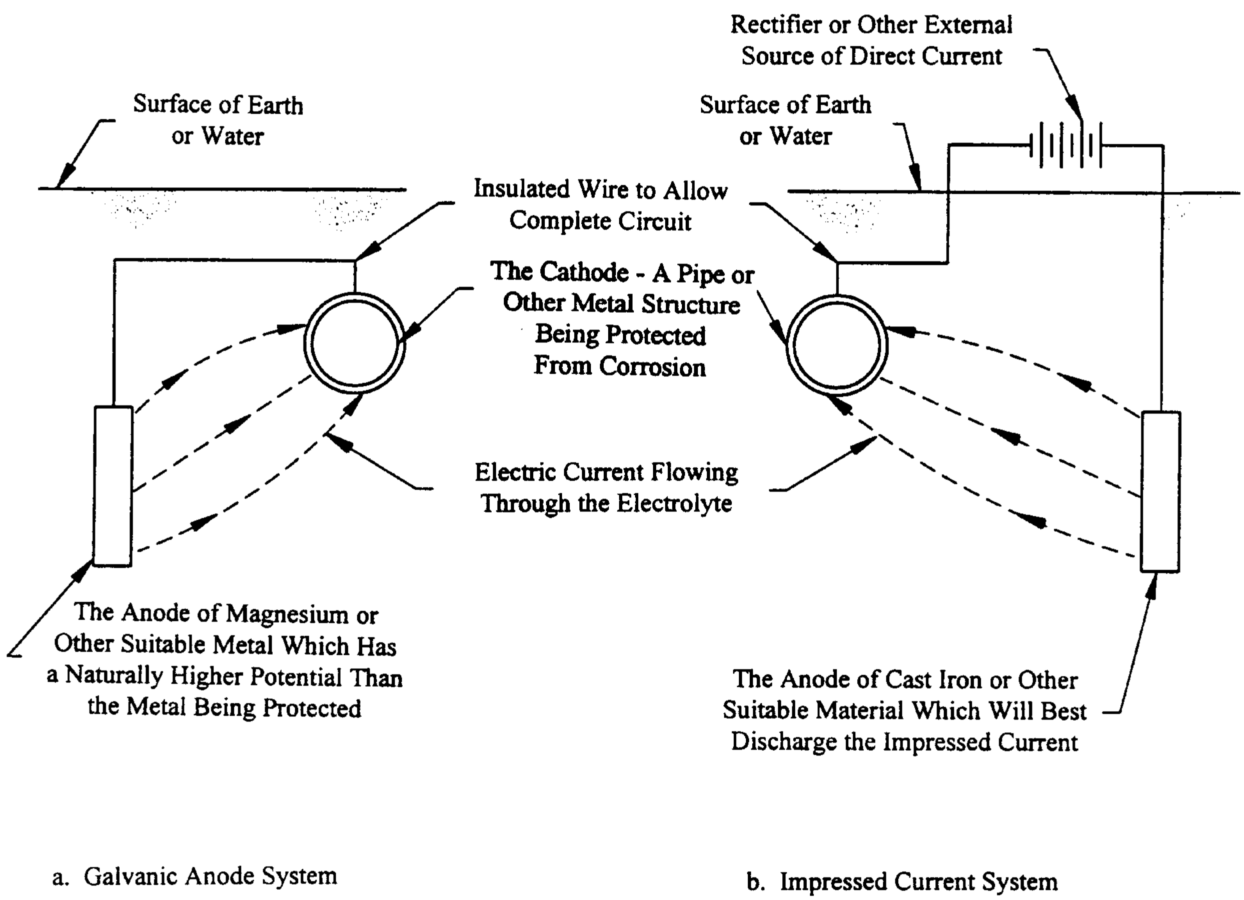


Figure 12-1. Cathodic Protection Methods
(Source: U.S. Air Force)

plain end pipe sections, see Chapter 11 for further information concerning these couplings; and under special aboveground situations that have USACE approval split-sleeve couplings. For the flanged isolation joints complete isolation is required; additional non-metallic bolt isolation washers, and full length bolt isolation sleeves are required. Dielectric isolation shall conform to NACE RP-0286. Copper water service lines will be dielectrically isolated from ferrous pipe.

a. Installation

Proper installation of isolation joints is critical. Installation procedures should follow the manufacturer's recommendations exactly.

b. Isolation from Concrete

A ferrous metallic pipe passing through concrete shall not be in contact with the concrete. The ferrous metal pipe shall be separated by a non-metallic sleeve with waterproof dielectric insulation between the pipe and the sleeve. Ferrous metal piping passing through a concrete thrust block or concrete anchor block shall be insulated from the concrete or cathodically protected.

c. Surge Protection

The need for surge and fault current protection at isolating devices (dielectrically insulated flanges) should be considered. If an insulated flange is installed in an area classified by National Fire Protection Association (NFPA) criteria, such as a flammable liquid pipe joint inside the classified area, a sealed, weatherproof surge arrester must be installed across each isolating device. The arrester should be the gapless, self-healing, solid state type, such as metal oxide varistor. Cable connections from arresters to isolating devices should be short, direct, and a size suitable for short-term, high current loading.

## 12-4. Protective Coatings

Since corrosion of metallic piping is electrochemical, if a protective coating that is continuous, impervious and insulating is applied to the piping exterior, the electrical circuit cannot be completed, and corrosion will not occur. The bases of selection for an exterior pipe coating are chemical inertness, adhesiveness, electrical resistance, imperviousness, and flexibility to adjust to both pipe deformation (for example, thermal expansion/contraction) and environmentally induced stress (for example, wind induced shear). Obviously, the coating must be applied without holidays and remain undamaged, without cracks or pinholes.