WATER AGENCIES' STANDARDS

Design Guidelines for Water, and Sewer Facilities

SECTION 11.2
CORROSION CONTROL DESIGN

11.2.1 PURPOSE

This section provides guidelines for in-house staff and design consultants in design of corrosion mitigating systems related to water and sewer facilities.

11.2.2 GENERAL

It is the responsibility of the user of these documents to make reference to and/or utilize industry standards not otherwise directly referenced within this document. The Engineer of Work may not deviate from the criteria presented in this section without prior written approval of the Agency's Engineer.

11.2.3 INTRODUCTION

Many facilities, underground or submerged, contain metallic structures and components which, when placed in contact with soil and/or water without protection against corrosion, tend to deteriorate and fail prematurely. This chapter addresses the application of corrosion control methods, such as coatings and linings and the selection of materials, needed to afford protection from corrosion to such facilities.

11.2.4 PROTECTIVE COATINGS AND LININGS

The term "coatings" refers to materials applied to pipe exterior for corrosion protection. "Linings" describes materials applied to pipe or tank interiors for corrosion protection.

Pipeline and tank coatings and linings must have certain common characteristics to ensure long-term corrosion protection. Characteristics considered during the selection of protective coating and lining systems include the ability to apply with minimal defects, adhesion to the pipe surface, ability to resist development of holidays as the coatings or lining ages, ability to withstand normal handling and storage, reparability, cost, and availability.

Dielectric (electrically insulating) coatings must provide and maintain effective electrical insulation and resist cathodic disbondment. Conductive coatings and linings, such as cement mortar, must be capable of resisting significant cracking and maintaining an alkaline environment to passivate underlying metal surfaces for a suitably long period of time.

A. Linings: Linings refer to coating materials used on the interior surface of carbon steel and concrete structures. Linings are used to prevent internal corrosion and maintain a smooth surface to maximize flow capacity. The linings must not impart any taste or odor to the water and should be approved by the National Sanitation Foundation (NSF) for potable water contact.

   The Design Engineer should consider reference materials from NACE, AWWA, and manufacturers' trade associations for pipe lining and other methods of corrosion prevention for pipeline interiors.

1. Cement Mortar: Cement mortar is the most commonly used lining for water mains made of ductile iron and steel larger than three inches (3”) in diameter. Experience has shown that cement mortar is durable lining capable of providing many years of service with minimal maintenance under most conditions. With a few precautions, cement mortar linings can be expected to be very reliable. Cement mortar protects the underlying metal surface by passivating it through contact with the alkaline cement paste. Under most conditions, the protection lasts as long as the lining is intact. Oil/Water Tests: Tests are made to characterize the corrosivity of electrolytes (existing soils and water) in which the structures are to be located. The required testing is described in the following paragraphs.

   a. General Considerations: Corrosion protection is provided to metal pipe surfaces by cement mortar for as long as the cement paste is intact. Cement paste can be leached out of the lining by prolonged contact with soft water. The leaching characteristics of water can be predicted by reviewing an accurate analysis of the water to be conveyed. Waters that promote leaching of cement paste are low in calcium and alkalinity, and may be low in pH. Waters of this type are generally found in coastal areas with surface water supplies, but rarely in inland areas.

      Cement mortar linings are rigid and crack if the pipe has excessive deflection (out-of-roundness). Although small cracks are self-healing, large cracks may expose the metal surface to the water, with resulting corrosion. Therefore, sturdy bracing or stulling is required to maintain the round shape of pipes lined with cement mortar before shipping and installation. The stulling is removed before the pipe is placed in service.

      Cement mortar linings may incur cracking under alternating wet and dry conditions. This is due to shrinkage of the lining as it dries. The best service life of cement mortar linings is obtained if the lining is kept in contact with water so that it remains fully hydrated.

      Sulfate-resistant cements are generally used where sulfates/chlorides exceed approximately 300 mg/L. ASTM C150 Type II or Type V are sulfate-resistant Portland cements. When sulfate concentration exceeds 1,000 ppm, Type V cement is required.

      Cement mortar linings are also susceptible to damage if the pipe is subjected to negative pressure or vacuum, even for brief periods. Therefore, surge protection is important and adequate vacuum relief valves must be provided for cement mortar-lined pipelines.

      A final important consideration for cement mortar-lined pipes is that all joints should be lined with cement mortar to match the body of the pipe. This is important to provide corrosion protection at the joints. Joint lining is normally done for all pipe types with the exception of ductile iron pipe.

   b. AWWA Specifications: Cement mortar linings are covered by AWWA standards for various types of pipe commonly used to convey water. The AWWA standards govern the thickness, mix design, and installation of the lining. In some cases, joint lining requirements are not included in the standard but are appended or may be obtained from pipe manufacturers.

c. Thickness for Alternative Pipe Materials: The thickness of cement mortar linings varies according to the type of pipe in which the lining is placed. All linings have manufacturing tolerances that allow slightly thinner linings. In concrete pressure pipe types, the cement mortar lining is considered part of the structural wall of the pipe and is included in calculations of pipe strength.

d. Welded Steel Pipe: Cement mortar linings for welded steel pipe are specified in AWWA C205.

Joint lining requirements are given in Appendix A of AWWA C205. Appendix A is not part of the standard, so the Design Consultant must specify joining lining requirements or paraphrase or reference Appendix A to ensure that the joint linings are covered by the specification.

Cement mortar linings are not NSF-Approved for potable water contact. However, some fast-setting rout materials used for patching joining and other defects are not NSF-approved and contain compounds that may impart taste and odor in transmission lines with low flow rates. Non-NSF approved compounds are not to be allowed.

Cement mortar linings can be applied to the pipe interior during pipe manufacture or during construction of the pipeline in the field. Plant-applied linings are applied by a centrifugal process to a thickness of three-quarter inch (¾”). Field joints are lined with cement mortar grout and trowled smooth with the plant-applied lining.

e. Ductile Iron Pipe: Cement mortar linings for ductile iron pipe are specified in AWWA C104. Minimum lining thickness for pipe and fittings must be double the AWWA requirements.

A seal coat of asphaltic material, which is commonly applied to cement mortar linings in ductile iron pipe is not required.

2. Epoxy Linings: Epoxy linings are used less commonly than cement mortar linings for water pipe. Epoxy linings are thin films compared to cement mortar. A typical epoxy lining is approximately 16 mils thick (1 mil equals 0.0001 inch).

Many paint manufacturers produce conventional epoxy coatings that are NSF-approved for potable water contact. Epoxy linings may be used in the following special situation.

- For pipes located in buildings or structures in instances where the pipe is disassembled periodically.
- For pipes with complicated shapes, such as discharge needed for pumps.
- For pipes where velocities are too high for cement mortar linings.
- For fabricated steel fittings such as flexible couplings.

B. Coatings: Coatings refer to materials applied to the exterior of pipes and components. The term “paint” is frequently used as a synonym, but is less accurate because it sometimes refers to materials applied for appearance, whereas coatings are applied primarily for surface corrosion protection.

1. Welded Steel Pipe Coatings: All modern applications of steel water pipelines use protective coatings for buried service. Several types of coatings are commonly used.

a. Cement Mortar: Cement mortar coatings and linings have a long service history for corrosion protection of steel and iron water pipelines. Cement mortar coatings are covered by AWWA C205. As with linings, joint coatings are not included in the body of AWWA C205 and must be properly specified.

Cement mortar coatings are applied to steel pipe by a pneumatic process during manufacture. Exterior coatings are a minimum of one and one-quarter inch (1¼") thick and are reinforced with spiral wire, wire mesh, or wire fabric. Field joints are coated with cement mortar grout. A circumferential bands or "diapers" is normally placed around the joint to retain the grout. Proper mortar coating of field joints is critical to long-term durability of this coating. Experience has shown that field joints tend to be the weakest points in cement mortar-coated pipelines.

The corrosion protection qualities of cement mortar coatings can be adversely affected by alternating wet and dry conditions. Salts from soil and groundwater can be wicked into the mortar coating and can concentrate under repeated drying cycles. The protective qualities of cement mortar can also be compromised if the pipe is struck by hard blows that cause disbondment between the mortar and the metal of the pipe.

Unlike the other exterior coatings discussed in this section, cement mortar is not a dielectric coating. Pipelines installed with cement mortar coatings require higher current densities for cathodic protection than pipelines with dielectric coatings in good condition. Since the coating is conductive, the effect of electromagnetic coupling (induced voltages) is less on cement mortar-coated pipelines. However, cement mortar-coated pipelines are still susceptible to elevated potentials under powerline fault conditions.

b. Tape and Cement Coatings: Prefabricated cold-applied polyolefin type and cement mortar coated pipelines can be used where protective qualities of cement mortar only might be compromised from mechanical damage or if cathodic protection is proposed.

Tape coating for pipelines and fittings should be in accordance with AWWA C214 for steel water pipelines, and AWWA C209 for fittings, exterior cement mortar (rockshield) are minimum three-quarter inch (¾") thickness and are reinforced with spiral wire, wire mesh, or wire fabric.

c. Epoxy Coatings: Liquid epoxy coatings include polyamide or polyamine-cured epoxy coating systems. These coating systems are commonly used to protect exterior surfaces of appurtenances such as valves, couplings, and blind flanges.

Coal tar epoxy and "conventional" epoxy (no coal tar fillers) are also available. Coal tar epoxy can be applied over a primer or directly to sandblasted steel. These coatings are applied in one or two coats to a dry film thickness of 16 to 18 mils.

To provide a suitable service life, liquid epoxy coatings must be applied to steel with a near-white metal sandblast (SSPC SP-10) surface preparation. White metal sandblasting (SSPC SP-5) should be used for submerged metal surfaces. Liquid epoxy coatings require a minimum cure time that depends on atmospheric conditions with good ventilation before the coated surface can be backfilled or submerged.

2. Ductile Iron Pipe:

a. Epoxy Coatings: Liquid epoxy coatings, the same as used for welded steel pipe coatings, can be used for ductile iron pipefittings. However, special attention should be used during application because of the surface roughness of ductile iron pipe and fittings. Epoxy coatings will have a tendency to pinhole unless the first coat is thinned or applied using a mist coat/full coat application.

b. Polyurethane Coatings: Ductile iron pipe and fittings are also coated with a high solids polyurethane coating using a two component, 1:1 mix ration, heated airless spray unit. These coatings are generally applied in a shop, but they can be applied in the field using special equipment. Shop-applied coatings require 100% holiday inspection with normal field inspection before and after installation.

C. Welded Steel Tanks and Reservoirs

Exterior coating, interior lining, and where necessary, complete removal and recoating surfaces of steel water tanks, surge tanks and reservoirs must be done in accordance with AWWA D102.

In general, for new steel tanks, AWWA D102, outside coating System No. 5 (three coat epoxy/polyurethane), and inside coating System No. 2 (three coat polyurethane) should be used. Lining material should be approved by the National Sanitation Foundation (NSF) for potable water contact.

Lining coating material selection must be coordinated with information for cathodic protection.

11.2.5 MATERIALS SELECTION

A. General Exposures: The following is a brief discussion of the main exposures to materials anticipated at water facilities.

1. Soil Exposures: Some soil environments and groundwaters can be corrosive to buried metal structures. Resistivity measurements, which can be made in the field or the laboratory, indicate how corrosion currents flow through soils or groundwaters. High concentrations of chlorides and sulfates contribute to a reduction in resistivity and an increase in the corrosion activity of a material. In the presence of oxygen, chloride ions can be extremely corrosive to steel. Similarly, high levels of sulfates can reduce soil or groundwater resistivity and corrode steel and concrete.

2. Surfaces Exposed to Fluids: Surfaces exposed to fluids include the interiors of pipelines and equipment such as pumps. Metals in contact with water streams are subject to corrosion, particularly when exposed in splash zones.

3. Atmospheric Exposures: Much of San Diego is exposed to a marine environment. This environment includes airborne salts and locations in which structures may be exposed to direct salt spray. Atmospheric exposure may, therefore be severe in projects in the San Diego Area. The combination of wet/dry cycling in the presence of chlorides found in salt spray can create the potential for significant corrosion activity on all exposed metal surfaces.

B. Material Considerations: The following paragraphs describe the performance to be expected from various materials used for water facilities in the Greater San Diego area. Table 11.2-1 gives supplemental information on acceptable materials.

1. Concrete: Soil exposure, concrete is typically a durable material in underground service. It is rarely affected by electrolytic corrosion like metals, and unless the pH of the soil, groundwater or process stream is less than 5.5, the chloride concentration is 300 ppm or more, or the sulfate concentration is greater than 1,000 ppm, concrete is suitable for use in soil exposures. Soils and groundwater found in the San Diego area may contain significant concentrations of chlorides and sulfates which are detrimental to concrete and reinforcing steel. Attack on concrete and steel is likely when soils are acidic. When the pH of the soil is at or below 5.5, barrier coatings are required to protect the concrete surface. In areas of high sulfate concentrations (greater than 1,000 ppm) modification of water-cement ratio, use of Type V cements (sulfate resistant) and barrier coatings must be considered for all buried concrete.

   Reinforced concrete structures are also subject to cracking and spalling due to corrosion of reinforcing steel. Because the volume of corrosion products is much greater than that of the reinforcing steel itself, great pressure is exerted on the concrete, causing it to crack and eventually spall. It is therefore recommended that exposure of concrete surfaces to chlorides be minimized through the use of coatings.

2. Steel: For all exposures, steel should be electrically isolated from dissimilar metals to prevent the formation of unfavorable galvanic corrosion cells. In areas where abrasive materials are likely to damage coatings, cathodic protection by impressed current or galvanic anodes may be desirable.

   a. Soil Exposure: Low resistivities and high chloride concentrations in the soil may lead to corrosion of buried steel pipelines or structures. Cathodic protection should be considered for all buried steel pipelines or structures. Where cathodic protection is not provided, corrosion monitoring equipment should be incorporated into the design to allow the operating staff to monitor the condition of the pipelines or structures. Nonwelded joints are bonded for electrical continuity. Coatings should also be considered. Coatings may be used alone or in conjunction with cathodic protection. Recommendations for coating systems are discussed later in these Guidelines.

      Steel structures should be well coated and cathodically protected where the potential for corrosion is high based on resistively and soil chemical analyses. This is expected to be common due to the corrosive nature of the soil environment in the San Diego area.

   b. Fluid Exposure: Bare or galvanized steel is subject to corrosion when exposed to fluids at a water facility. Corrosion is most severe in the splash zone where atmospheric oxygen hastens the corrosion process. Steel, if submerged, should be coated or lined with a material suitable for use in the anticipated exposure. Because of concerns regarding the corrosion of steel in contact with the process streams, cathodic protection must be provided for these steel structures considered to be in a corrosive exposure. This type of corrosion control should be incorporated along with suitable coatings or linings.

   c. Atmospheric Exposure: Corrosion of steel structures at water facilities is likely due to exposure to atmospheric chlorides near marine environments or chlorine process streams.

3. Ductile Iron:

   a. Soil Exposure: Ductile iron pipe can be expected to provide performance similar to steel in most exposures. However, because ductile iron generally has a greater wall thickness for a given diameter pipe than does steel, the time to reach failure may be increased. Ductile iron pipe is treated in a manner similar to steel.

      Fluid and Atmospheric Exposure: When exposed to fluids or under atmospheric conditions, ductile iron can be expected to corrode at a rate similar to that for bare or galvanized steel. Ductile iron is treated in a manner similar to steel.

4. Copper and Brass:

   a. Soil Exposure: Copper and brass typically perform quite well in underground applications where the pH is neutral to alkaline and the concentration of aggressive ions, such as chloride and sulfate, is low. They are often used for potable water lines and fittings. Copper is a corrosion-resistant material, which does not depend on the formation of an oxide or other surface film to be protected from corrosion. Because it is cathodic to iron and aluminum, it hastens their corrosion when coupled to them. Isolation of copper from most materials commonly used in wastewater plant construction is therefore required in buried service. Because copper is an excellent electrical conductor and maintains a low resistivity interface with the soil, bare copper cable is often used for grounding systems. Unfortunately, this can lead to galvanic corrosion of steel and iron, and to very high current requirements for cathodic protection systems.

      Various solutions have been proposed, such as grounding cells, which are essentially dielectric until large potential differences (ground faults) occur. When ground faults do occur, the cell short circuits and dissipates the charge. Copper is subject to changes in corrosion resistance with changes in temperature, so electrolytic corrosion can occur on hot and cold water lines buried in a common trench. To prevent this, the two lines should be isolated from each other at points of electrical contact. This can be accomplished with the use of insulating couplings. However, where high concentrations of chlorides (300 ppm or more) or high sulfate concentrations (1,000 ppm or more) or low pH values are found (5l5 or less), cooper or brass piping should not be used without a tape wrap coating and cathodic protection. Furthermore, when copper or brass is used in an aggressive environment, it should be electrically isolated from other structures. If copper piping is used to connect copper service lines to plastic mains, brass-tapping saddles should be used.

   b. Fluid Exposure: Copper and brass typically have good corrosion resistance in aqueous solutions. Further, if copper is coupled to a less noble metal like steel or aluminum, galvanic corrosion of the less noble metal may result. Because copper is a fairly soft material, it is also subject to erosion corrosion. This type of corrosion is accelerated by high fluid velocities, high temperatures and abrasive particulate matter.

Copper and brass should not be used in streams, which allow exposure of the metal to solutions carrying residual chlorine (2 ppm or more). This is especially critical in reclaimed water system, as chlorine (2 ppm or more) can cause sever corrosion of copper and brass.

Brasses containing over 15% zinc may suffer dezincification. This form of corrosion is especially prevalent in stagnant, acidic solutions. Copper and brass are therefore not recommended for fluid exposures.

c. Atmospheric Exposure: Copper and brass typically have excellent atmospheric corrosion resistance.

5. Stainless Steel:

a. Soil Exposure: In soil, stainless steel is fairly resistant to uniform corrosion, which occurs over the entire surface. However, it may be subject to pitting corrosion. Stainless steel pip is most often used in situations where contamination of the material carried in the pipe is the prime concern. However, because pitting of the buried structures might occur where soil conditions surrounding the pipe vary, it is prudent to install stainless steel pipe with a uniform, well-installed backfill where differential oxygen corrosion cells will not occur. Coatings and cathodic protection of buried pipelines in corrosive soils should be provided. In noncorrosive soils, coatings for stainless steels should be considered.

b. Fluid Exposure: Stainless steels are typically resistant to corrosion in flowing waters. Of the various types of stainless steels, the austenitic grades (300 series) show the best performance. In stagnant waters, however, pitting of stainless steel may occur. Oxidizing metal salts such as ferric chloride may also attack stainless steel. Type 304 and 316 alloys are more resistant to chlorine, hypochlorous acid (HOCI) and hypochlorite ions than other alloys that might be used in the process streams.

Cathodic protection of stainless steel is an option for preventing pitting which might otherwise occur. Although stainless steels are essentially immune to uniform corrosion, pitting has been encountered in many aqueous environments and can be prevented by the use of cathodic protection. By electrically coupling stainless steel to a large immersed structure made of steel, zinc, or other metal, which is more anodic to stainless steel, pitting is reduced or eliminated. However, where galvanic couples exist, stainless steel increases the magnitude of corrosion deterioration of the structure to which it is bonded. It is therefore recommended that electrical contact be eliminated where the anode/cathode ratio is not favorable, i.e., small anode to large cathode.

c. Atmospheric Exposure: Stainless steel has been used with much success in both outdoor and indoor applications. Of the various types of stainless steel, the austenitic grades (typically 302, 304, and 316) generally have the best corrosion resistance. Of these three alloys, 316, although more expensive than the others, is the most resistant to pitting.

The austenitic alloys are resistant to chlorides and moisture likely to be found in water facilities. There are also advantages to using stainless steel in combination with other metals. This is true where the more anodic material has a much larger surface area than the cathodic material. For example, galvanic corrosion has not been a problem where stainless steel fasteners are used to hold down aluminum deck plates. This is because the amount of stainless steel (cathodic material) used to hold down the aluminum (anodic material) is quite small in comparison with surface area ratios. Overall, stainless steel has been demonstrated to provide excellent corrosion resistance in severe atmospheric environments.

6. Polyvinyl Chloride (PVC):

   a. Soil Exposure: PVC is often used in soil exposures. Being a polymeric material, its resistance to corrosion in water and soil is excellent. PVC is widely used for electrical conduits and water pipelines. When buried, mechanical damage is unlikely. Even when buried, further protection can be provided by encasement in colored concrete and/or the use of warning tape. Where it is important that the pipe be located easily, metallized tape or a tracer wire can be routed in the same trench as the PVC pipe to enable detection.

   b. Fluid and Atmospheric Exposures: In wastewater plant applications, PVC has had excellent success. It is unaffected by the levels of moisture and atmospheric chlorides. However, its resistance to many organics is limited (particularly ketones, esters, and aldehydes) so it should not be used to carry these materials. Care should be taken in the use of PVC in contact with chlorine. PVC is suitable for the transport of dilute chlorine solutions; however, its use is not recommended for transporting liquid or gaseous or dry chlorine above 73ºF and it is only marginal for dry chlorine at less than 73ºF. Similarly, PVC should not be used in applications where temperatures can exceed roughly 140ºF. The manufacturer should be consulted prior to using PVC products in chemical exposures or high temperature applications.

7. Other Polymeric Materials (All Exposures)

   Most other polymers are resistant to the chemicals normally encountered in water facilities. However, this does not apply to concentrated chlorine (dry or wet gas), which is extremely corrosive. Polyolefins (polyethylene, polypropylene) have very good resistance to corrosion. Chemically, they are essentially inert, and, with the exception of chlorine, should be resistant to the chemicals likely to be encountered. Polypropylene is suitable for temperatures up to 180ºF and polyethylene is suitable up to 140ºF.

   Most plastics are suitable for burial. Polyolefin are waterproof and may also be buried. Polyethylene is often used for natural gas service due, in part, to its corrosion resistance, toughness and resistance to cutting.

Table 11.2-1
General Guidelines for Material Selection

Item	Acceptable Materials of Construction
Buried Pipe	
• Transmission Pipe	DIP (1) (2) SCRW (1) (8) and CMLTCMC steel (1) (8), CMLC steel (3) and PVC
• Transmission Pipe Fittings	Steel (1) (4) (5) and ductile iron (1) (2)
• Distribution Pipe	Ductile iron (2) and PVC
• Distribution Pipe Fittings	Ductile iron (2)
• Service Pipe	PVC and copper type K
• Bolts and Fasteners	Stainless steel (6) (7), and galvanized steel (7)
Exposed Pipe	DIP (9), steel (9), PVC (10)
Water Pipe Valves	
• Body	Cast-iron(7), ductile iron (7), and cast steel (7)
• Stem and Trim	Bronze and stainless steel (6)
• Control Tubing	Stainless steel (6)
Pumps	
• Body	Cast-iron and ductile iron
• Impeller	Bronze
• Shaft	Stainless steel (6)
Water Reservoirs	Reinforced concrete or steel
Drains, Sanitary	PVC
Culverts and Storm Drains	Reinforced concrete pipe
Structural Concrete	Type V cement, minimum 2-inch cover over reinforcement
Structural Metal	Galvanized steel
Ladders	
• Dry	Aluminum, Galvanized steel and fiberglass
• Submerged	Stainless steel and fiberglass
Hydraulic Gates	Cast-iron
Handrail	Aluminum, galvanized steel
Electrical Enclosures	Galvanized steel, stainless steel and fiber-reinforced plastic
Electrical Conduit (low voltage)	
• Buried	Concrete encased PVC
• Exposed	Galvanized steel or PVC coated galvanized steel in corrosive areas

Notes:

1. Provide cathodic protection in immersion services and where soil conditions are corrosive.
2. Cement mortar lined with liquid epoxy or polyurethane coating. Requires cement mortar lining and detailed quality control to ensure coating damage is repaired prior to backfilling pipe and to ensure proper backfilling procedures.
3. Not used in aggressive soils.
4. Cement mortar lined and coated.
5. Cement mortar lined, tape wrapped, mortar coated for corrosive soils.
6. Use type 316 stainless steel.
7. Polyamide-cured epoxy coated and wrapped in petrolatum/wax tape for buried service.
8. At structures adjacent to cathodically protected transmission pipe, pipe shall also have a liquid epoxy coating.
9. Cement lined, allphatic acryli8c polyurethane coated.
10. Acrylic latex coated.

Abbreviations:

ABS	Acrylonitrile-Butadiene Styrene
CMLC	Cement Mortar Lined and Coated
CMLTCMC	Cement Mortar Lined, Tape and Cement Mortar Coated
DIP	Ductile Iron Pipe
PVC	Polyvinyl Chloride
SCRW	Steel Cylinder Rod Wrapped
VC	Vitrified Clay

11.2.6 REFERENCE

A. Should the reader have any suggestions or questions concerning the material in this section, contact one of the member agencies listed.

B. The publications listed below form a part of this section to the extent referenced and are referred to in the text by the basic designation only. Reference shall be made to the latest edition of said publications unless otherwise called for. The following list of publications, as directly referenced within the body of this document, has been provided for the users convenience. It is the responsibility of the user of these documents to make reference to and/or utilize industry standards not otherwise directly referenced within this document.

1. Water Agencies' Standards (WAS):

   a. Design Guidelines:

      1. Section 11.1, Corrosion Control

   b. Standard Specifications:

      1. Section 13110, Cathodic Protection and Joint Bonding

   c. Standard Drawings:

      1. WC – Series Cathodic Protection Details

2. Others:

   a. American Society for Testing and Materials (ASTM):

      1. ASTM C150, Specification for Portland Cement

   b. American Water Works Association Standards (AWWA) Standards and Publications:

      1. AWWA C104, Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
      2. AWWA C205, Cement-Mortar Protective Lining and Coating for Steel Water Pipe, 4 In. (100 mm) and Larger, Shop Applied
      3. AWWA C209, Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines
      4. AWWA C214, Tape Coating Systems for the Exterior of Steel Water Pipelines
      5. AWWA D102, Coating Steel Water-Storage Tanks

   c. The Society for Protective Coatings (SSPC):

      1. SSPC SP-5, White Metal Blast Cleaning
      2. SSPC SP-10, Near White Blast Cleaning

END OF SECTION