

# Cathodic Protection of Metallic Structures Submerged in Fresh Water

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## Document History:

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AMPP values your input. To provide feedback on this standard, please contact: [standards@ampp.org](mailto:standards@ampp.org)

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## Foreword

This standard practice presents procedures and practices for achieving effective control of external corrosion on metallic structures submerged in fresh water.

## Scope

This standard presents acceptable methods and practices for the control of external corrosion on non-mobile structures constructed of steel, stainless steel, cast iron, or aluminum immersed in fresh water through the use of cathodic protection (CP). Such structures may include, but are not limited to trash racks, dams, gates, dock pilings, sheet pilings, and other similar structures located in lakes, rivers, streams, canals, or other similar bodies of fresh water.

These recommendations are not intended for pipelines or structures submerged in waters with elevated salinity. Neither is it intended for mobile structures such as boats, barges, or similar conveyances. However, under some circumstances, these recommendations may be applicable to these situations. It is intended for use by corrosion control personnel concerned with the corrosion of structures submerged in fresh water, including dams, docks, gates, piers, pilings, and similar structures. This standard describes the use of electrically insulating coatings, electrical isolation, and cathodic protection (CP) as external corrosion control methods. It contains specific provisions for the application of CP to existing bare, existing coated, and new structures. The procedures in this standard may best be applied by persons with experience in the design and operation of corrosion control on submerged structures.

## Rationale

This standard fills a gap in the protection of structures by cathodic protection. Standards for the protection of buried or submerged pipelines or offshore structures have existed for many years. While all or portions of these standards may be applicable to structures submerged in fresh water, they do not address the unique features of these structures. Fresh water structures are commonly more structurally complex than pipelines. Many are subject to continual significant variation in electrolyte resistivity. By their very nature, many are intended to have close interaction with the public, which may expose the public to the CP system. The CP systems of some of these structures may also negatively impact local wildlife. This standard attempts to address the unique characteristics of protection of structures submerged in fresh water.

This standard should be used in conjunction with the practices described in the following AMPP standards, when appropriate:

SP0108 SP0169 SP0176 SP0196 SP0388 SP0408 TM0101 TM0113 TM0204 TM0497 SP0104

For accurate and correct application of this standard, the standard must be used in its entirety. Using or citing only specific paragraphs or sections can lead to misinterpretation and misapplication of the requirements, recommendations, and practices contained in this standard.

This standard does not designate practices for every specific situation because of the complexity of conditions that exist on submerged structures.

## Referenced Standards and Other Consensus Documents

Unless specifically dated, the latest edition, revision, or amendment of the documents listed in the table below shall apply.

### **AMPP/NACE/SSPC, [www.amp.org](http://www.amp.org):**

|                |                                                                                                                        |
|----------------|------------------------------------------------------------------------------------------------------------------------|
| NACE SP0108    | Corrosion Control of Offshore Structures by Protective Coatings                                                        |
| NACE SP0169    | Control of External Corrosion on Underground or Submerged Metallic Piping Systems                                      |
| NACE SP0176    | Corrosion Control of Steel Fixed Offshore Platforms Associated with Petroleum Production                               |
| NACE SP0196    | Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks                         |
| NACE SP0388    | Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks                      |
| NACE SP0408    | Cathodic Protection of Reinforcing Steel in Buried or Submerged Concrete Structures                                    |
| NACE TM0101    | Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Tank Systems   |
| NACE TM0113    | Evaluating the Accuracy of Field-Grade Reference Electrodes                                                            |
| NACE TM0204    | Exterior Protective Coatings for Seawater Immersion Service                                                            |
| NACE TM0497    | Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems |
| NACE SP0104    | The Use of Coupons for Cathodic Protection Monitoring Applications                                                     |
| NACE/ASTM G193 | Standard Terminology and Acronyms Relating to Corrosion                                                                |

### **International Electrotechnical Commission (IEC), [www.iec.ch](http://www.iec.ch):**

|                |                                                  |
|----------------|--------------------------------------------------|
| IEC/TS 60479-1 | Effects of Current on Human Beings and Livestock |
|----------------|--------------------------------------------------|

### **National Fire Protection Association (NFPA), [www.nfpa.org](http://www.nfpa.org):**

|         |                                |
|---------|--------------------------------|
| NFPA 70 | National Electrical Code (NEC) |
|---------|--------------------------------|

### **Standards Australia, [www.standards.org.au](http://www.standards.org.au):**

|           |                                                                  |
|-----------|------------------------------------------------------------------|
| AS 2832.3 | Cathodic Protection of Metals, Part 3: Fixed Immersed Structures |
|-----------|------------------------------------------------------------------|

In AMPP standards, the terms *shall* and *must* are used to state requirements and are considered mandatory. The term *should* is used to state something that is recommended, but is not considered mandatory. The term *may* is used to state something considered optional.

## Section 1: General

- 1.1** This standard presents acceptable methods and practices for the control of external corrosion on non-mobile structures constructed of steel, stainless steel, cast iron, or aluminum immersed in fresh water through the use of cathodic protection (CP). Such structures may include, but are not limited to trash racks, dams, gates, dock pilings, sheet pilings, and other similar structures located in lakes, rivers, streams, canals, or other similar bodies of fresh water.
- NOTE:** The requirements of this standard may be applicable under some circumstances for structures immersed in brackish water (i.e., water with a salinity between 0.5 ‰ and 30‰, a specific gravity between 1.005 and 1.010). Depending upon the expected salinity, the user may be better served by reference to NACE SP0176, "Corrosion Control of Steel Fixed Offshore Platforms Associated with Petroleum Production."
- 1.2** CP as described in this standard may be used alone to control corrosion of submerged steel surfaces or may be used as a complement to the protection provided by coatings or other procedures. CP cannot protect surfaces that are not submerged; these surfaces are typically protected by coatings alone.
- 1.3** CP may be installed to control corrosion on both newly constructed and existing structures. When CP is used on existing structures, it may be necessary to dewater the structure during installation.
- 1.4** This standard is not intended for application to:
- 1.4.1** Mobile structures such as ships, barges, or watercraft. However, under some circumstances, the principles put forward here may be applicable.
  - 1.4.2** Pipelines submerged in fresh water and/or buried, or embedded in rock or concrete. For these, the reader should consult other publications, such as the applicable version of NACE SP0169, "Control of External Corrosion on Underground or Submerged Metallic Piping Systems."
  - 1.4.3** The splash and spray zones or atmospheric areas of a partly immersed structure.
  - 1.4.4** The internal surfaces of water storage tanks are addressed in NACE Standards SP0196 and SP0388.
- 1.5** Areas of an immersed structure that may extend downward and be buried are considered in this standard. This standard also considers adjacent structures, not intended to be protected, which may be electrically continuous with the protected structure or may be influenced by the CP system.
- 1.6** The provisions of this standard shall be applied under the direction of competent persons who, by reason of knowledge of the physical sciences and the principles of engineering and mathematics, acquired by education and related practical experience, are qualified to engage in the practice of corrosion control on immersed metallic structures. (Note: such persons particularly include registered professional corrosion engineers or persons recognized as Corrosion Specialists or Cathodic Protection Specialists by AMPP, where their professional activities include suitable experience in corrosion control of submerged structures).
- 1.7** This standard may not be applicable in all situations. Special conditions in which corrosion mitigation measures mentioned here are inapplicable, ineffective, or only partly effective may sometimes exist. Deviation from this standard might be warranted in specific situations, provided that corrosion control personnel in responsible charge are able to demonstrate that the objectives expressed in [Paragraph 5.2](#) of this standard have been achieved.
- 1.8** Pontoons, neutral buoyancy items: This standard may be applicable to stationary pontoons and other neutral buoyancy apparatuses. In assessing the use of CP for these items, consideration must be given to the impact the CP system may have on the buoyancy and functionality of the apparatus.

## Section 2: Definitions

Terms not included in the Definitions section may be found in NACE/ASTM<sup>(1)</sup> G193, "Standard Terminology and Acronyms Relating to Corrosion."

**Anode:** The electrode of an electrochemical cell at which oxidation occurs. (Electrons flow away from the anode in the external circuit. It is usually the electrode where corrosion occurs and metal ions enter solution).

**Calcareous Coating:** A layer consisting of calcium carbonate and other salts deposited on the surface. When the surface is cathodically polarized as in cathodic protection, this layer is the result of the increased pH adjacent to the protected surface.

**Cathode:** The electrode of an electrochemical cell at which reduction is the principal reaction. (Electrons flow toward the cathode in the external circuit).

**Cathodic Disbondment:** The destruction of adhesion between a coating and the coated surface caused by products of a cathodic reaction.

**Cathodic Protection:** A technique to reduce the corrosion rate of a metal surface by making that surface the cathode of an electrochemical cell.

**Close-mounted Anode:** Either a flush-mounted or stand-off anode.

**Coating:** (1) A liquid, liquefiable, or mastic composition that, after application to a surface, is converted into a solid protective, decorative, or functional adherent film; (2) (in a more general sense) a thin layer of solid material on a surface that provides improved protective, decorative, or functional properties.

**Conductivity:** (1) A measure of the ability of a material to conduct an electric charge. (2) The current transferred across a material (e.g., coating) per unit area, per unit potential gradient (Conductivity is the reciprocal of resistivity).

**Corrosion:** The deterioration of a material, usually a metal, that results from a chemical or electrochemical reaction with its environment.

**Corrosion Potential (represented by the symbol  $E_{\text{corr}}$ ):** The potential of a corroding surface in an electrolyte measured under open-circuit conditions relative to a reference electrode. (Also known as electrochemical corrosion potential, free corrosion potential, and open-circuit potential).

**Cathodic Protection (CP) Coupon:** A coupon that is connected to the external surface of, and immersed in the electrolyte adjacent to, the structure being protected by cathodic protection.

**Current Density:** The electric current flowing to or from a unit area of an electrode surface.

**Dissimilar Metal Couple:** Different metals that could form an anode-cathode relationship in an electrolyte when connected by an electron-conducting (usually metallic) path.

**Electrical Isolation:** The condition of being electrically separated from other metallic structures or the environment.

**Electrode:** A material that conducts electrons, is used to establish contact with an electrolyte, and through which current is transferred to or from an electrolyte.

**Electrode Potential:** The potential of an electrode in an electrolyte as measured against a reference electrode.

**Electrolyte:** A chemical substance containing ions that migrate in an electric field.

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<sup>(1)</sup> ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org).

**Flush-mounted Anode:** An anode mounted directly on the surface of a protected structure or separated only by a coating or a dielectric shield. Sometimes also called a surface-mounted anode.

**Fresh Water:** Water having a relatively low mineral content. Fresh water may be defined as that having less than 0.5 ppt (‰) dissolved salts by weight (i.e., < 0.5 g/l of solution; or 500 ppm dissolved salts).<sup>1</sup>

**Galvanic Anode:** A metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.

**Galvanic Couple:** A pair of dissimilar conductors, commonly metals, in electrical contact in an electrolyte.

**Holiday:** A discontinuity in a protective coating that exposes an unprotected surface to the environment.

**Impressed Current:** An electric current supplied by a device employing a power source that is external to the electrode system. (An example is direct current for cathodic protection).

**Impressed Current Anode:** An electrode, suitable for use as an anode when connected to a source of impressed current. (It is often composed of a substantially inert material that conducts by oxidation of the electrolyte and, for this reason, is not corroded appreciably).

**Narcosis:** A state of unconsciousness or drowsiness produced by a drug, or by heat, cold, or electricity.

**Open Circuit Potential:** See Corrosion Potential.

**Polarization:** The change from the corrosion potential as a result of current flow across the electrode/electrolyte interface.

**Polarized Potential:** (1) (general use) The potential across the electrode/electrolyte interface that is the sum of the corrosion potential and the applied polarization; (2) (cathodic protection use) the potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

**Reference Electrode:** An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials.

**Reference Half-Cell:** See Reference Electrode.

**Remote Earth:** A location on the earth far enough from the affected structure that the soil potential gradients associated with currents entering the earth from the affected structure are insignificant.

**Resistivity:** The electrical resistance between opposite faces of a unit cube of material.

**Salinity:** (1) The relative concentration of dissolved salts in water. (2) The total dissolved solids in salt water after all carbonates and organic matter have been oxidized and all bromide and iodide have been replaced with chloride. This type of salinity is usually reported in grams per kilogram or parts per thousand (‰).<sup>2</sup>

**Shielding:** (1) Protecting; protective cover against mechanical damage; (2) preventing or diverting cathodic protection current from its natural path.

**Stand-off Anode:** A close-mounted anode that is spaced from the protected surface to which it is attached at much less than remote earth.

**Structure-to-Electrolyte Potential:** The potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.

**Tetany:** A state marked by severe, intermittent tonic contractions and muscular contractions.

**Voltage Drop:** The voltage across a resistance when the current is applied in accordance with Ohm's Law. This term is also referred to as "IR Drop."

## Section 3: Determination of Need for Cathodic Protection

### 3.1 Introduction

- 3.1.1 Metallic structure surfaces submerged in fresh water are subject to corrosion. The methods and procedures used to control corrosion should be governed by the cost of maintaining the structure in the desired condition for the desired service life.
- 3.1.2 All coatings are subject to damage and deterioration. Therefore, the required level of corrosion control by use of coatings alone on the submerged surfaces of a metal structure may not be adequate to maintain the structure in the desired condition for the desired service life.
- 3.1.3 CP is only effective in controlling corrosion on metal surfaces while in contact with an electrolyte. CP does not reverse structural damage already caused by corrosion. CP may not be effective under disbonded coating.
- 3.1.4 When deciding whether to utilize CP for a structure, the compatibility with CP must be considered. For new structures, verify that the provisions necessary to meet the requirements of Sections 4 and 5 will not negatively impact the design and/or functionality of the structure. For existing structures, determine whether the requirements of Sections 4 and 5 can be reasonably met.

### 3.2 Coated and Uncoated Structures

- 3.2.1 If the fresh water is sufficiently corrosive to justify the use of a coating, then CP may also be justified, and the combination provides a greater degree of protection than when either method is used alone.
- 3.2.2 CP should be used to reduce corrosion on submerged, coated metal structure surfaces where holidays exist – or are anticipated – and where corrosion would occur as a result of those holidays.
- 3.2.3 Properly designed and maintained CP systems may extend the interval between recoating the submerged surfaces.
- 3.2.4 It is feasible to design a CP system to provide protection for uncoated submerged surfaces of metal structures. It may be more practical to protect a bare or poorly coated metal structure with an impressed current CP system versus a galvanic anode cathodic protection (GACP) system.
- 3.2.5 The current required for CP is much lower for coated metal structures compared with the same bare or poorly coated metal structures.

### 3.3 Economic Considerations

- 3.3.1 For coated steel structures, the cost of CP should be compared with the cost of coating repair, recoating, and metal loss. CP can increase the interval for recoating, repairs, and replacement caused by metal loss at holidays in the coating.
- 3.3.2 Metal loss can be reduced by the application of CP, where the submerged surfaces are not coated or where the coating has deteriorated to the point that these surfaces can be considered uncoated. The cost of installing CP, projected maintenance costs (including replacement of damaged or depleted anodes), and monitoring costs should be compared with the cost of coating maintenance, metal loss, service disruption, and reduction in structure life.

### 3.4 Operational Considerations

- 3.4.1 Removing the structure from service for coating maintenance or repairing corrosion damage can be minimized if the CP system is designed and operated properly.

- 3.4.2** Benefits of keeping the structure operational include:
- 3.4.2.1** Lost opportunity cost: protection of the structure reduces maintenance costs and minimizes service outages.
  - 3.4.2.2** Safety: reduces the risk of structural failure due to corrosion and associated injury to persons.
  - 3.4.2.3** Extending the life of the asset; reduced life cycle cost.
  - 3.4.2.4** Maintaining public goodwill; prevention of aesthetic deterioration and loss of use to the public. Reduces impact on the public from repairs.

## **Section 4: Structure Design for Corrosion Control**

- 4.1** All seams should be seal welded, if practical (e.g., sheet piling, existing submerged structures).
- 4.1.1** Open seams create a crevice which will lead to increased corrosion within the crevice.
  - 4.1.2** Neither CP nor coatings can protect within the crevice.
  - 4.1.3** If a seam cannot be seal welded, it must be sealed with caulk, and the caulking must be maintained throughout the service life of the structure.
- 4.2** Avoid enclosed compartments with small openings.
- 4.2.1** These compartments may be subject to water intrusion.
  - 4.2.2** Due to the limited access, these compartments cannot receive adequate surface preparation and coating.
  - 4.2.3** CP from the outside will be ineffective within these compartments.
  - 4.2.4** If such compartments are necessary, they should be sealed with welded plates or threaded plugs.
  - 4.2.5** An exception is compartments that can be physically accessed by personnel for coating and/or cathodic protection.
- 4.3** Avoid dissimilar metal couples.
- 4.3.1** If such couples cannot be avoided, the cathodic protection criterion for the most anodic metal must be used and 100 mV shift cannot be utilized.
  - 4.3.2** If such couples cannot be avoided, the most cathodic metal should be coated.
  - 4.3.3** Connection to rebar in concrete should be considered a dissimilar metal couple for purposes of design.
  - 4.3.4** Weld consumables that can cause welds to be anodic to the base metal should not be used without special corrosion mitigation precautions.
- 4.4** If possible, electrical connection to external structures such as rebar in concrete, electrical grounding, pipelines, or buried metal structures should be avoided. Such structures may draw significant CP current, which must be considered during design.
- 4.5** The design shall specify for each metallic interface the need for electrical continuity vs. the need for electrical isolation when applying cathodic protection.