ANSI/AWWA D106-16
(Revision of ANSI/AWWA D106-10)

American Water Works Association

Dedicated to the World's Most Important Resource®

AWWA Standard

Sacrificial Anode Cathodic Protection Systems for the Interior Submerged Surfaces of Steel Water Storage Tanks

Effective date: June 1, 2016.
First edition approved by AWWA Board of Directors June 20, 2010.
This edition approved Jan. 16, 2016.
Approved by American National Standards Institute Oct. 30, 2015.

STANDARD
American Water Works Association | Since 1881

Approved American National Standard ANSI

AWWA Standard

This document is an American Water Works Association (AWWA) standard. It is not a specification. AWWA standards describe minimum requirements and do not contain all of the engineering and administrative information normally contained in specifications. The AWWA standards usually contain options that must be evaluated by the user of the standard. Until each optional feature is specified by the user, the product or service is not fully defined. AWWA publication of a standard does not constitute endorsement of any product or product type, nor does AWWA test, certify, or approve any product. The use of AWWA standards is entirely voluntary. This standard does not supersede or take precedence over or displace any applicable law, regulation, or code of any governmental authority. AWWA standards are intended to represent a consensus of the water supply industry that the product described will provide satisfactory service. When AWWA revises or withdraws this standard, an official notice of action will be placed on the first page of the Official Notice section of *Journal – American Water Works Association*. The action becomes effective on the first day of the month following the month of *Journal – American Water Works Association* publication of the official notice.

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether that person has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review, and users are cautioned to obtain the latest editions. Producers of goods made in conformity with an American National Standard are encouraged to state on their own responsibility in advertising and promotional materials or on tags or labels that the goods are produced in conformity with particular American National Standards.

CAUTION NOTICE: The American National Standards Institute (ANSI) approval date on the front cover of this standard indicates completion of the ANSI approval process. This American National Standard may be revised or withdrawn at any time. ANSI procedures require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036; 212.642.4900; or emailing info@ansi.org.

ISBN-13, print: 978-1-62576-151-4 eISBN-13, electronic: 978-1-61300-374-9

DOI: http://dx.doi.org/10.12999/AWWA.D106.16

Committee Personnel

The AWWA Cathodic Protection Task Force, which developed this standard, had the following personnel at the time:

David H. Kroon, *Chair*

W.J. Czaska, CB&I, Plainfield, Ill.	(AWWA)
C.W. Dessens, City of Houston, Houston, Texas	(AWWA)
R.A. Gummow, Correng Consulting Services, Downsview, Ont., Canada	(AWWA)
T.D. Hopper, Tank Connection Affiliate Group, Lindale, Texas	(AWWA)
C.C. Johnson, Corrpro Companies Inc., San Diego, Calif.	(AWWA)
R.J. Kochilla, City of Cleveland, Parma, Ohio	(AWWA)
D.H. Kroon, Aegion Corporation, Houston, Texas	(AWWA)
L.D. Scott, Paso Robles Tank Inc., Paso Robles, Calif.	(AWWA)
G.R. Stein, Tank Industry Consultants, Indianapolis, Ind.	(AWWA)
J.J. Sweeney, CST Storage, Dekalb, Ill.	(AWWA)

The Standards Committee on Steel Elevated Tanks, Standpipes, and Reservoirs, which reviewed and approved this standard, had the following personnel at the time of approval:

Stephen W. Meier, *Chair*
Gregory R. Stein, *Vice-Chair*

User Members

J. Camarena, East Bay Municipal Utility District, Oakland, Calif.	(AWWA)
T.M. Dawson, Emerald Coast Utilities Authority, Pensacola, Fla.	(AWWA)
M.F. Gaffey, Naval Facilities Expeditionary Warfare Center, Washington Navy Yard, Washington, D.C.	(AWWA)
C.P. Harder, City of Fort Worth, Fort Worth, Texas	(AWWA)
E.J. King, Connecticut Water Company, Clinton, Conn.	(AWWA)
M.J. Mazurek, Baltimore County Department of Public Works, Towson, Md.	(AWWA)
J.L. Ortiz, San Francisco Public Utilities Commission, San Francisco, Calif.	(AWWA)
J. Travers, City of Richardson, Richardson, Texas	(AWWA)

General Interest Members

D.M. Algranti, Albert A. Webb Associates, Riverside, Calif. (AWWA)
J.D. Brock, Poggemeyer Design Group Inc., Bowling Green, Ohio (AWWA)
M.M. Coleman,* Standards Council Liaison, Wade Trim Associates Inc., Detroit, Mich. (AWWA)
E. Darrimon, Bay Area Coating Consultants Inc., Denair, Calif. (AWWA)
W.J. Dixon, Dixon Engineering Inc., Lake Odessa, Mich. (AWWA)
M.L. Hickey, Murray, Smith & Associates Inc., Portland, Ore. (AWWA)
F.S. Kurtz,* Standards Engineer Liaison, AWWA, Denver, Colo. (AWWA)
S.W. Meier, Tank Industry Consultants, Indianapolis, Ind. (AWWA)
G.R. Stein,† Tank Industry Consultants, Indianapolis, Ind. (AWWA)
J.I. Strand, Short Elliott Hendrickson Inc., Chippewa Falls, Wis. (AWWA)
T.A. Tovey, CH2M, Bellevue, Wash. (AWWA)

Producer Members

G.A. Burke, Caldwell Tanks Inc., Louisville, Ky. (AWWA)
W.J. Czaska, CB&I, Plainfield, Ill. (AWWA)
J.W. Davis, Tnemec Company, North Kansas City, Mo. (AWWA)
B.E. Kromer, Tank Builders Inc., Euless, Texas (AWWA)
K. McGuire, CST Storage, Parsons, Kan. (AWWA)
R.L. Moore, Pure Technologies Ltd., St. Louis, Mo. (AWWA)
L.D. Scott, Paso Robles Tank Inc., Paso Robles, Calif. (AWWA)

* Liaison, nonvoting
† Alternate

Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

This page intentionally blank.

Foreword

This foreword is for information only and is not a part of ANSI/AWWA D106.*

I. Introduction.

I.A. *Background.* This standard describes sacrificial anode cathodic protection systems for the interior submerged surfaces of steel water storage tanks. This standard does not cover automatically controlled impressed current systems (see ANSI/AWWA D104) or impressed current systems with manually controlled rectifiers.

I.B. *History.* Cathodic protection equipment, which was previously included in Section 4 of AWWA D102-64, Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage, was not included in AWWA D102-78, Painting Steel Water-Storage Tanks. Therefore, AWWA D104 was developed by the Standards Committee on Steel Elevated Tanks, Standpipes, and Reservoirs to include this information. The first edition of ANSI/AWWA D104 was approved by the AWWA Board of Directors on Jan. 27, 1991. It has gone through a series of revisions since that time. Subsequently, in 2004, the need for a sacrificial anode cathodic protection standard was identified, resulting in the development of AWWA D106. The first edition of the standard was approved by the AWWA Board of Directors on June 20, 2010. This second edition was approved on Jan. 16, 2016.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the Water Research Foundation (formerly AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.† Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† Persons outside the United States should contact the appropriate authority having jurisdiction.

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.

2. Specific policies of the state or local agency.

3. Two standards developed under the direction of NSF*: NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.

4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,† and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdictions. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA D106 does not address additives requirements. Users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.

2. Determine the status of certifications by parties offering to certify products for contact with, or treatment of, drinking water.

3. Determine current information on product certification.

II. Special Issues.

II.A. *Protective Coatings.* Protective coatings are commonly used in steel water storage tanks. They are an effective method of corrosion control except where flaws exist in the coating caused by poor surface preparation, improper application, defective materials, unanticipated conditions, deterioration over time, or damage. When properly designed and maintained, cathodic protection systems will arrest corrosion at flaws in the submerged coated surface. Properly applied coatings reduce the bare surface area requiring protection and reduce the amount of current required to protect the surface.

---

* NSF International, 789 North Dixboro Road, Ann Arbor, MI 48105.

† Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20001.

Use and maintenance of protective coatings extend the life of the cathodic protection system and reduce operating costs. For submerged areas of a tank, cathodic protection also reduces the required frequency of coating maintenance. Cathodic protection or coatings alone can reduce corrosion on the interior submerged surfaces; however, the combination of coatings and cathodic protection is normally more economical and effective than using coatings or cathodic protection alone.

II.B. *Cathodic Protection.* The two major components of a sacrificial anode cathodic protection system are the anodes and the test box for monitoring and current control. In lieu of a test box, the manufacturer may provide an alternative means for monitoring and current control. The range of sacrificial anode output current capacity required for a specific tank is determined by estimating the area of submerged bare steel to be protected when the interior tank coating is new and when the interior coating has deteriorated to the point where recoating is necessary. In potable water, current density requirements can range from 0.5 to 5.0 mA/ft^2 (5.4 to 53.8 mA/m^2) of bare steel surface. Applications involving turbulence, high temperature, or both may require higher current densities. For newly coated tanks, the total current requirement may be as little as 1 percent of the current required to protect an uncoated interior tank surface. As a rule, sacrificial anode systems for newly coated tanks should have sufficient current capacity to protect the anticipated bare submerged surface area before coating repairs or replacement.

A sacrificial anode cathodic protection system should include a test box or other means for measuring tank-to-water potentials and adjusting the current output of the sacrificial anodes. One or more long-life reference electrodes should be included in the system to monitor the protection levels on the submerged steel surfaces. The reference electrode is used to monitor the tank-to-water potential, free of IR drop error. IR drop must be eliminated or minimized to accurately determine the potential between the tank surface and the reference electrode submerged in the tank. The test box allows for the anode current to be instantaneously interrupted, providing an IR drop-free potential that closely approximates the polarized potential of the tank.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

Contractual responsibilities for items such as design, material, fabrication, construction, inspection, testing, and operation have been removed from the standard and must be addressed in the contract documents.

Many tanks using sacrificial anode cathodic protection systems* for interior submerged surfaces have been in service for more than 30 years. Proper design and maintenance of sacrificial anode cathodic protection systems can help steel water storage tanks achieve an almost unlimited service life.

This standard does not cover systems where the purchaser specifies criteria for protection other than those listed in this standard. This standard does not cover systems to be installed in areas subject to regulations or requirements that are more stringent than the requirements contained herein. Where local, municipal, county, or state government requirements apply to the installation of the sacrificial anode cathodic protection system, such requirements govern, and this standard should be interpreted to supplement them. It is the purchaser's responsibility to supplement or modify this standard for compliance with these local requirements.

At a minimum, it is important that all of the requirements in this standard be met. A sacrificial anode cathodic protection system cannot be represented as a system compliant with ANSI/AWWA D106 if it does not meet the minimum requirements of this standard.

Annual inspection and maintenance of the system are important to ensuring maximum tank life.

AWWA Manual M27, *External Corrosion Control for Infrastructure Sustainability*, chapter 6, addresses corrosion and corrosion protection for water tanks; and AWWA Manual M42, *Steel Water Storage Tanks*, provides guidance on inspection and maintenance of welded steel tanks for water storage.

This standard assumes the tank owner utilizes procedures or equipment to prevent freezing of the water in the tank. Where the possibility of freezing exists, the owner should implement procedures or equipment to prevent freezing. The purchaser is referred to National Fire Protection Association (NFPA) document NFPA 22, Standard for *Water Tanks for Private Fire Protection*, for heater sizing. Purchasers are cautioned against allowing ice to form inside a tank because it may damage system components and even the tank itself.

This standard does not cover tank disinfection procedures or cleaning and painting. ANSI/AWWA C652, Disinfection of Water Storage Facilities, should be consulted for recommended procedures for disinfection of water storage facilities.

---

* The word *system* and the phrase *cathodic protection system* are used hereinafter broadly in place of the lengthy phrase *sacrificial anode cathodic protection system for interior submerged surfaces of steel water storage tanks*.

III.A. *Purchaser Options and Alternatives.* Proper use of this standard requires that the purchaser specify certain requirements. The purchaser may desire to modify, delete, or amplify sections of this standard to suit special conditions. It is strongly recommended that such modifications, deletions, or amplifications be made by supplementing this standard.

III.A.1. Options and Alternatives. The following list identifies aspects of the system that have more than one acceptable style, configuration, or value. The purchaser must specify the desired option for each of these items or specify that the system designer may select any appropriate option.

1. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required.

2. The type of anode connection (included in Sec. III.A.3, Information to Be Specified by Purchaser).

a. Direct connection of the anodes to the tank.

b. Connection of the anodes through a test box that allows for monitoring and adjustment of anode current output.

III.A.2. Items to Be Provided by Purchaser or Installer. The following recommendations represent good practice about what each party should provide, but they are not requirements of ANSI/AWWA D106. The contract documents should specify which party is to provide each of the following items.

1. When a sacrificial anode cathodic protection system is to be purchased under this standard, the purchaser should provide the following:

a. Access to the site on which the tank is to be built, including sufficient space to permit access to install, inspect, and test the system by customary methods.

b. A sufficient volume of water in the tank at the time of system installation to allow full system testing.

c. Safe access to the tank roof for installation and inspection of system components.

d. Certification that the tank roof is safe to access.

e. Any materials to be furnished by the purchaser for installation in the system by the system installer.

2. The system designer should submit design calculations, specifications, and construction drawings.

3. The system installer should furnish the following items:

a. All labor and materials, except materials provided by the purchaser, necessary to complete the installation of the system, including inspection and testing required by this standard.

b. Any additional work specified separately by the purchaser in the contract documents, such as disinfection of the tank.

c. Operation and maintenance manual.

III.A.3. Information to Be Specified by Purchaser. This standard provides minimum requirements for the design, construction, inspection, and testing of tanks without any designation of which party must perform these tasks or select the options. For this reason, the following information should be specified by the purchaser when contracting for a sacrificial anode cathodic protection system for interior submerged surfaces of a steel water storage tank:

1. Standard used—that is, ANSI/AWWA D106, Sacrificial Anode Cathodic Protection Systems for the Interior Submerged Surfaces of Steel Water Storage Tanks, of latest revision.

2. Compliance requirement for NSF/ANSI 61, Drinking Water System Components—Health Effects (see Sec. 4.1.2[1]).

3. Gross capacity of the tank, the tank diameter, and the type of roof.

4. For elevated tanks, the style or shape of tank, the bottom capacity level (BCL), the head range, and the diameter and type of riser.

5. For ground-supported flat-bottom tanks, the top capacity level (TCL).

6. Chemical analysis of the water to be stored.

7. Water resistivity (for all sources of supply).

8. Water turbulence.

9. Operating temperature and flow rate.

10. Type and age of protective coatings.

11. Maximum anticipated coating deterioration expressed as a percentage of the submerged coating surface area that is allowed to become bare before the coating is repaired or replaced (for design purposes).

12. Cathodic polarization characteristics.

13. Anode metal and alloy required (see Sec. 4.1.2.3).

14. Type of anode connection required (see Sec. 4.1.2.4).

15. Required design life of the anode system.

16. Location of the site.

17. Desired time for completion.

III.A.4. Information to Be Provided by the Bidder for a Sacrificial Anode Cathodic Protection System for Interior Submerged Surfaces of a Steel Water Storage Tank:

1. A description of the anode material, size, and configuration.
2. A description of the quantity and location of the anodes.
3. A statement of the design basis of the system, including tank size and configuration, all water properties, type of coatings, design percentage of bare steel surface protected, and design life of the anodes.
4. The type of anode connection employed in the design.
5. Outline of the recommended service and maintenance plan.

III.B. *Modification to Standard.* Any modification of the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. The major revisions to this edition of the standard include the following:

1. Language regarding dissimilar metals inside the tank below the TCL has been added (Sec. 4.1.1).
2. Requirements for roof hand-hole configuration have been added (Sec. 4.1.2.4).
3. Numerous editorial revisions have been made throughout the standard to improve clarity.

V. Comments. If you have any comments or questions about this standard, please contact AWWA Engineering and Technical Services at 303.794.7711, FAX at 303.795.7603; write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098; or email the group at standards@awwa.org.

This page intentionally blank.

ANSI/AWWA D106-16
(Revision of ANSI/AWWA D106-10)

American Water Works Association
Dedicated to the World's Most Important Resource®

AWWA Standard

Sacrificial Anode Cathodic Protection Systems for the Interior Submerged Surfaces of Steel Water Storage Tanks

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes sacrificial anode cathodic protection systems intended to minimize corrosion of interior submerged surfaces of steel water storage tanks.

This standard does not describe automatically or manually controlled impressed current systems.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for sacrificial anode cathodic protection systems for the interior submerged surfaces of steel water storage tanks, including design, system components, quality of work, installation, operation, and maintenance.

Sec. 1.3 Application

This standard can be referenced in specifications for designing and installing sacrificial anode cathodic protection systems for the interior submerged surfaces of steel water storage tanks. The stipulations of this standard apply when referenced and then only to sacrificial anode cathodic protection systems for the interior submerged surfaces of steel water storage tanks.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI*/AWWA C652—Disinfection of Water Storage Facilities.

ANSI/AWWA D100—Welded Carbon Steel Tanks for Water Storage.

ANSI/AWWA D102—Coating Steel Water-Storage Tanks.

ANSI/AWWA D103—Factory-Coated Bolted Carbon Steel Tanks for Water Storage.

ASTM† B843—Standard Specification for Magnesium Alloy Anodes for Cathodic Protection.

ASTM B418—Standard Specification for Cast and Wrought Galvanic Zinc Anodes.

NSF‡/ANSI 61—Drinking Water System Components—Health Effects.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *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.)

2. *Anode life:* The anticipated number of years of service before anode replacement is required.

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

4. *Cathodic polarization:* The change in electrode potential in the negative (active) direction caused by current across the electrode/electrolyte interface.

5. *Cathodic protection:* A method of corrosion control that reduces the corrosion of a submerged metal surface by making that surface the cathode of an electrochemical cell.

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.
‡ NSF International, 789 North Dixboro Road, Ann Arbor, MI 48105.

6. *Coating:* All components of the protective coating system, the sum of which substantially isolates (electrically) the underlying metal from the electrolyte (water).

7. *Conductivity:* A measure of the ability of a material to carry an electric current, expressed in micromhos or siemens per centimeter (*S*/cm). In water, this depends on the total concentration of ionic specie and the temperature. Conductivity is the reciprocal of resistivity.

8. *Constructor:* The party that provides the work and materials for placement or installation.

9. *Corrosion:* The deterioration of a material, usually a metal, caused by a reaction with its environment.

10. *Corrosion potential:* The potential of a corroding surface in an electrolyte relative to a reference electrode under open-circuit conditions.

11. *Coupon:* An object of similar metallurgy to the structure.

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

13. *Driving voltage:* The potential difference between the sacrificial anodes and the tank wall when the cathodic protection system is in operation.

14. *Electrode:* A conductive material through which an electric current enters or leaves an electrolyte.

15. *Electrode potential:* The potential of an electrode in an electrolyte as measured against a reference electrode. (The electrode potential does not include any resistance losses in potential in either the electrolyte or the external circuit. It represents the reversible work to move a unit of charge from the electrode surface through the electrolyte to the reference electrode.)

16. *Electrolyte:* A chemical substance or mixture containing ions that migrate in an electric field. For the purpose of this standard, *electrolyte* refers to the water, including the chemicals contained therein, in contact with the submerged metal surface.

17. *Elevated tank:* A container or storage tank supported on a tower.

18. *Energized:* State of the cathodic protection system in which the anodes are operating and protective current is flowing.

19. *Freshwater:* Water that is not saline; used for drinking, fire protection, or irrigation.

20. *Half-cell:* An electrode contacting an electrolyte; in common usage, any reference electrode.

21. *Half-cell potential:* The potential in a given electrolyte of one electrode of a pair. Potentials can only be measured and expressed as the difference between half-cell potentials of two electrodes.

22. *Holiday:* A void in the coating that will allow the passage of electrical current.

23. *Instant-off measurement:* Potential measurement taken with the current interrupted to determine the polarized potential that is free of IR drop.

24. *IR drop:* The voltage across a resistance in accordance with Ohm's Law.

25. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

26. *Ohm's Law:* $E = IR$, where E = voltage in volts, I = current in amperes, and R = resistance in ohms.

27. *Polarization:* The change in open circuit potential of an electrode resulting from the passage of current.

28. *Polarized potential:* The potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

29. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

30. *Reference electrode:* An electrode the open-circuit potential of which is constant under similar conditions of measurement, which is used for measuring the relative potentials of other electrodes.

31. *Reservoir:* A flat-bottom cylindrical tank having a shell height equal to or less than its diameter.

32. *Resistivity:* A measure of the resistance of a material to the passage of electric current, as a function of its geometry, expressed in ohm-centimeters. Resistivity is the reciprocal of conductivity.

33. *Sacrificial 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 current source for the systems described in this standard.

34. *Standpipe:* A flat-bottom cylindrical tank having a shell height greater than its diameter.

35. *Tank-to-water potential:* The voltage difference between a submerged metallic structure and the electrolyte (water), which is measured with a reference electrode in contact with the electrolyte.

36. *Voltage:* An electromotive force or a difference in electrode potentials.

37. *Water tank:* An elevated water storage tank, a standpipe, or a reservoir of welded, bolted, or riveted steel construction.

SECTION 4: REQUIREMENTS

Sec. 4.1 Design

4.1.1 *Criteria for protection.* The cathodic protection system shall maintain the polarized tank-to-water potential at least as negative as –0.850 V to a copper/copper sulfate reference electrode (CSE) in contact with the stored water and the submerged tank surface, or at least 100 mV of cathodic polarization. The formation or decay of polarization can be measured to satisfy this criterion.

CAUTIONARY NOTES:

1. The 100-mV polarization criterion is only applicable to steel water storage tanks not having corrosion cells caused by connection to more noble metals such as copper, brass, or passive stainless steel (nonisolated dissimilar metals).

2. Dissimilar metals (e.g., stainless steel, copper, brass, etc.) installed inside the tank below the TCL shall be electrically isolated from the carbon steel tank components to which they are attached. Where electrical isolation is not possible, the application of a barrier coating on the more noble metallic components may be used in lieu of separate electrical isolation of components, provided that the selected coating system manufacturer validates the coating as having sufficient dielectric strength to provide a suitable barrier and that the coating can be properly applied and maintained.

3. Depending on the type of tank coating, polarized tank-to-water potentials (instant-off) more negative than –1.100-V CSE may cause blistering of the submerged coating.

4. The CSE potentials are at 25°C and should be adjusted for actual water temperature [E at temperature $T = E$ at 25°C + k (T – 25°C) where k = 0.9 mV/°C].

4.1.1.1 Potential measurements. The potentials shall be measured free of the effect of voltage gradients (IR drops). The long-life reference electrode may be positioned anywhere in the tank.

4.1.2 *System design.* The cathodic protection system provided according to this standard shall achieve and maintain the criteria for protection (Sec. 4.1.1). In addition, the design of a sacrificial anode system shall include the evaluation of the tank information listed below:

1. Compliance requirement for NSF/ANSI 61, Drinking Water System Components—Health Effects.

2. Total interior submerged coating surface area to be protected.

3. Chemical analysis of the water to be stored.

4. Water resistivity (for all sources of supply).

5. Operating temperature and flow rate.

6. Type and age of protective coatings.

7. Maximum allowable coating deterioration (for design purposes) expressed as a percentage of the total interior submerged coating surface area that is allowed to become bare before the coating is repaired or replaced.

8. Type of anode connection to be used.

9. Specified design life of the anode system.

4.1.2.1 System capacity. Nominal current capacity of the sacrificial anodes shall be determined based on the estimated current density required for cathodic protection. The required current density is expressed in milliamps per unit area of total submerged bare surface. The required current density shall be determined for each specific tank and dependent on the conductivity of the water, condition of the coatings, temperature, aeration, and flow rate.

4.1.2.2 Design life. The design life of the cathodic protection system shall be calculated from the current discharge and consumption rate of the anodes. The magnitude of current shall be that necessary to protect the tank in accordance with the criteria listed under Sec. 4.1.1, considering future coating deterioration. The design of the sacrificial anode cathodic protection system shall be capable of providing sufficient current to protect the tank for the full design life of the cathodic protection system.

4.1.2.3 Anode selection. Sacrificial anodes shall be manufactured from either magnesium or zinc alloys. The alloy shall be chosen to be compatible with water chemistry and design life.

4.1.2.4 Anode configuration. The anode array shall provide and maintain a uniform distribution of protective current without exceeding the potential limits described in Sec. 4.1.1. The anode array shall incorporate satisfactory anode supports for the life of the system, including high flow rates that may be encountered when the tank is filled or emptied. The system design shall consist of sacrificial anodes with lead wires that connect to a collector cable, both ends of which terminate in a test box with a tank connection cable, a tank test lead, a calibrated shunt, and a reference electrode lead. Where hand holes are to be cut in the top

of the tank for anode installation and future access, the hand-hole design shall provide a watertight seal between the roof and hand-hole cap plate to prevent rain water and other contaminants from entering the tank. Alternatively, the system design may consist of sacrificial anodes, each with a lead wire that connects directly to the tank. If the sacrificial anodes are connected directly to the tank and the anode current flow cannot be interrupted, a coupon and reference electrode shall be configured to evaluate the IR drop and approximate the polarized potential of the tank.

4.1.2.5 Monitoring and maintenance testing. For systems with a control box, monitoring and maintenance testing shall include tank-to-water polarized (instant-off) potential and anode current output measurements. For systems with other means of disconnecting the electrical connection between the tank and anodes, the required measurements include disconnecting the anode(s) and measuring an instant-off tank-to-water potential. Where anodes are connected directly to the tank, polarized tank-to-water potential shall be determined by instantaneously disconnecting the coupon from the tank and measuring the coupon potential with respect to the reference electrode.

Sec. 4.2 System Components

4.2.1 *Sacrificial anodes.* Sacrificial anodes shall be manufactured from either magnesium or zinc alloys. Magnesium alloys shall be type AZ63B, AZ31B, or M1C in accordance with ASTM B843; and zinc alloy shall be type II in accordance with ASTM B418. Sacrificial anodes shall be cast or extruded on a full-length galvanized-steel core.

4.2.2 *Anode suspension and support system.* Suspension, support materials, and wiring shall be designed to provide suitable service for tank operations and environmental conditions within the tank. The anode shall be supported by means other than the lead wire.

4.2.3 *Reference electrodes.* Copper/copper sulfate reference electrodes shall be used for freshwater applications. For other types of water, the type of reference electrode shall be compatible with the water chemistry. The permanent reference electrode used to measure the tank-to-water potential for monitoring and maintenance shall be designed to maintain a stable potential in continuous immersion in the water for a minimum of 10 years. The reference electrodes shall have a potential drift of less than 10 mV. The reference electrode lead wire shall be insulated.

4.2.4 *Cable and wiring.* Conductors shall be stranded copper and shall be insulated to prevent both moisture penetration and contact with the tank.

Sec. 4.3 Installation

4.3.1 *General.* Welding, cutting, and coating work required in conjunction with the installation of the cathodic protection system—including the installation of fittings, hand-hole assemblies, anchors, and brackets—and the repair of damaged coating shall conform to applicable requirements of ANSI/AWWA D100, ANSI/AWWA D102, and ANSI/AWWA D103. Coating material used to repair existing field-applied coatings shall be of the same generic type and have the same regulatory approval as the existing coating systems. Surface preparation shall be as recommended by the coatings manufacturer. Damaged coatings shall be feathered, and coatings shall be applied in the same order and number of coats as the original systems. Repair of factory-applied coatings shall be as recommended by the tank manufacturer.

Work within the tank shall be evaluated by the purchaser to determine the need for disinfection. Disinfection work shall be performed in accordance with ANSI/AWWA C652.

When a test box is used, it shall be installed between 4 ft and 5 ft above grade, so that it may be readily serviced.

Anode locations and method of suspension and support shall be as specified.

Lead wires and connections shall be waterproof. The system shall be tested to ensure there are no short circuits between the cable system or lead wires and the tank.

Underwater splices to the anode lead wires shall not be used. Connections between the anode lead wires and collector cables shall be mechanically secure, electrically conductive, and sealed to prevent moisture penetration.

There shall be only one electrical splice, within the tank, above the high water level, for each stationary reference electrode and coupon.

NOTE: Electrical continuity between sections of the tank is necessary. Welded tanks ensure electrical continuity, but tanks that are bolted or riveted may require electrical bonding of tank sections.

4.3.2 *Cleanup.* On completion of the installation, rubbish and other unsightly material caused by the cathodic protection construction operations shall be removed, and the premises shall be left in as good a condition as found at the start of the project.

4.3.3 *Materials.* Materials shall comply with the requirements of the Safe Drinking Water Act and other federal, state or provincial, and local requirements.

SECTION 5: VERIFICATION

Sec. 5.1 Inspection and Handling

System components shall be inspected to ensure conformance to the purchaser's specifications for material, size, length and insulation of lead wire, and method of wire connection. Handle anodes and lead wires carefully to avoid damage. Final installation shall be inspected for loosening of lead wire connections and damage to system components.

Sec. 5.2 Testing

After the installation is completed, the system shall be energized, tested, and adjusted. Testing shall not be conducted until the system has had time to polarize. A representative potential profile shall be conducted to verify the tank-to-water potential satisfies the criteria for protection as described in Sec. 4.1.1 and the system is operating in accordance with the purchaser's specifications. The system shall be field tested by conducting IR drop-free potential measurements. The instant-off measurement shall be used for this test.

If the system is not to be commissioned until after the internal coating warranty inspection, the master anode disconnect switch in the control box shall be locked in the off position.

Sec. 5.3 Operation and Maintenance Manual

An operation and maintenance manual for the cathodic protection system shall be provided and shall include the results of the testing required by Sec. 5.2. In addition, the following information shall be included:

1. Name and address of system installer.
2. System design criteria (see Sec. 4.1.2).
3. Date that cathodic protection installation was completed and tested.
4. As-built drawings showing anode composition, anode configuration, anode suspension, and support system.
5. Operation and maintenance instructions.

This page intentionally blank.

APPENDIX A

Commentary and Additional Information

This appendix is for information only and is not part of ANSI/AWWA D106.

SECTION A.1: SCOPE

The purpose of this appendix is to provide additional information regarding corrosion protection for the interior submerged surfaces of steel water storage tanks.

Steel surfaces submerged in water are subject to galvanic corrosion. Galvanic corrosion is a natural, continuous electrochemical process that generates direct electrical current, resulting from differences in potential between two metal surfaces, and that removes metal from unprotected surfaces in contact with water. The methods used to control corrosion should be governed by the rate of corrosion and the cost of maintaining the tank over its service life. Cathodic protection will only control corrosion on the interior tank surfaces that are submerged.

SECTION A.2: DETERMINATION OF NEED FOR CATHODIC PROTECTION

For internally coated steel tanks, there may be holidays in protective coatings. If the water to be stored in the tank is sufficiently corrosive to require the use of a protective coating, cathodic protection should also be applied. For bare steel tanks where waters are corrosive, cathodic protection should be used for corrosion control of the interior submerged surfaces of bare steel tanks.

SECTION A.3: PRINCIPLES OF CATHODIC PROTECTION

Cathodic protection uses direct current to control the corrosion process and reduce corrosion of submerged surfaces. Cathodic protection systems can be installed on new or existing tanks and on coated or uncoated tanks.

Cathodic protection current requirements for control of corrosion vary with changes in water level, coating deterioration, temperature, water chemistry, and water turbulence. The effectiveness of a cathodic protection system is determined by measuring the voltage between the submerged surface of the tank and a copper/copper sulfate reference electrode submerged in the tank contents. This measurement is commonly called the *tank-to-water potential*. When the tank-to-water potentials measured at several locations representing the entire submerged surface area of the tank meet the criteria for protection, corrosion protection is considered effective (Sec. 4.1.1 of ANSI/AWWA D106).

Cathodic protection is generally used in conjunction with protective coatings. Organic coatings are permeable to some degree. Coatings used with cathodic protection should be resistant to an alkaline environment, should not absorb water, and should be well bonded to the steel substrate. For internally coated tanks, cathodic protection will extend the time interval between recoating of submerged surfaces.

SECTION A.4: DESIGN

The electrical current required for cathodic protection of a well-coated tank is much lower than for a bare or poorly coated tank. The combination of coatings and cathodic protection is often the most effective and most economical method of corrosion control for the interior submerged surfaces of steel water storage tanks.

Cathodic protection can also be used for corrosion control of the interior submerged surfaces of bare steel tanks. Under these conditions, it may be more economical to protect with an automatically controlled, impressed-current cathodic protection system as described in ANSI/AWWA D104.

For bare steel tanks, the cost of cathodic protection should be compared with the cost of metal loss, repairs, leakage, service disruption, reduction in tank life, and water degradation. For coated steel tanks, the cost of recoating and the savings created by extending the recoating interval should also be considered.

SECTION A.5: INSTALLATION

The cathodic protection system is typically installed by a design–install constructor. Regardless of who installs the cathodic protection system, the installation should be completed in accordance with the project specifications.

SECTION A.6: ENERGIZING THE SYSTEM

The energizing, testing, and adjusting of the system is performed in accordance to Sec. 5.2 of ANSI/AWWA D106. As noted in Sec. 5.2, for new tanks, the cathodic system might not be energized and made fully operational until the performance of the internal coating system has been assessed after the coating system warranty inspection and, if necessary, repaired. Sufficient time is necessary for the system to polarize, which may vary from several hours to several weeks or more, depending on the tank configuration, coating system, and water chemistry. Testing does not commence until the system has been polarized.

SECTION A.7: AFFIDAVIT OF COMPLIANCE

An affidavit of compliance with all applicable provisions of this standard may be requested. The affidavit should be signed by a corrosion specialist and the system installer. As used here, a corrosion specialist is a person who is accredited by NACE International* as a senior corrosion technologist, corrosion specialist, or cathodic protection specialist.

SECTION A.8: CATHODIC PROTECTION AND TANK-MOUNTED ANTENNAS

Tank-mounted antennas have not been found to cause interference with the performance of a cathodic protection system, and cathodic protection systems have not been found to cause interference with the performance of antenna signals.

* NACE International, 1440 South Creek Drive, Houston, TX 77084-4906.

This page intentionally blank.

APPENDIX B

Operation Guidelines for Cathodic Protection Systems

This appendix is for information only and is not part of ANSI/AWWA D106.

SECTION B.1: GENERAL

The owner should refer to reports and manuals provided by the constructor (Sec. 5.3 of ANSI/AWWA D106).

SECTION B.2: MONITORING

To properly monitor the system performance and avoid damaging the protective coating, anode current outputs and tank-to-water potential should be recorded at least annually. If any system component is damaged or a malfunction is discovered, the system should be tested and repaired.

SECTION B.3: RECORDS

Records of the current and potential testing should be retained for the last three years to verify the system is performing consistently.

In addition to the reports and manuals provided by the constructor (Sec. 5.3 of ANSI/AWWA D106), the following information should be maintained to help the owner monitor and operate the system:

1. Tank information, including name and address of the tank constructor, date of erection, dimensions, including high and low water levels, and tank capacity.
2. Chemical analysis of water and history of ice conditions.
3. Type of coatings applied and when applied.
4. Service reports by constructor, corrosion specialist, or service company. As used here, a corrosion specialist is a person who is accredited by NACE International as a senior corrosion technologist, corrosion specialist, or cathodic protection specialist.

5. If the tank is emptied, the condition of the coating, evidence of corrosion, or any calcareous buildup on the surface of the tank should be recorded.

NOTE: Severe ice formation in tanks should be prevented by using operating procedures such as water circulation or other acceptable methods. If the interior of the tank is entirely frozen or if the tank is drained when heavy accumulations of ice exist, the anode system should be inspected and repaired as required.

APPENDIX C

Service and Maintenance of Sacrificial Anode Cathodic Protection Systems

This appendix is for information only and is not part of ANSI/AWWA D106.

SECTION C.1: SCOPE

A cathodic protection system should be tested and maintained to ensure the system continues to control corrosion on the interior submerged surface of the tank. It is recommended that the periodic testing and maintenance of the cathodic protection system be performed by the system constructor or a corrosion specialist. As used here, a corrosion specialist is a person who is accredited by NACE International as a senior corrosion technologist, corrosion specialist, or cathodic protection specialist.

SECTION C.2: ANNUAL INSPECTION AND POTENTIAL TESTING

Inspection of the system should be performed at least annually and should include tank-to-water potential measurements to monitor the effectiveness of the system for the submerged surfaces of the tank. When a tank-to-water potential survey is conducted, five separate measurements should be taken vertically through the tank water at equidistant heights from the tank bottom to the top of the water. Additional vertical potential profiles should be taken at various locations throughout the tank if there are other locations of access to the tank interior. The method of conducting the measurements should be in accordance with Sec. 5.2 of ANSI/AWWA D106 using a calibrated, portable reference electrode. A report of the inspection and testing should include observed measurements, an evaluation and interpretation of the measurements, and recommendations for continued performance of the system.

SECTION C.3: SEASONAL ANODE SERVICE

Seasonal anode systems usually require annual replacement. This work can be part of an annual service agreement. For tanks subject to freezing, anode replacement should be performed in the spring. After the anodes are replaced, the system should be energized, tested, and adjusted in accordance with methods used to verify the criteria for cathodic protection (Sec. 5.2 of ANSI/AWWA D106).

SECTION C.4: REPAIRS AND REPLACEMENTS

System components such as the test box, anodes, and stationary reference electrodes do not require annual replacement but should be inspected annually. For parts and installation services for these components of the cathodic protection system, the system constructor or corrosion specialist should be consulted. As used here, a corrosion specialist is a person who is accredited by NACE International as a senior corrosion technologist, corrosion specialist, or cathodic protection specialist.

This page intentionally blank.

This page intentionally blank.

This page intentionally blank.

American Water Works Association

6666 West Quincy Avenue
Denver, CO 80235-3098
T 800.926.7337
www.awwa.org

Dedicated to the world's most important resource, AWWA sets the standard for water knowledge, management, and informed public policy. AWWA members provide solutions to improve public health, protect the environment, strengthen the economy, and enhance our quality of life.

ISBN 978-1-62576-151-4

1P–2M 44106-2016 (06/16) IW

Printed on Recycled Paper