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American Water Works Association

The Authoritative Resource on Safe Water®

AWWA Standard

Disinfection of Water-Storage Facilities

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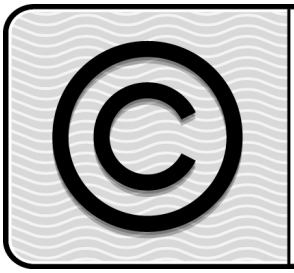

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All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C652.*

I. Introduction.

I.A. *Background.* This standard describes methods of disinfecting water storage tanks. The disinfecting agents discussed in this standard are chlorine solutions, and several combinations of free chlorine residual and contact time (CT) are provided. The chlorine solutions may be derived from liquid chlorine (Cl_2), calcium hypochlorite ($Ca(OCl)_2$), or sodium hypochlorite (NaOCl).

I.B. *History.* This standard was first approved on June 15, 1980, under the designation ANSI/AWWA D105, Standard for Disinfection of Water Storage Facilities. The 1980 edition was developed from information originally contained in AWWA D102-64, modified to include disinfection of water-storage facilities constructed of steel or other materials. The standard was redesignated ANSI/AWWA C652 with the 1986 edition. It was later revised in 1992 and again in 2002. This edition was approved by the AWWA Board of Directors on June 12, 2011.

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 American Water Works Association Research Foundation (AwwaRF, now Water Research Foundation†) 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

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

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* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† Water Research Foundation, 6666 W. Quincy Avenue, Denver, CO 80235.
‡ Persons outside the United States should contact the appropriate authority having jurisdiction.

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 jurisdiction. 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 C652 does not address additives requirements. Thus, 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. *Information on Application of This Standard.* Utilities are increasingly focusing on water storage reservoir management and maintenance as part of preserving distribution system water quality. Disinfection of water storage tanks presents special challenges due to the quantity of water that must be dealt with, the conditions of the water supplied to the tank, and the ability to collect representative samples of the water in the tank.

Disinfection of tanks and other facilities used for drinking water relies on high levels of free chlorine to ensure bacteria and other potential pathogens are inactivated.

* NSF International, 789 N. Dixboro Road, Ann Arbor, M 48105.

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

It should be noted that pH and temperature are two important factors affecting the disinfection process. Hypochlorous acid and hypochlorite are the two forms of chlorine present in water at pH greater than 3. Hypochlorous acid has been shown to be significantly more effective than hypochlorite for disinfection. Above pH 9 there is essentially no hypochlorous acid, only hypochlorite. Temperature also affects the effectiveness of disinfection; low temperatures are not as effective as high temperatures for chlorine disinfection. The high chlorine dosages required in this standard are necessary to provide effective disinfection under varying conditions of pH, temperature, and other factors.

Following disinfection and prior to activating the tank for use, water in the storage tank should be tested to determine that it meets expected parameters typical in the system. Consider especially the work done in the tank and appropriate parameters to measure. Test results should confirm that the water quality is appropriate for distribution. Although this assessment is unique for each system, suggested test parameters include pH, alkalinity, turbidity, odor, and specific conductance. If the tank was painted or if epoxy was applied, measuring levels of volatile organic compounds (VOC) or other components of the coating material (such as zinc), may be necessary, noting that the trihalomethanes (THMs) chloroform, bromodichloromethane, dibromochloromethane, and bromoform, which are part of the VOC test, are a result of disinfection, not coating materials, and would be expected to be present. Satisfactory chlorine residual and coliform results are also required.

When collecting samples for analysis of coliform or other parameters, it is important that the sample represent the water quality in the tank. Sample taps need to be clean and sanitary. In some cases, samples may need to be collected from the top of the tank or hatch. When sampling from the top of the tank or hatch, use of a depth sampler may be beneficial to best represent the quality of water that will enter the system.

For bacteriological tests, the results of testing must show no coliform. Given the different test procedures available for coliform analysis, results should be expressed as "confirmed coliform" and should be <1 cfu/100mL, < 1 MPN/100 mL, or "Absent."

While bacteriological testing in accordance with Section 5 is used to verify the absence of coliform organisms and is generally accepted as verification that acceptable disinfection has been accomplished, following sanitary procedures during the course of all work is necessary to ensure the disinfected tank will be ready for activation.

Disinfectants other than chlorine may be appropriate to use. While this standard describes only the use of liquid chlorine, sodium hypochlorite solutions, and calcium hypochlorite, the applicability of other disinfectants should be evaluated. Ozone and

chemical cleaners have been used, and these warrant further investigation. Whichever disinfectant or method is selected, approval from the local regulatory agency is required.

As more frequent inspections and cleaning of reservoirs are required, utilities are turning to methods that minimize downtime and wasted water. Utilities may use methods employing divers or remotely operated vehicles (ROVs) for both inspection and sediment removal. Sec. 4.4 of this standard describes the disinfection procedures and operational considerations for conducting inspection and cleaning in potable-water-storage facilities. It should be noted that any underwater retrieval of remotely operated vehicles with divers must be performed in accordance with all aspects of this standard. When selecting a contractor to perform this type of work, it is essential to evaluate their experience, safety procedures, and methods. Each bidder should be willing to meet the minimum requirements set by this standard for safe performance of the work. This standard includes references to pertinent OSHA regulations. There are specific technical skills a utility should look for when considering a firm for this type of work, such as the following:

- Qualifications for conducting in-service operations in compliance with OSHA.
- Qualifications for inspecting and evaluating steel/concrete/wood or membrane-covered reservoirs.
- Resumes for the specific personnel who will perform underwater inspection and/or cleaning.

Sec. 4.4 does not address the following items, each of which must be specified by the purchaser:

1. The type of inspection to be performed (structural, coating, bottom sediment, cathodic protection, bacteriological, and so forth).
2. The technical requirements of the inspection and/or cleaning.

For additional guidance, refer to AWWA Manual M42, *Steel Water-Storage Tanks*.

Sec. 4.4 does not attempt to rewrite existing safety standards and relies on the existing applicable OSHA Standards, including but not limited to

OSHA, 29 CFR, Subpart T, Commercial Diving Operations, 1910.401 through 1910.441.

OSHA, 29 CFR, Permit Required Confined Spaces, 1910.146.

III. Use of This Standard. This standard describes methods of disinfecting water-storage facilities that are newly constructed, have been entered for construction or inspection purposes, or that continue to show the presence of coliform bacteria during normal operation. In addition, the standard defines disinfection procedures for

underwater inspections because water utilities increasingly are employing divers and remotely operated vehicles to conduct underwater inspections and/or cleaning of in-service potable-water-storage facilities to minimize water loss and downtime normally associated with necessary maintenance. The standard does not describe the type and technical requirements of underwater inspection and/or cleaning or the required skill level of the diving inspector.

A storage facility is defined as a reservoir from which water, without further treatment other than booster disinfection, is supplied directly to the distribution piping system for domestic use. From a practical standpoint, this standard applies to the disinfection of covered storage facilities constructed of steel, concrete, or materials that would provide a similar structure from a water quality standpoint. Because wood may support the growth of coliform bacteria, it is recommended that any submerged wood surface (columns, baffles, and so forth) be coated with epoxy or other durable, effectively impermeable paint or coating approved for domestic water use.

Parts of this standard may be applicable to the disinfection of large, finished-water, open storage reservoirs, such as reservoirs formed by concrete or earth dams, but these applications are incidental, and this standard is not intended to cover those kinds of storage facilities.

Three methods of chlorinating storage facilities are described in this standard. Each utility should decide which method is most suitable for a given situation. In selecting the method to be used, utility personnel should consider the availability of materials and equipment for disinfection, the training of personnel who will perform the disinfection, chlorinated water disposal options, and safety. For example, gas chlorination should be used only when properly designed and constructed equipment is available; makeshift equipment is not acceptable when liquid-chlorine cylinders are used. Spray equipment should be used inside the storage facility only when thorough ventilation is ensured or when appropriate protection is provided using canister-type gas masks or self-contained breathing units. If a chlorination method is selected that requires the storage facility to be drained in order to dispose of highly chlorinated water, thorough consideration should be given to the effect on the receiving environment. If there is any question as to whether a chlorinated-waste discharge may cause damage to fish life, plant life, physical installations, or other downstream water uses of any type, an adequate amount of a reducing agent should be applied to the discharged water in order to thoroughly neutralize the chlorine residual.

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

III.A. *Purchaser Options and Alternatives.* This standard is written as though the work will be done by the purchaser's personnel. If the purchaser is contracting for the work to be done, appropriate provisions should be included in the contract agreement to ensure the contractor is specifically instructed as to his or her responsibilities. At a minimum, the purchaser should specify the following:

1. Standard used—that is, ANSI/AWWA C652, Disinfection of Water-Storage Facilities, of latest revision.
2. Whether compliance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, is required.
3. Method of disinfection to be used.
4. Any required disposal and precautions to be taken in disposing of chlorinated water in the storage facility.
5. Bacteriological testing and method to be used.
6. Redisinfection procedure if required.
7. Details of other federal, state or provincial, and local requirements (Section 4).

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. Major changes made in this revision of ANSI/AWWA C652 are as follows:

1. Several definitions have been added or updated.
2. Addition of Sec. 5.1.1.5, Optional Sampling and Testing.
3. Broad revision of Sec. 4.4.7, Post-inspection chlorine residual, turbidity, and bacteriological testing.

V. Comments. If you have any comments or questions about this standard, please call 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 e-mail at standards@awwa.org.

ANSI/AWWA C652-11
(Revision of ANSI/AWWA C652-02)

American Water Works Association

AWWA Standard

Disinfection of Water-Storage Facilities

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard for disinfection of water-storage facilities describes materials, facility preparation, application of disinfectant to interior surfaces of facilities, and sampling and testing for the presence of coliform bacteria, chlorine residual, and acceptable aesthetic water quality. The standard also includes disinfection procedures for underwater inspection and/or cleaning of potable-water-storage facilities but does not describe the technical aspects of underwater inspection and/or cleaning. All new storage facilities shall be disinfected before they are placed in service. All storage facilities taken out of service for inspection, repair, painting, cleaning, or other activity that might lead to water contamination shall be disinfected before they are returned to service.

Sec. 1.2 Purpose

The purpose of this standard is to define the minimum requirements for the disinfection of water storage facilities, including the preparation of water storage facilities, application of chlorine, procedures for disinfecting underwater inspection and cleaning equipment, and sampling and testing for the presence of coliform bacteria, chlorine residual, and acceptable aesthetic water quality.

Sec. 1.3 Application

This standard can be referenced in specifications for the disinfection of water storage facilities and can be used as a guide in preparing water storage facilities for disinfection procedures following inspection or maintenance. These procedures include the application of chlorine, disinfection procedures to be used during underwater inspections and/or cleaning, and testing for the presence of coliform bacteria, chlorine residual, and acceptable aesthetic water quality. The stipulations of this standard apply when this document has been referenced and then only to the disinfection of water storage facilities.

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 B300—Hypochlorites.

ANSI/AWWA B301—Liquid Chlorine.

ANSI/AWWA C655—Field Dechlorination.

Standard Methods for the Examination of Water and Wastewater. APHA,† AWWA, and WEF.‡ Washington, D.C. (latest edition).

Additional materials relating to activity according to this standard include the following:

Chlorine Manual—Chlorine Institute Inc.§

Water Treatment. WSO Series, Vol. 2. AWWA, Denver.

Material safety data sheets for forms of chlorine used (provided by suppliers).

NSF/ANSI 60—Drinking Water Treatment Chemicals—Health Effects.

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

Safety Practices for Water Utilities. AWWA Manual M3. AWWA, Denver.

Water Chlorination/Chloramination Practices and Principles. AWWA Manual M20. AWWA, Denver.

Water Quality and Treatment. AWWA, Denver.

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† American Public Health Association, 800 I Street NW, Washington, DC 20001.
‡ Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314.
§ Chlorine Institute Inc., 2001 L St. NW, Suite 506, Washington, DC 20036.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Available chlorine:* A measure of the amount of chlorine in chlorinated lime, hypochlorite compounds, chloramines, and other materials that are used for disinfection as compared to the amount in elemental (liquid or gaseous) chlorine.

2. *Chlorine, combined:* The amount of chlorine combined with ammonia (NH_3) or other compounds in water.

3. *Chlorine, free:* Also called free available chlorine, the amount of chlorine available as dissolved gas (Cl_2), hypochlorous acid (HOCl), and hypochlorite (OCl^-) that is not combined with ammonia (NH_3) or other compounds in water that is available for disinfection.

4. *Chlorine residual:* Concentration of chlorine species present in water after the oxidant demand has been satisfied.

5. *Chlorine, total:* The summation of free chlorine, combined chlorine, and organochlorine species.

6. *Contractor:* The party that provides the work and materials for placement or installation.

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

8. *Organochlorine:* Any organic compound containing chlorine as a constituent. Organochlorine compounds can form when chlorine reacts with organic substances.

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

10. *Potable water:* Water that is safe and satisfactory for drinking and cooking.

11. *ROV:* Remotely operated vehicle

12. *Supplier:* The party that supplies material or services. A supplier may or may not be the manufacturer.

SECTION 4: REQUIREMENTS

Sec. 4.1 Materials and Cleaning

4.1.1 *Materials.* Materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for potable water, wastewater, and reclaimed water systems as applicable.

4.1.2 *Materials entering tank.* Scaffolding, planks, tools, rags, and other materials not part of the structural or operating facilities of the tank shall be removed. Then the surfaces of the walls, floor, and operating facilities of the storage facility shall be cleaned thoroughly using a high-pressure water jet, sweeping, scrubbing, or equally effective means. Water, dirt, and foreign material accumulated in this cleaning operation shall be discharged from the storage facility or otherwise removed. Water used for cleaning, preparation of solutions, and tank filling shall be potable water.

4.1.3 *Other materials.* Following the cleaning operation, the vent screen, overflow screen, and any other screened openings shall be checked and put in satisfactory condition to prevent birds, insects, and other possible contaminants from entering the facility. Any material required to be in the operating storage facility after the cleaning procedure has been completed shall be clean and sanitary when placed in the facility. In these instances, care shall be taken to minimize the introduction of dirt or other foreign material.

Sec. 4.2 Forms of Chlorine for Disinfection

The forms of chlorine that may be used in the disinfecting operations are liquid chlorine, sodium hypochlorite solution, and calcium hypochlorite granules or tablets. Appropriate personal protective equipment should be worn when using these products.

4.2.1 *Liquid chlorine.* Liquid chlorine conforming to ANSI/AWWA B301 contains 100 percent available chlorine and is packaged in steel containers usually of 100-lb, 150-lb, or 1-ton (45.4-kg, 68.0-kg, or 907.2-kg) net chlorine weight. Liquid chlorine shall be used only (1) in combination with appropriate gas-flow chlorinators and ejectors to provide a controlled high-concentration solution feed to the water to be chlorinated; (2) under the direct supervision of a person who is familiar with chlorine's physiological, chemical, and physical properties, and who is trained and equipped to handle any emergency that may arise; and (3) when appropriate safety practices to protect working personnel and the public are observed.

4.2.2 *Sodium hypochlorite.* Sodium hypochlorite conforming to ANSI/AWWA B300 is available in liquid form in glass, rubber-lined, or plastic containers typically ranging in size from 1 qt (0.95 L) to 5 gal (18.92 L). Containers of 30 gal (113.6 L) or larger may be available in some areas. Sodium hypochlorite contains approximately 5 percent to 15 percent available chlorine by volume, and care must be taken to control storage conditions and length of storage to minimize its deterioration.

4.2.3 *Calcium hypochlorite.* Calcium hypochlorite conforming to ANSI/AWWA B300 is available in granular form or in small tablets and contains approximately 65 percent available chlorine by weight. The material should be stored in a cool, dry, dark environment to minimize its deterioration.

Sec. 4.3 Methods of Chlorination

Three methods of chlorination are explained in this standard. Typically, only one method will be used for a given storage-facility disinfection, but combinations of the methods may be used. The three methods are (1) chlorination of the full storage facility such that, at the end of the appropriate retention period, the water will have a free chlorine residual of not less than 10 mg/L; (2) spraying or painting of all storage facility water-contact surfaces with a solution of 200-mg/L available chlorine; and (3) a two-step process of chlorinating the bottom portion of the storage facility with 50-mg/L available chlorine followed by filling to overflow and maintaining a free chlorine residual of at least 2 mg/L for 24 hr.

4.3.1 *Chlorination method 1.* The water-storage facility shall be filled to the overflow level with potable water to which enough chlorine shall be added to provide a free chlorine residual in the full facility of not less than 10 mg/L at the end of the appropriate 6-hr or 24-hr period, as described in Sec. 4.3.1.4. The chlorine, either as calcium hypochlorite, sodium hypochlorite, or liquid chlorine, shall be introduced into the water as described in the following subsections.

4.3.1.1 Liquid-chlorine use. Liquid chlorine shall be introduced into the water filling the storage facility in such a way as to give a uniform chlorine concentration during the entire filling operation. Portable chlorination equipment shall be carefully operated and shall include a liquid-chlorine cylinder, gas-flow chlorinator, chlorine ejector, safety equipment, and an appropriate solution tube to inject the high-concentration chlorine solution into the filling water. The solution tube shall be inserted through an appropriate valve located on the inlet pipe and near the storage facility such that the chlorine solution will mix readily with the influent water.

4.3.1.2 Sodium hypochlorite use. Sodium hypochlorite shall be added to the water entering the storage facility by means of a chemical-feed pump or shall be applied by hand-pouring into the storage facility and allowing the influent water to provide the desired mixing.

4.3.1.2.1 When a chemical-feed pump is used, the concentrated chlorine solution shall be pumped through an appropriate solution tube so as to inject the high-concentration chlorine solution at a rate that will give a uniform chlorine concentration in the filling water. The solution tube shall be inserted through an appropriate valve located on the inlet pipe and near the storage facility, or through an appropriate valve located on the storage facility such that the chlorine solution will mix readily with the filling water.

4.3.1.2.2 When sodium hypochlorite is poured into the storage facility, the filling of the storage facility shall begin immediately thereafter or as soon as any removed manhole covers can be closed. Sodium hypochlorite may be poured through the cleanout or inspection manhole in the lower course or level of the storage facility, in the riser pipe of an elevated tank, or through the roof manhole. Sodium hypochlorite shall be poured into the water in the storage facility when the water is not more than 3 ft (0.9 m) in depth, nor less than 1 ft (0.3 m) in depth or as close thereto as manhole locations permit.

4.3.1.3 Calcium hypochlorite use. Calcium hypochlorite granules or tablets broken or crushed to sizes not larger than ¼-in. (6.4-mm) maximum dimension may be poured or carried into the storage facility through the cleanout or inspection manhole in the lower course or level of the storage facility, into the riser pipe of an elevated tank, or through the roof manhole. The granules or tablet particles shall be placed in the storage facility before flowing water into it. The granules or tablets shall be located so that the influent water will circulate through the calcium hypochlorite, dissolving it during the filling operation. The calcium hypochlorite shall be placed only on dry surfaces unless adequate precautions are taken to provide ventilation or protective breathing equipment.

4.3.1.4 Retention period. After the storage facility has been filled with the disinfecting water, it shall stand full as follows: (1) for a period of not less than 6 hr when the water entering the storage facility has been chlorinated uniformly by gas-feed equipment or chemical pump, or (2) for a period of not less than 24 hr when the storage facility has been filled with water that has been mixed with sodium hypochlorite or calcium hypochlorite within the storage facility as described in Sec. 4.3.1.2 and 4.3.1.3.

4.3.1.5 Handling of disinfection water. After the retention period stated in Sec. 4.3.1.4, the free chlorine residual in the storage facility shall be reduced to a concentration appropriate for distribution by completely draining the storage facility and refilling with potable water, or by a combination of additional holding time and blending with potable water having a lower chlorine concentration. Following this procedure and subject to satisfactory bacteriological testing, appropriate chlorine residual, and acceptable aesthetic water quality, the water may be delivered to the distribution system.

4.3.1.5.1 The environment into which the chlorinated water is to be discharged shall be inspected, and if there is any likelihood that the chlorinated discharge will cause damage, a reducing agent shall be applied to the water to be discharged to neutralize the chlorine residual in the water. Federal, state or provincial, and local environmental regulations may require special provisions or permits prior to disposal of highly chlorinated water. Proper authorities should be contacted prior to disposal of highly chlorinated water.

4.3.2 *Chlorination method 2.* A solution of at least 200-mg/L available chlorine shall be applied directly to the surfaces of parts of the storage facility that would be in contact with water when the storage facility is full to the overflow elevation.

4.3.2.1 Method of application. The chlorine solution may be applied with suitable brushes or spray equipment. The solution shall thoroughly coat surfaces to be treated, including the inlet and outlet piping, and shall be applied to any separate drain piping such that it will have available chlorine of not less than 10 mg/L when filled with water. Overflow piping need not be disinfected.

4.3.2.2 Retention. The disinfected surfaces shall remain in contact with the strong chlorine solution for at least 30 min, after which potable water shall be admitted, the drain piping purged of the 10-mg/L chlorinated water, and the storage facility then filled to its overflow level. Following this procedure and subject to satisfactory bacteriological testing, appropriate chlorine residual, and acceptable aesthetic water quality, the water may be delivered to the distribution system.

4.3.3 *Chlorination method 3.* Water and chlorine shall be added to the storage facility in amounts such that the solution will initially contain at least 50 mg/L available chlorine and will fill approximately 5 percent of the total storage volume. This solution shall be held in the storage facility for a period of not less than 6 hr. The storage facility shall then be filled to the overflow level by flowing potable water into the highly chlorinated water. It shall be held full for a period of not less

than 24 hr. Highly chlorinated water shall then be purged from the drain piping. Following this procedure and subject to satisfactory bacteriological testing, appropriate chlorine residual, and acceptable aesthetic water quality, the remaining water may be delivered to the distribution system.

4.3.3.1 Adding chlorine. Chlorine shall be added to the storage facility by the method described in Sec. 4.3.1.1, 4.3.1.2, or 4.3.1.3. The actual volume of the 50-mg/L chlorine solution shall be such that, after the solution is mixed with filling water and the storage facility is held full for 24 hr, there will be a free-chlorine residual of not less than 2 mg/L.

Sec. 4.4 Disinfection Procedures When Conducting Underwater Inspection and/or Cleaning of Potable-Water-Storage Facilities

4.4.1 *Pre-job meeting.* A pre-job meeting involving the contractor and water utility representatives shall be held to ensure the following: that the personnel understand the configuration of the reservoir and the disinfection procedures; that underwater appurtenances are identified; that time restrictions are discussed; that the diving conditions are considered; that safety procedures are in place; and that inspection and/or cleaning requirements are understood. Any problems associated with logistics should be resolved at this time. Clear communication between utility operations personnel and the contractor is essential.

4.4.2 *Storage-facility isolation.* It is strongly recommended that the water storage facility be removed from service and isolated from the system prior to inspection and/or cleaning by closing inlet and outlet valves. Flowmeters and the tank level should be monitored to verify that the facility has been isolated. The underwater inspection and/or cleaning should be made with the reservoir as full as possible, while still leaving room for access to the roof area. If the reservoir must be inspected with the inlet/outlet valves in the open position, system valves further upstream or downstream should be closed. Off-line inspection and/or cleaning of storage facilities may not be possible or convenient for certain tanks or clearwells. In-service diving work may be completed safely, but strict attention to safety is required. If special operational conditions necessitate underwater inspection and/or cleaning without isolation, diving work should be done during periods when positive flow into the reservoir is maintained and rates into or out of the water-storage facility are minimal. For underwater inspection and/or cleaning of nonisolated facilities having a common inlet/outlet pipe, it is strongly recommended that a positive flow into the storage facility be maintained during the dive.

4.4.3 *Storage-facility access.* Special care should be taken to keep equipment and personnel clean prior to entering the tank. Dirt and contaminants on the reservoir roof/adjacent to the hatch can contaminate equipment. Before the facility access hatch is opened, the hatch and immediate area shall be cleaned of loose dirt and debris.

4.4.4 *Initial water quality.* The utility shall establish the chlorine residual and turbidity in the reservoir water before entering it. The utility should take representative water samples from several depths and locations, if possible, and analyze for chlorine residual and turbidity. The results shall be recorded. Chlorine residual testing is not necessary if the system does not operate with a chlorine residual. If the water storage facility remains in service during the cleaning operation, samples shall be collected daily from the tank and tested for coliform bacteria, chlorine residual (if applicable), and turbidity.

4.4.5 *Equipment and personnel requirements.*

4.4.5.1 Equipment and clothing. Equipment used for inspection and/or cleaning of potable-water-storage facilities shall be dedicated for that purpose only. Equipment shall be constructed and maintained in such a fashion so that water quality will not be affected. Equipment shall be available for inspection.

4.4.5.1.1 According to this standard, both SCUBA (self-contained underwater breathing apparatus) and externally supplied air methods are acceptable air sources.

4.4.5.1.2 Equipment exposed to the water shall be suitable for disinfection. Divers shall be completely encapsulated with no bare skin exposed. Diving clothing shall be of the dry-suit type and shall be in good condition, free from tears, scrapes, unrepaired areas, or other imperfections that may impair the integrity of the suit. Equipment and dry suits dedicated for potable-water underwater inspection and/or cleaning work shall be stored in a manner that prevents both chemical and bacteriological contamination.

4.4.5.1.3 There shall be no contact of the mouth or head with the water during any underwater operations. The head shall be fully encapsulated by one or a combination of the following: helmet or dry suit hood with full-face mask.

4.4.5.1.4 Divers shall have communication in accordance with federal, state or provincial, and local regulations.

4.4.5.1.5 Underwater operations may be videotaped or documented with still photographs at the utility's request.

4.4.5.1.6 Disturbing tank bottom sediment may impair water quality. Sediment may contain bacteria, which if resuspended can cause contamination. Disturbed sediment will create localized turbidity. In some cases, it may be desirable to disturb a small area of thin sediment in order to inspect the underlying coating or floor condition. Divers or remotely operated vehicles shall not disturb the sediment in any way unless explicitly approved by the utility to do so; this includes "walking on the floor."

4.4.5.2 Personnel requirements. Because of the hazardous nature of this work, which combines elevated work, confined-space entry, and diving, the contractor performing the work shall comply with all federal, state or provincial, and local regulations.

4.4.5.2.1 Certain diving contractors who have been providing these services for many years may not have the formal certifications listed below. Utilities should carefully review the documentation of training and experience for these firms and require a detailed personal diver's log for the personnel who will conduct the on-site work. The presentation of a sport diver certification card for SCUBA by itself is not acceptable proof of proper training.

The following is a limited list of examples of diver qualifications that are acceptable—but not without detailed documentation of training and direct tank inspection and/or cleaning work experience:

2nd Class US Navy Diver Training

ANSI/ACDE 01 (latest version) Commercial Diver Certification

ADC Commercial Certification

4.4.5.2.2 Personnel on the dive team must be OSHA Confined Space Certified. These certificates should be provided on the job site for all personnel.

4.4.5.2.3 All personnel on the dive team shall be free of communicable disease and shall not have been under a physician's care within the seven-day period prior to the entering of the facility. No person who knowingly has an abnormal temperature or symptoms of illness shall work in a water-storage facility.

4.4.5.2.4 The American Red Cross or an equivalent agency shall certify all dive team members in the use of CPR and First Aid.

4.4.5.3 Safety. The dive team shall comply with all applicable local, state or provincial, and federal safety requirements and shall provide all necessary safety equipment suitable for the specific access opening, depth to water, and other aspects of the water-storage facility to be inspected.

4.4.5.3.1 The contractor shall have a comprehensive safety manual on-site, which addresses all of the potential hazards. The safety manual shall include certifications for all safety and emergency response requirements at the site. The contractor shall have a method and the equipment readily available for the extraction of an injured diver and a method for lowering a person to the ground who is incapacitated. This may include the use of a properly trained and equipped local fire department or rescue squad. The use of an outside response team must be covered in the pre-job meeting, and they must be able to respond quickly or be on-site during the work.

4.4.6 *Equipment and personnel disinfection.* All equipment and personnel that will enter the water-storage facility must be disinfected immediately prior to entry into the potable-water reservoir. Any equipment making contact with the tank roof must be disinfected again prior to entry into the water. The method of equipment disinfection can be submersion in, spraying with, or sponging with disinfectant solution as defined in Sec. 4.3.2. The diver and the clothing shall be disinfected after the diver is suited up and on top of the tank as per Sec. 4.3.2. Care must be taken when applying disinfectant solution to the diver, remotely operated vehicle, and other cleaning equipment so that any excess, runoff, or spillage is controlled so it does not enter the reservoir. Handle chlorine solutions with care so as not to contact personnel clothing or skin. Appropriate personal protective equipment should be worn when using these products.

4.4.7 *Post-inspection chlorine residual, turbidity, and bacteriological testing.* Collect samples and test as described in Section 5, Verification. If the storage tank was removed from service, satisfactory bacteriological and chlorine residual (if applicable) results are required before the facility can be placed back in service. If it is necessary to rebuild chlorine residuals in the storage facility, bacteriological samples should be collected after chlorine residuals are brought to an acceptable level.

4.4.8 *Affidavit of compliance.* The purchasing utility may require that the contractor performing the inspection and/or cleaning services provide an affidavit of compliance with the requirements of this standard.

SECTION 5: VERIFICATION

Sec. 5.1 Water Quality Sampling and Testing

5.1.1 *Standard conditions.* After the chlorination procedure is completed and before the storage facility is placed in service, water from the full facility shall be sampled and tested for coliform bacteria and chlorine residual in accordance with the latest edition of *Standard Methods for the Examination of Water and Wastewater*.

5.1.1.1 Test for odor. The water in the full facility should also be tested to ensure that no offensive odor exists.

5.1.1.2 Results of testing. If the test for coliform organisms is negative and chlorine residuals are at acceptable distribution system levels, the storage facility may be placed in service. If the test shows the presence of coliform bacteria, the situation shall be evaluated by qualified personnel. In this case, repeat samples shall be taken until two consecutive samples are negative, or the storage facility shall again be subjected to disinfection.

5.1.1.3 Care in sampling. The samples shall be taken from a sample tap on the outlet piping from the storage facility or from a sample tap connected directly to the storage facility, or sampling from the top of the tank or hatch may be required. In any case, the operation shall be such so as to ensure that the sample collected is actually from water that has been in the storage facility. Sample equipment and methods shall follow aseptic techniques for bacteria sampling.

5.1.1.4 Recommended additional samples. It may be advisable to collect samples of water flowing into the storage facility to determine if coliforms are present in the typical potable water source, particularly if coliform bacteria are found in the tank.

5.1.1.5 Optional sampling and testing. Following disinfection and prior to activating the tank for use, water in the storage tank should be tested to determine that it meets expected parameters typical in the system. Test results should confirm that the water quality is appropriate for distribution. Although this assessment is unique for each system, suggested test parameters include pH, alkalinity, turbidity, odor, and specific conductance. If the tank was painted or if epoxy was applied, measuring levels of volatile organic compounds or other components of the coating material (such as zinc) may be necessary (noting that THMs, which are part of the VOC test, are a result of disinfection, not coating materials, and would be expected to be present). Depending on the size of the storage facility,

more samples may be appropriate. While the number of samples above the required number is up to the discretion of the water system operator, suggested numbers include one sample for tanks of 10 MG or less and an additional sample for each additional 10 MG volume, using another tap or hatch if available. The specific number of samples necessary should be determined beforehand and will depend on tank volume and sample tap or hatch availability.

SECTION 6: DELIVERY

This standard has no applicable information for this section.

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APPENDIX A

Chlorine Residual Testing

This appendix is for information only and is not part of ANSI/AWWA C652.

SECTION A.1: DPD DROP DILUTION METHOD (FOR FIELD TEST)

The N, N-diethyl-p-phenediamine (DPD) drop dilution method of approximating residual chlorine is suitable for concentrations above 10 mg/L, such as those applied in the disinfection of water mains or tanks.

Sec. A.1.1 Apparatus

1. A graduated cylinder for measuring distilled water.
2. An automatic or safety pipette.
3. Two dropping pipettes that deliver a 1-mL sample in 20 drops. One pipette is for dispensing the water sample, and the other is for dispensing the DPD and buffer solutions. The pipettes should not be interchanged.
4. A comparator kit containing a suitable range of standards.

Sec. A.1.2 Reagents

1. DPD indicator solution. Prepare as prescribed in *Standard Methods for the Examination of Water and Wastewater* (latest edition), Section 4500-Cl, p. F.2b.
2. Phosphate buffer solution. Prepare as prescribed in *Standard Methods for the Examination of Water and Wastewater* (latest edition), Section 4500-Cl, p. F.2a.

Sec. A.1.3 Procedure

1. Add 10 drops of DPD solution and 10 drops of buffer solution (or 20 drops of combined DPD-buffer solution) to a comparator cell.
2. Fill the comparator cell to the 10-mL mark with distilled water.
3. With a dropping pipette, add the water sample one drop at a time, mix until a red color is formed that matches one of the color standards.
4. Record the total number of drops used and the final chlorine reading obtained (that is, the chlorine reading of the matched standard).

5. Calculate the milligrams per liter of chlorine residual as follows:

$$\text{mg/L chlorine} = \frac{\text{reading} \times 200}{\text{drops of sample}}$$

SECTION A.2: HIGH-RANGE CHLORINE TEST KITS

Several manufacturers produce high-range chlorine test kits that are inexpensive, easy to use, and satisfactory for the precision required.

APPENDIX B

Chlorine Dosages

This appendix is for information only and is not a part of ANSI/AWWA C652.

Table B.1 Amounts of chemical required to give various chlorine concentrations in 100,000 gal (378.5 m^3) of water*

Desired Chlorine Concentration in Water	Chlorine Required		Sodium Hypochlorite Required						Calcium Hypochlorite Required	
			5 Percent Available Chlorine		10 Percent Available Chlorine		15 Percent Available Chlorine		65 Percent Available Chlorine	
mg/L	*lb*	*(kg)*	*gal*	*(L)*	*gal*	*(L)*	*gal*	*(L)*	*lb*	*(kg)*
2	1.7	(0.8)	3.9	(14.7)	2.0	(7.6)	1.3	(4.9)	2.6	(1.1)
10	8.3	(3.8)	19.4	(73.4)	9.9	(37.5)	6.7	(25.4)	12.8	(5.8)
50	42.0	(19.1)	97.0	(367.2)	49.6	(187.8)	33.4	(126.4)	64.0	(29.0)

*Amounts of sodium hypochlorite are based on concentrations of available chlorine by volume. For either sodium hypochlorite or calcium hypochlorite, extended or improper storage of chemicals may cause a loss of available chlorine. Also, amounts do not take into account chlorine demand or chlorine residual that might be present in the water.

Table B.2 Amounts of chemical required to give a chlorine concentration of 200 mg/L in various volumes of water*

Volume of Water		Chlorine Required		Sodium Hypochlorite Required						Calcium Hypochlorite Required	
				5 Percent Available Chlorine		10 Percent Available Chlorine		15 Percent Available Chlorine		65 Percent Available Chlorine	
gal	*(L)*	*lb*	*(kg)*	*gal*	*(L)*	*gal*	*(L)*	*gal*	*(L)*	*lb*	*(kg)*
10	(37.9)	0.02	(9.1)	0.04	(0.15)	0.02	(0.08)	0.02	(0.08)	0.03	(13.6)
50	(189.3)	0.10	(45.4)	0.20	(0.76)	0.10	(0.38)	0.07	(0.26)	0.15	(68.0)
100	(378.5)	0.20	(90.7)	0.40	(1.51)	0.20	(0.76)	0.15	(0.57)	0.30	(146.1)
200	(757.1)	0.40	(181.4)	0.80	(3.03)	0.40	(1.51)	0.30	(1.14)	0.60	(272.2)

*Amounts of sodium hypochlorite are based on concentrations of available chlorine by volume. For either sodium hypochlorite or calcium hypochlorite, extended or improper storage of chemicals may cause a loss of available chlorine. Also, amounts do not take into account chlorine demand or chlorine residual that might be present in the water.

APPENDIX C

Disposal of Highly Chlorinated Water

This appendix is for information only and is not a part of ANSI/AWWA C652. Refer to ANSI/AWWA C655.

1. Check with the local sewer department for the conditions of disposal to the sanitary sewer.

2. Chlorine residual of water being disposed of will be neutralized by treatment with one of the chemicals listed in Table C.1.

Table C.1 Amounts of chemical required to neutralize various residual chlorine concentrations in 100,000 gal (378.5 m^3) of water

Residual Chlorine Concentration	Chemical Required							
	Sulfur Dioxide (SO_2)		Sodium Bisulfite ($NaHSO_3$)		Sodium Sulfite (Na_2SO_3)		Sodium Thiosulfate ($Na_2S_2O_3•5H_2O$)	
mg/L	*lb*	*(kg)*	*lb*	*(kg)*	*lb*	*(kg)*	*lb*	*(kg)*
1	0.8	(0.36)	1.2	(0.54)	1.4	(0.64)	1.2	(0.54)
2	1.7	(0.77)	2.5	(1.13)	2.9	(1.32)	2.4	(1.09)
10	8.3	(3.76)	12.5	(5.67)	14.6	(6.62)	12.0	(5.44)
50	41.7	(18.91)	62.6	(28.39)	73.0	(33.11)	60.0	(27.22)

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