Thermosetting Fiberglass-Reinforced Plastic Tanks

This edition approved Jan. 25, 2009.
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 codes 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 classified advertising section of Journal AWWA. The action becomes effective on the first day of the month following the month of Journal AWWA 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 This American National Standard may be revised or withdrawn at any time.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.

This AWWA content is the product of thousands of hours of work by your fellow water professionals. Revenue from the sales of this AWWA material supports its ongoing development. Unauthorized distribution, either electronic or photocopied, is illegal and hinders AWWA's mission to support the water community.

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information or retrieval system, except in the form of brief excerpts or quotations for review purposes, without the written permission of the publisher.

Copyright © 2009 by American Water Works Association
Printed in USA

Copyright © 2009 American Water Works Association, All Rights Reserved.
Committee Personnel

The AWWA Standards Committee on Thermosetting Fiberglass-Reinforced Plastic Tanks, which developed and approved this standard, had the following personnel at the time of approval:

Phillip A. Sharff, Chair

General Interest Members

J.J. Cusack Jr., Bryant Associates, Boston, Mass. (AWWA)
M.W. Grimm,* Standards Council Liaison, Sunrise Water Authority, Happy Valley, Ore. (AWWA)
R. Lewandowski, Corrosion Resistant Composites, Timonium, Md. (AWWA)
S.M. Passarelli,* Standards Engineer Liaison, AWWA, Denver, Colo. (AWWA)
P.A. Sharff, Simpson Gumpertz & Heger Inc., Waltham, Mass. (AWWA)

Producer Members

S.D. Curran, Fiberglass Tank & Pipe Institute, Houston, Texas (AWWA)
J. Small, Darco Incorporated, Denver, Colo. (AWWA)

User Members

C.J. Patla, Connecticut Water Service Inc., Clinton, Conn. (NEWWA)
C.N. Strother, Denver Water, Denver, Colo. (AWWA)

*Liaison, nonvoting
This page intentionally blank.
Contents

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

<table>
<thead>
<tr>
<th>SEC.</th>
<th>PAGE</th>
<th>SEC.</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td></td>
<td>4.6</td>
<td>Physical and Mechanical Properties of Tank Shell</td>
</tr>
<tr>
<td>I</td>
<td>Introduction</td>
<td>vii</td>
<td>Environmental Resistance of Tank Shell</td>
</tr>
<tr>
<td>1.A</td>
<td>Background</td>
<td>vii</td>
<td>Leakage Under Internal Pressure</td>
</tr>
<tr>
<td>1.B</td>
<td>History</td>
<td>vii</td>
<td>Additional Requirements for Underground Tanks</td>
</tr>
<tr>
<td>1.C</td>
<td>Acceptance</td>
<td>viii</td>
<td>Construction</td>
</tr>
<tr>
<td>II</td>
<td>Special Issues</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Use of This Standard</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>III.A</td>
<td>Purchaser Options and Alternatives</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>III.B</td>
<td>Modification to Standard</td>
<td>xi</td>
<td></td>
</tr>
<tr>
<td>III.C</td>
<td>Information to Be Supplied by Manufacturer</td>
<td>xi</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Major Revisions</td>
<td>xi</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Comments</td>
<td>xi</td>
<td></td>
</tr>
</tbody>
</table>

Standard

1 General

1.1 Scope | 1

1.2 Purpose | 2

1.3 Application | 2

2 References | 2

3 Definitions | 4

4 Requirements

4.1 Classification | 5

4.2 Potable Water Service | 5

4.3 Materials | 5

4.4 General Requirements | 6

4.5 Design | 7

5 Verification

5.1 General | 17

5.2 Production Tests | 18

5.3 Physical and Mechanical Properties of Tank Shell | 19

5.4 Environmental Resistance | 20

5.5 Additional Tests for Underground Tanks | 21

5.6 Aboveground-Tank Surface Burning Characteristics | 23

5.7 Retest | 23

5.8 Inspection and Testing by Purchaser | 23

6 Delivery

6.1 Marking | 24

6.2 Packaging and Shipping | 24

6.3 Handling | 25

6.4 Installation | 25

6.5 Affidavit of Compliance | 26
### Appendixes

| A | Explanatory Notes to D120 | 27 |
| B | Preinstallation Site Analysis for Underground Tanks | 29 |
| C | Accessories for Underground Tanks | 31 |
| D | Flanged-Joint Bolts, Gaskets, and Installation | 33 |

### Figures

| 1 | Flanged Nozzle | 15 |
| 2 | Reinforcement of Cut Tank Wall for Nozzle Attachment | 16 |
| 3 | Installed Nozzle (With Pipe Penetration) | 17 |
| 4 | Installed Nozzle (Without Pipe Penetration) | 17 |

### Tables

| 1 | Design Loads | 7 |
| 2 | Minimum Widths of Overlaid Joints (Exclusive of Taper) | 11 |
| 3 | Pipe for Nozzle Assembly | 14 |
| 4 | Minimum Flange Thickness for FRP Nozzles | 14 |
| 5 | Shear-Bond Area—Nozzles | 16 |
| 6 | Torques on Pipe Fittings | 22 |
Foreword

This foreword is for information only and is not a part of ANSI/AWWA D120.

1. Introduction.

1.A. Background. The purpose of this standard is to establish the significant quality requirements for commercially available thermosetting fiberglass-reinforced plastic (FRP) tanks for use in the water utility industry. This standard is based on the technology for the fabrication of the tanks by either the contact-molded or filament-wound process. It is intended that the tanks are to be used for the storage of water and other liquids. Both aboveground and underground tanks are covered. The specific application must consider the limitations as specified according to Sec. 1.1, and information must be provided by the user to completely describe the tank requirements.

1.B. History. In June 1971, the Engineering and Construction Committee, appointed by the AWWA Technical and Professional Council, evaluated the use of reinforced plastics in the water utility industry and found sufficient use of products made from this material to recommend the development of an AWWA standard. One of the most extensive uses of reinforced plastics was for the construction of tanks. At the 1974 fall meeting, the AWWA Standards Council approved the formation of a committee for the preparation of an AWWA standard for reinforced plastic tanks for the water utility industry.

The standards committee began the preparation of the new standard early in 1975. The responses to a questionnaire sent out by the Engineering and Construction Committee indicated that the methods being followed for specifying and purchasing reinforced plastic products varied within the water utility industry. Frequently, it was the practice for the water utilities that were planning on using reinforced plastic products to state the actual or anticipated service conditions, and the manufacturer then warranted the product for that service. In other instances, the manufacturer presented a product for a particular type and condition of service, and the water utility then made the selection based on this presentation. Because of these practices, functional and product-design requirements used by both water utilities and tank fabricators evolved, and many of these were available to the committee.

In addition, applicable standards, specifications, and test methods published by ASTM International* (ASTM) and the US Department of Commerce were reviewed.

* ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.
by the committee. There were two documents the committee used as the basis for the AWWA standard: (1) ASTM D3299, Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks, and (2) National Bureau of Standards Voluntary Product Standard PS-15, Custom Contact-Molded Reinforced Polyester Chemical-Resistant Process Equipment.

The initial draft of the first edition of the standard was prepared and circulated to the committee members in 1976. The final draft was submitted to the committee for letter ballot voting on Apr. 15, 1983, and a consensus for acceptance was received. The standard was reaffirmed without revision on June 18, 1989.

In June 1997, the AWWA Standards Committee on Thermosetting Fiberglass-Reinforced Plastic Tanks began preparation of the revised standard. Inquiries into the water storage industry indicated the need for standards governing underground fiberglass-reinforced plastic tanks. The committee decided to incorporate in the revised standard current relevant standards for underground tanks used for storage of products other than water. For this purpose, the committee referred to UL' 1316, Glass-Fiber-Reinforced Plastic Underground Storage Tanks. Further, the committee recognized the need to update the standard to incorporate current standards for aboveground tank design and production. Standards referred to for this purpose included (1) ASTM D3299, Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks and (2) ASTM D4097, Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks.

The initial draft of the second edition of the standard was prepared and circulated to the committee members in 1998. The final draft was submitted to the committee for letter ballot voting in December 2001, and a consensus for acceptance was received. The second edition was approved by the AWWA Board of Directors on June 16, 2002.

This edition was approved on Jan. 25, 2009.

IV. 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 consortium included the American Water Works Association Research Foundation (AwwaRF), the Conference of State Health and Environmental Managers (COSHEM), the American Water Works Association (AWWA), and the Association of State Drinking Water Administrators (ASDWA). The consortium is responsible for

* Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

Copyright © 2009 American Water Works Association. All Rights Reserved.
the cooperative effort of manufacturers, regulators, product users, and other interested parties that develop and maintain the NSF standards.

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

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 to NSF/ANSI 61, “Toxicology Review and Evaluation Procedures,” 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.

This standard does not address additives requirements. Thus, users of ANSI/AWWA D120 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.

---

* NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.
† American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
‡ Both publications available from National Academy of Sciences, 500 Fifth Street, N.W., Washington, DC 20001.
II. Special Issues. This standard has no applicable information for this section.

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. Section III.A summarizes supplemental information that should be considered. The purchaser should review this information and other appropriate data and make provisions in the supplemental conditions to describe the specific service requirements.

III.A. Purchaser Options and Alternatives. Purchasers are advised that, while this standard presents information on materials and procedures for manufacture of the tank, it does not contain complete engineering information needed to prepare complete requirements for a particular tank installation. A specific installation may require provisions more restrictive than those in the standard and most certainly will require additional design and installation features. In placing orders for thermosetting fiberglass-reinforced plastic tanks to be manufactured in accordance with this standard, the purchaser, in its requirements, should include the following information:

1. Standard used—that is, ANSI/AWWA D120, Thermosetting Fiberglass-Reinforced Plastic Tanks, of latest revision.

2. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required, in addition to the requirements of the Safe Drinking Water Act.

3. Type of tank—aboveground or underground.


5. Material to be stored in the tank.

6. Height, width, and weight limitations.

7. Temperature conditions.

8. Fittings and attachments to be provided and their description.

9. Installation conditions.

10. Operating conditions.

11. Whether certified drawings are to be provided (Sec. III.C. Foreword).

12. Details of other federal, state or provincial, and local requirements (Sec. 4.2.1 and Sec. 4.3).

13. Whether ultraviolet absorbers are to be added (Sec. 4.3.1.2).

14. Whether fire-retardant agents are to be added (Sec. 4.3.1.4).

15. Loading conditions and design criteria (Sec. 4.5).
16. Whether the outside surface is to be pigmented, painted, or dyed (Sec. 4.10.2.4).
17. Type of flange gaskets (Sec. 4.10.5).
18. Location of hold-down or lift lugs (Sec. 4.10.7 and 4.10.8).
19. Test samples to be provided by the manufacturer (Sec. 5.1.3).
20. Test media for immersion tests (Sec. 5.4.2.2).
21. Test temperature for immersion tests (Sec. 5.4.2.4).
22. Retest agreement (Sec. 5.7).
23. Whether plant inspection is required (Sec. 5.8.1).
24. Tests to be performed by the manufacturer (Sec. 5.8.4).
25. Whether an affidavit of compliance is to be provided (Sec. 6.5).

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

III.C. Information to Be Supplied by Manufacturer. When required, the manufacturer or its representative shall submit, for acceptance by the purchaser, certified drawings showing the principal dimensions, construction details, and materials used for the fabrication. Work shall be done in accordance with these certified drawings after they have been accepted by the purchaser.

IV. Major Revisions. Major revisions made to the standard in this edition include the following:

1. Acceptable types of fittings for tanks have been expanded and clarified.
2. The internal pressure test for aboveground tanks was limited to hydrostatic testing; and the standard was updated to allow either hydrostatic or aerostatic testing for underground tanks subject to manufacturer's input.
3. Nonmandatory guidance on manways, manway extensions, anchor straps, and connection hardware for underground tanks has been expanded.
4. A new nonmandatory appendix on flanged-joint bolts, gaskets, and installation has been added.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group at 303.794.7711, FAX at 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail at standards@awwa.org.
Thermosetting Fiberglass-Reinforced Plastic Tanks

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes the composition, performance requirements, construction practices and workmanship, design, and methods of testing thermosetting fiberglass-reinforced plastic (FRP) tanks for the storage of water or other liquids used in water supply service.

1.1.1 Limit of standard. This standard is limited to atmospheric pressure, vented, cylindrical, and spherical tanks, installed either aboveground or underground.

1.1.2 Temperature limits. This standard is limited to tanks whose service temperature does not exceed 180°F (82°C) for aboveground tanks and 150°F (66°C) for underground tanks. Consult the tank manufacturer for recommended temperature limits (both minimum and maximum) for specific equipment and service requirements.

1.1.3 Service limits. The service limits for environmental exposure and structural loads shall be determined based on tests of laminates that are determined by the engineer to be representative of the materials and methods of fabrication used in the tank.
Sec. 1.2 Purpose

The purpose of this standard is to provide purchasers, manufacturers, and suppliers with the minimum requirements for thermosetting FRP tanks, including material and design.

Sec. 1.3 Application

This standard can be referenced in specifications for purchasing and receiving thermosetting FRP tanks. This standard can be used for manufacturing this type of tank. The stipulations of this standard apply when this document has been referenced, and then only to FRP tanks.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, these documents 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 C207—Steel Pipe Flanges for Water Works Service—Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm).

ASME† B1.1—Unified Inch Screw Threads (UN and UNR Thread Form).

ASME B16.1—Cast Iron Pipe Flanges and Flanged Fittings.

ASME B16.5—Pipe Flanges and Flanged Fittings.

ASME B18.2.1—Square and Hex Bolts and Screws, Inch Series.

ASME B18.2.2—Square and Hex Nuts, Inch Series.

ASME B36.10—Welded and Seamless Wrought Steel Pipe.

ASTM‡ A307—Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.


‡ASTM International. 100 Barr Harbor Drive, West Conshohocken, PA 19428.
ASTM D3567—Standard Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings.
NSF/ANSI† 60—Drinking Water Treatment Chemicals—Health Effects.
NSF/ANSI 61—Drinking Water Treatment Components—Health Effects.
UL‡ 1316—Glass-Fiber-Reinforced Plastic Underground Storage Tanks.

† NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48113.
‡ American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
§ Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062.
SECTION 3: DEFINITIONS

Unless otherwise indicated, the plastics terminology used in this standard is in accordance with ASTM D883, Standard Terminology Relating to Plastics. In this standard, the following definitions shall also apply:

1. **Constructor:** The person, firm, or corporation that provides the work and materials for installation of the FRP tank according to this standard.

2. **Contact molded:** A method of manufacture whereby a laminate of fiberglass reinforcement and resin is built up either by hand or by the use of a special spray gun that directs short fibers and catalyzed resin onto the mold surface.

3. **Corrosion-resistant barrier:** The inside portion of the laminate, composed of the inner surface and the interior layer, that acts as a protective barrier to the structural layer.

4. **Engineer:** The engineer responsible for the design and/or specification of the tank for the intended use.

5. **Filament-wound:** A method of manufacture whereby a continuous fiberglass-strand reinforcement, together with resin, is placed in a predetermined pattern onto a suitable mandrel until sufficient layers have been applied to form a laminate or part of a laminate.

6. **Head:** The end closure of cylindrical FRP tanks: may apply either to the top or to the bottom of an aboveground tank or to the ends of an underground tank.

7. **Manufacturer:** The person, firm, or corporation that actually manufactures the FRP tank according to this standard.

8. **Purchaser:** The person, firm, corporation, or government subdivision that purchases the FRP tank according to this standard.

9. **Relaxation:** The time-dependent reduction in stress under sustained strain.

10. **Resins:** A thermosetting polyester or vinyl ester that is cross-linked with styrene. The physical and chemical properties of resins vary greatly. Each type of resin has particular strengths and weaknesses for a given application, which require evaluation.

11. **Surfacing veil:** A fine reinforcement-mat layer applied to the laminate surface.
SECTION 4: REQUIREMENTS

Sec. 4.1 Classification

This standard describes the fabrication of thermosetting FRP tanks defined by principal method of manufacture (type) and resin materials used in the construction (grade).

4.1.1 Type. Type I—contact molded; type II—filament-wound. (See note in appendix A.)

4.1.2 Grade. Grade I—tanks manufactured with a single generic type of thermoset resin throughout; grade 2—tanks manufactured with a different generic type of resin in the inner surface or interior layer than in the structural layer.

Sec. 4.2 Potable Water Service

4.2.1 Qualification. Tanks specified for potable water service shall be constructed of materials that meet governing state and local regulations for potable water certification, including the Safe Drinking Water Act.

4.2.2 Certification. Tanks specified for potable water service shall be certified as suitable by a testing laboratory acceptable to the purchaser, in accordance with the requirements in Sec. 4.2.1. (See note in appendix A.)

Sec. 4.3 Materials

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

4.3.1 Resin. The resin shall be a commercial-grade, thermosetting plastic resin that has been evaluated in a laminate by test in accordance with Section 5 or that has been determined by the engineer to be acceptable for the service conditions based on previous documented service. The resin shall not contain fillers or pigments except as specified in Sec. 4.3.1.1, 4.3.1.2, 4.3.1.3, 4.3.1.4, and 4.3.1.5.

4.3.1.1 Thiokol agent. Up to 5 percent (by weight) thiokol agent that will not interfere with visual inspection may be added for viscosity control. Resin pastes used to fill crevices before overlay shall not be subject to this limitation.

4.3.1.2 Ultraviolet absorbers. Ultraviolet absorbers may be added to the final resin coating to improve weather resistance.

4.3.1.3 Pigments. Resins, catalysts, and other additives may contain pigments, dyes, or colorants, provided their concentration does not prevent detection of visual defects or adversely affect performance of the laminate.
4.3.4 Fire retardants. Fire-retardant agents may be added for improved fire resistance. (See note in appendix A.)

4.3.1.5 Fillers. Particulate fillers may be used only in accordance with Sec. 4.10.1.4.

4.3.2 Reinforcing material.

4.3.2.1 Fiberglass. The reinforcing material shall be a commercial-grade glass fiber having a coupling agent; it shall be compatible with the resin used and suitable for the particular fabrication technique. The reinforcing material used to fabricate the tank shall be comparable to that used to generate environmental-resistance and physical-property design data.

4.3.3 Surfacing materials.

4.3.3.1 Surfacing veil. The surfacing veil, when used in the interior layer, shall be commercial grade and chemical resistant, having a coupling agent.

Sec. 4.4 General Requirements

4.4.1 General. The FRP tank shall be compounded, designed, and constructed so as to conform to the requirements of this standard.

4.4.2 Design parameters. The manufacturer shall provide to the purchaser a written summary of design properties that are necessary for evaluating the conformance of the tank to this standard.

4.4.3 Workmanship. The workmanship shall be in accordance with good commercial practices. The tank manufactured shall be free of injurious defects and shall meet the appearance requirements of Sec. 4.10.2.

4.4.4 Installation. The installation of the tank shall be in accordance with the manufacturer's recommendations. (See appendix B for guidance on pre-installation site analysis for underground tanks.)

4.4.5 Venting. The tank shall be positively vented to the atmosphere. Minimum vent size shall be equal to the largest pipe outlet or inlet. The vent piping should be adequately sized to prevent excessive pressure buildup while the tank is being filled or evacuated. The required venting capacity depends on the filling or withdrawal rate, whichever is greater, and the vent line length. (See note in appendix A.)

4.4.6 Dimensions and tolerances. Tank diameters shall be measured internally. Tolerance on the as-manufactured inside diameter, including out-of-roundness, shall not exceed ±1 percent. Tolerance on overall height or length shall be ±2 in. unless lower tolerances are specified by the purchaser.

4.4.7 Repairs. Any tank may be repaired prior to shipment, provided the repaired tank meets the requirements of this standard.
Table 1  Design loads

<table>
<thead>
<tr>
<th>Design Load Condition</th>
<th>Aboveground Tanks</th>
<th>Underground Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of tank, appurtenances, and contents</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Internal pressure (due to test or overfill)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Vibrations due to attached equipment or fluid flow</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Temperature variations</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Earthquake</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Handling and installation</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Wind</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Snow</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Soil overburden</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>External hydrostatic</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Traffic surcharge</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Sec. 4.5  Design

4.5.1  General. The design of the FRP tank shall be based on accepted structural engineering design practice for FRP composite structures and in accordance with the governing building codes. The engineer shall endorse the design of the tank.

4.5.2  Safety factors. Design safety factors shall be established based on rational evaluation of the variability of fabrication procedures, variability in material properties, uncertainty in design and analysis, and consequence of failure.

4.5.3  Design loads. Loads that should be considered in designing the tank are listed in Table 1.

4.5.4  Strength and stiffness properties. Design values for strength and stiffness of the FRP laminate in the design of the tank shall be based on limiting values established by analysis and tests as required in Sec. 4.5.4.1 and 4.5.4.2.

4.5.4.1 Strength properties. The limiting strength of the tank laminate shall be determined by tests in accordance with Sec. 5.3 on laminates of the same construction as that used in the tank. For Type II laminates, the validity of coupon tests for establishing strength properties shall be confirmed by tests on full-scale or prototype structures constructed with the same type and grade of laminate used in the tank.

4.5.4.2 Stiffness properties. Modulus of elasticity and Poisson’s ratio may be determined by laminate analysis, provided the method of analysis has been
confirmed by tests on FRP laminates of the same type and grade as that used in the tank.

4.5.5 *Duration of load effects.* The design of the FRP tank shall account for the effects of duration of load on strength and stiffness properties as required in Sec. 4.5.5.1 and 4.5.5.2.

4.5.5.1 Creep and relaxation. The time-dependent effects caused by creep and relaxation shall be accounted for in design.

4.5.5.2 Long-term rupture strength. Unless otherwise determined by tests, the long-term strength of the laminate under sustained load shall be taken as 50 percent of the short-term strength determined by tests specified in Sec. 5.3.4 and 5.3.5.

4.5.6 *Environment effects.* The effects of exposure to the service environment, both internal and external, on the strength and stiffness properties shall be accounted for in design, based on tests specified in Sec. 5.4.

4.5.7 *Stress concentrations.* The design of the FRP tank shall account for localized stress concentrations occurring at points of geometric or material discontinuities and at points of concentrated loads such as supports and attachments.

4.5.8 *Underground tanks.* The design of underground FRP tanks shall account for the interaction of the tank structure and the surrounding soil, using accepted structural design methods for flexible underground vessels. The design shall account for the stresses resulting from the differential stiffnesses of stiffening ribs, tank heads, compartmentation bulkheads, joints, and other attachments, relative to the stiffness of the tank shell wall.

**Sec. 4.6 Physical and Mechanical Properties of Tank Shell**

4.6.1 *Wall thickness.* The average wall thickness of the tank shell, when measured in accordance with Sec. 5.2.1, shall be no less than the design nominal wall thickness. The thickness of the tank wall at any one location shall not be less than 90 percent of the design nominal wall thickness. No tank shall have a tank shell wall thickness less than 0.1875 in.

4.6.2 *Surface hardness.* The surface hardness of both the interior and exterior surfaces of the tank shall be at least 90 percent of the resin manufacturer’s minimum specified hardness for the cured resin, when tested in accordance with Sec. 5.2.2. (See note in appendix A.)

4.6.3 *Glass content.* The glass content of the structural layer, when measured in accordance with Sec. 5.3.3, shall be no less than 90 percent of the design glass content.
4.6.4 Modulus of elasticity. The modulus of elasticity of the laminate measured in either tension or flexure in accordance with Sec. 5.3.4 and 5.3.5 shall be no less than 700,000 psi. The initial, unaged flexural modulus of elasticity shall be determined for evaluating the laminate for environmental exposure and quality control.

4.6.5 Tensile strength. The initial, unaged ultimate tensile strength of the laminate in the weakest direction when measured in accordance with Sec. 5.3.4 shall be no less than 6,000 psi. When the weakest direction of the laminate is in the direction of curvature, the tensile strength shall be determined on samples cut from a test cylinder or flat laminate fabricated to eliminate curvature in the direction of testing.

4.6.6 Flexural strength. The initial, unaged ultimate flexural strength of the laminate in the weakest direction when measured in accordance with Sec. 5.3.5 shall be no less than 12,000 psi. The initial, unaged flexural strength shall be determined for evaluating the laminate for environmental exposure and quality control.

Sec. 4.7 Environmental Resistance of Tank Shell

4.7.1 Immersion. The FRP laminate shall be evaluated by immersion in accordance with Sec. 5.4.2. The laminate shall exhibit no erosion of resin or surface defects as the result of immersion. The thickness, weight, and hardness shall exhibit no change greater than 10 percent. The extrapolated flexural properties (strength and modulus of elasticity) at 100,000 hr shall not be less than 50 percent of the initial properties.

4.7.2 Light and water exposure. The FRP laminate shall be evaluated by light and water exposure in accordance with Sec. 5.4.3. The flexural properties (strength and modulus of elasticity) shall be at least 80 percent of initial properties.

Sec. 4.8 Leakage Under Internal Pressure

4.8.1 Internal pressure. The tank, including fittings and nozzles, shall be capable of withstanding an internal pressure without leakage or loss of pressure when tested in accordance with Sec. 5.2.3.

Sec. 4.9 Additional Requirements for Underground Tanks

4.9.1 Leakage test. A sample underground tank for each model line (i.e., similar shape, diameter, thickness, and materials) shall be subjected to the tests specified in Sec. 5.5, without damage, distress, or leakage.

Sec. 4.10 Construction

4.10.1 Laminate construction. The laminate shall consist of an inner surface, an interior layer, a structural layer, and an exterior surface. In Type I laminates,
if fillers are not used in the structural layer, the interior layer and structural layer may be of like construction. (See notes in appendix A.)

4.10.1.1 Inner surface. The inner surface exposed to the tank contents shall provide a barrier to penetration of the contents into the laminate. It shall consist of either a reinforced layer 10 to 20 mil thick, containing a surfacing veil conforming to Sec. 4.3.3, or a 20-mil-thick resin surfacing layer. (See notes in appendix A.)

4.10.1.2 Interior layer. The interior layer shall be reinforced only with noncontinuous glass strands applied in a minimum of two plies of 1.5-oz chopped strand mat or, as an alternative, in a minimum of two passes by the spray-up process of equivalent thickness. Glass content shall be 20 to 35 percent by weight. In Type II laminates, the interior layer shall be allowed to gel completely before applying any filament winding to avoid overcompressing the interior layer. The combined thickness of the inner surface and interior layer shall not be less than 0.10 in. (i.e., 100 mil).

4.10.1.3 Structural layer. The structural layer of Type I laminates shall be contam-molded layers of chopped strand, chopped mat, tape, cloth, or woven roving, or combinations thereof, having a glass content of 20 to 35 percent by weight. If cloth or woven roving is used, a layer of chopped strand glass shall be placed as alternate layers. The structural layer of Type II laminates shall be primarily filament winding containing 50 to 80 percent glass by weight. Layers of lay-up materials (mat, cloth, tape, woven roving) shall be lapped a minimum of 1 in., and end laps shall be staggered. For vertical tanks, the thickness of the structural layer may be varied with tank height (tapered-wall construction), provided the requirements of this standard are met at every location.

4.10.1.4 Fillers. The structural layer may contain particulate fillers, provided that the fillers are compatible with the other laminate constituents and do not adversely affect the performance of the laminate. The glass volume fraction in a filled laminate shall be no less than the glass volume fraction in an unfilled laminate based on the glass content requirements in Sec. 4.10.1.3.

4.10.1.5 Exterior surface. The exterior surface shall be a resin coating of sufficient thickness to provide a uniform surface finish to prevent exposure of the glass fibers in the structural layer. For added chemical resistance, an exterior surface of chopped glass or surfacing veil or both, made from either glass or organic fibers, may be used. For aboveground tanks, unless otherwise specified, the exterior surface shall contain stabilizers to prevent ultraviolet degradation. Stabilizers are
not required for underground tanks, unless otherwise specified. The appearance of
the exterior surface shall be in accordance with Sec. 4.10.2.

4.10.2 Appearance. The visual appearance of the finished laminate shall
conform to Sec. 4.10.2.1 through 4.10.2.4.

4.10.2.1 Exposed surfaces. The exposed surfaces shall be free of cracks
and crazes. The surface shall have a smooth finish with an average of not more
than 2 pits/sq ft, providing the pits are less than 1/8 in. in diameter, are not more
than 1/2 in. deep, and are covered with sufficient resin to prevent exposure of the
glass fibers. Some wrinkles are permissible, provided their surfaces are smooth and
free of pits.

4.10.2.2 Finished laminate. The finished laminate shall be as free as com-
mmercially practical from objectionable visual defects, such as foreign inclusions, dry
spots, air bubbles, pinholes, pimples, and delamination. The manufacturer shall
establish and conform to acceptance levels for visual defects as part of its quality
control program in accordance with ASTM D2563.

4.10.2.3 Exterior surface. The exterior surface shall be smooth, with no
exposed fibers or sharp projections.

4.10.2.4 Outside surface color. The outside surface of the tank shall not
be pigmented, painted, or dyed, except as allowed by Sec. 4.3.1.3 and as specified
by the manufacturer and the purchaser.

4.10.3 Joints. Joints between tank wall sections shall be overlaid or
overlaid to a thickness that develops the full strength of the tank wall, using the
appropriate properties for the tank at the point of overlay.

4.10.3.1 Layer widths. The width of the first layer of joint lay-up shall
be 3 in. minimum. Successive layers shall uniformly increase in width. The rein-
forcement shall be centered on the joint and shall extend on each side of the joint
a sufficient distance to make it at least as strong as the tank wall. Minimum joint
widths exclusive of taper are given in Table 2.
4.10.3.2 Interior joint. The interior of the joint shall be sealed by a laminate of a minimum of two layers of 1.5-oz mat overlaid with appropriate surface in mat or veil. Minimum width exclusive of taper is 4 in. This inner reinforcement shall be considered to be a corrosion-resistant barrier only and not a structural material. Where the interior of the tank cannot be accessed, the interior overlay may be deleted, provided laminate edges are coated with resin and two additional layers of 1.5-oz mat are applied to the outside overlay.

4.10.3.3 Joint overlays. Joint overlays shall be tapered on each edge over a width no less than six times the overlay thickness.

4.10.3.4 Crevices. Joints shall be free of objectionable crevices. Crevices between joined pieces shall be filled with resin or thixotropic resin paste prior to overlay, leaving a smooth surface for a lay-up.

4.10.3.5 Joint surfaces. Cured, noninhibited resin surfaces where parts are to be joined shall first be roughened by sanding or sandblasting. The roughened area shall extend beyond the work areas so that no lay-up is made on a molded surface. Surfaces shall be clean and dry before lay-up. The entire roughened area shall be resin-coated when the joint is made.

4.10.3.6 Cut edges. Cut edges shall be coated with resin so that no glass fibers are exposed and all voids are filled.

4.10.3.7 Resins. When air-inhibited resins are cured with an air-exposed surface, the lay-up shall be coated with a resin containing paraffin to achieve full surface cure. (The acetone sensitivity test can be used to check surface cure.) Use of other techniques, such as sprayed or wrapped films, is also an acceptable method of attaining an air-free cure.

4.10.4 Heads. Heads may be fabricated integrally with the tank wall or separately by contact molding. Heads fabricated by contact molding shall satisfy the mechanical property requirements of Sec. 4.6. The inner surface of the head shall present the same corrosion-resistant construction to the fluid as the tank wall (Sec. 4.10.1.1 and 4.10.1.2). Joints between head and shell wall shall conform to Sec. 4.10.3.

4.10.4.1 Top heads. Top heads of vertical tanks may be integrally attached or removable and may be any shape.

4.10.4.2 Bottom heads. Bottom heads of vertical tanks may either be fabricated integrally with the shell wall or be separately molded with a flange and subsequently jointed to the shell, and meet the requirements of Sec. 4.10.4.2.1 through 4.10.4.2.4. The inner surface of the head shall present the same corrosion-
resistant construction to the fluid as the tank wall (Sec. 4.10.1.1 and 4.10.1.2).

Joints between head and shell wall shall conform to Sec. 4.10.3.

4.10.4.2.1 For integral heads, shell and bottom reinforcement shall overlap a minimum of 4 in., exclusive of taper.

4.10.4.2.2 For separately molded heads, the minimum straight flange length is 4 in.

4.10.4.2.3 As a minimum, the knuckle area (the radial transition of the head to the shell) shall be reinforced to the same thickness and width as a joint (Sec. 4.10.3 and Table 2). The reinforcement shall be centered over the knuckle and shall taper uniformly into the bottom thickness over a distance of not less than 5 in.

4.10.4.2.4 Flat-bottom tanks must have full bottom support. Tanks with conical or rounded bottom heads must have other means of support, such as a cradle, skirt, or extension legs.

4.10.5 FRP fittings. Standard flanged nozzles shall be fabricated either from contact-molded FRP pipe and a suitable flange, from integrally molded pipe and flanges, or from FRP machine-made pipe and a suitable flange. Vents and nonwetted fittings do not require flanges, but they shall use either contact-molded, integrally molded, machine-made FRP pipe or internally threaded FRP couplings. Where flange fittings are used, suitable gaskets shall be provided. Flange gaskets shall be full face, have \( \frac{1}{8} \) in. minimum thickness, and have a durometer hardness of 40 to 60, unless otherwise specified or required for the service conditions. Manways in underground tanks do not need to meet the requirements of Sec. 4.10.5. Provided the manways are designed and tested in accordance with other requirements of this standard. (See note in appendix A.)

4.10.5.1 Pipe wall thickness. The pipe used shall have minimum wall thickness as shown in Table 3.

4.10.5.2 Flange thickness. Flanges shall be of the minimum thickness given in Table 4. Bolting pattern shall be as referenced in Table 4.

4.10.5.2.1 The minimum flange shear surface shall be four times the flange thickness indicated in Table 4. The thickness of flange hub reinforcement measured at the top of the fillet radius shall be at least one-half the flange thickness and shall be tapered uniformly the length of the hub reinforcement. The fillet radius, where the back of the flange meets the hub, shall be \( \frac{3}{8} \) in. minimum (Figure 1).

4.10.5.2.2 The flange face shall be perpendicular to the centerline of the pipe within 1\(^\circ\), and it shall be flat to \( +\frac{1}{2} \) in. for flanges up to and including 18-in.
### Table 3  Pipe for nozzle assembly

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Minimum Wall Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in.</td>
</tr>
<tr>
<td>2–12</td>
<td>3/8</td>
</tr>
<tr>
<td>14–24</td>
<td>3/4</td>
</tr>
<tr>
<td>30</td>
<td>5/16</td>
</tr>
<tr>
<td>36</td>
<td>3/8</td>
</tr>
<tr>
<td>42</td>
<td>3/8</td>
</tr>
</tbody>
</table>

**Filament-Wound and Centrifugally Cast FRP Pipe Minimum Wall Thickness**

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Minimum Wall Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in.</td>
</tr>
<tr>
<td>2–3</td>
<td>0.140</td>
</tr>
<tr>
<td>4–6</td>
<td>0.180</td>
</tr>
<tr>
<td>8–12</td>
<td>0.200</td>
</tr>
</tbody>
</table>

### Table 4  Minimum flange thickness for FRP nozzles

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Minimum Flange Thickness</th>
<th>Flange Dimensions &amp; Bolting (Except Thickness) Reference Standard*</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1/2</td>
<td>1, 2</td>
</tr>
<tr>
<td>3</td>
<td>3/4</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>4</td>
<td>1/2</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>6</td>
<td>1/2</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>8</td>
<td>3/16</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>10</td>
<td>11/16</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>12</td>
<td>3/4</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>14</td>
<td>13/16</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>16</td>
<td>7/8</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>18</td>
<td>15/16</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>24</td>
<td>1/8</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>30</td>
<td>1/8</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>36</td>
<td>1/4</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>42</td>
<td>2</td>
<td>2, 3, 4</td>
</tr>
</tbody>
</table>


**Notes:**
1. Based on flat-faced flanges with full-face soft gaskets.
2. Table 4 is based on a safety factor of 8 to 1 and a flexural strength of 20,000 psi.
diameter and \( \frac{3}{16} \) in. for larger-diameter flanges, unless otherwise specified. (See note in appendix A.)

4.10.5.3 Assembly. At assembly, there shall be a minimum dimension of 3 in. from the wall of the tank to the flange hub for compression-molded flanges or to the flange back for hand lay-up flanges. Where angular loadings are anticipated, nozzles shall be supported by a suitable gusseting technique.

4.10.5.3.1 Standard orientation shall have bolt holes straddling the principal centerline of the vessel.

4.10.5.3.2 Location of nozzles on the vessel shall be \( \pm \frac{1}{4} \) in. Tolerance on angle of nozzle centerline shall be within 1°.

4.10.5.3.3 When cut for the attachment of nozzles, the wall shall be reinforced as shown in Figure 2. Reinforcement diameter, \( D_2 \), shall equal at least twice the nozzle diameter, \( D_1 \), but in no case be less than 3 in. The cross-sectional area of the reinforcement shall be at least 125 percent of the cross-sectional area of the material removed. Thickness of reinforcement shall be that calculated for a joint according to Sec. 4.10.3. (See note in appendix A.)

4.10.5.3.4 The length of the nozzle's shear-bond area shall be as specified in Table 5. The fillet radius where the nozzle meets the tank wall shall be \( \frac{3}{8} \) in. minimum (Figures 3 and 4). The thickness of overlay shall not be less than the wall thickness specified for contact-molded pipe in Table 3. The overlay shall present the same corrosion-resistant construction to the fluid as specified in Sec. 4.10.1.1 and 4.10.1.2. Reinforcement (Figures 3 and 4) shall be in accordance with Sec. 4.10.5.3.3.
Figure 2  Reinforcement of cut tank wall for nozzle attachment

### Table 5  Shear-bond area—nozzles

<table>
<thead>
<tr>
<th>Pipe Wall Thickness (in.)</th>
<th>Bond Area Length (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/16</td>
<td>3</td>
</tr>
<tr>
<td>1/4</td>
<td>4</td>
</tr>
<tr>
<td>5/32</td>
<td>5</td>
</tr>
<tr>
<td>3/8</td>
<td>6</td>
</tr>
</tbody>
</table>

*Shear-bond areas A are shown in Figures 3 and 4.*

4.10.5.4 Cut edges. Cut edges shall be coated with resin so that no glass fibers are exposed and voids are filled. Structural elements having edges exposed to the chemical environment shall only be made with chopped-glass reinforcement, coated with resin, or the edges shall be sealed with a laminate conforming to Sec. 4.10.1.1 and 4.10.1.2.

4.10.6 Stiffeners. External stiffeners, when used, may be molded integrally with the tank shell wall or built up with circumferential windings or other suitable reinforced layers of FRP. Overwound or overlaid cores are permissible, provided they are completely enclosed in FRP material and the width of the stiffener-to-tank-shell bond equals or exceeds the width of the unbonded portion of the stiffener.

4.10.6.1 Open-top vertical tanks. Open-top vertical tanks shall be constructed with a flange or a ring bonded to the top of the shell. Alternatively, the shell shall be overwound or overlaid to provide sufficient rigidity for retaining the shape of the tank.

4.10.7 Hold-down lugs for aboveground tanks. Hold-down lugs shall be provided on aboveground tanks for outdoor service and, where required, for special
service and local design conditions. The design capacity of hold-down lugs shall be accepted by the engineer.

4.10.8 Lift lugs. Tanks shall be equipped with suitable lift lugs bonded to the tank and reinforced to resist lifting and handling forces.

SECTION 5: VERIFICATION

Sec. 5.1 General

Tanks shall be sampled and tested as required in Sec. 5.1 through 5.6. Test results shall be submitted to the purchaser upon request. Test results shall be maintained in the files of the manufacturer.
5.1.1 *Testing of aboveground tanks.* Aboveground tanks shall be tested in accordance with Sec. 5.2, 5.3, 5.4, and 5.6.

5.1.2 *Testing of underground tanks.* Underground tanks shall be tested in accordance with Sec. 5.2, 5.3, 5.4, and 5.5.

5.1.3 *Test samples.* If required by the purchaser, the manufacturer shall provide suitable test samples meeting the requirements of this standard to the purchaser or its designated representative.

**Sec. 5.2 Production Tests**

Each FRP tank shall be tested at the time of production for wall thickness, surface hardness, and internal pressure in accordance with Sec. 5.2.1, 5.2.2, and 5.2.3.

5.2.1 *Thickness.* Each FRP tank shall be tested for total wall thickness in accordance with ASTM D3567, except that the minimum number of readings shall be thirty taken as follows: three sets of ten readings, each set taken at three separate, representative locations on the tank, readings spaced equally around the circumference of the tank.

5.2.2 *Surface hardness.* Determine the surface hardness on each FRP tank in accordance with ASTM D2583, except D2583 sections 6.1, 8.1, 8.2, and 10.1. Allowable surface-temperature range shall be 65° to 80°F. Readings shall not be taken on pits, heavy mold release, or other irregularities that may affect the readings. Only dense resin-rich surfaces shall be tested. Take two sets of ten readings, each set taken at two separate, representative locations, readings spaced equally around the circumference of the tank. After eliminating the two high and the two low readings for each set of ten readings, the average of the remainder shall be the reported hardness reading. If low Barcol readings are encountered on wax-top-coated surfaces, retest after removing the wax by light sanding or scraping. Barcol test data must verify that the surface hardness of laminates with or without glass-surfacing veil has reached at least 90 percent of the hardness specified by the resin manufacturer for a clear resin casting.

5.2.3 *Internal pressure.* Close and seal off fittings and nozzles on the tank. Test for leakage under internal pressure in accordance with either Sec. 5.2.3.1 or 5.2.3.2. The test method selected shall be suitable for the tank being tested, as determined by the tank manufacturer. For double-wall tanks, pressure-test both the primary and secondary tanks. Pressurization of the interstitial space between the primary and secondary tank walls shall be in accordance with the manufacturer's recommendations.
5.2.3.1 Hydrostatic test (acceptable for aboveground tanks and underground tanks). Attach a 4-in.-diameter standpipe to the tank that extends 4 ft above the top of the tank. Fill the tank and standpipe with water and let stand for 24 hr. Examine for leakage or drop in water elevation in the standpipe. The tank shall show no visible signs of leakage, and the water level shall not fall more than 0.5 in. within the 24-hr test period.

5.2.3.2 Aerostatic test (acceptable for underground tanks). Attach a pressure gauge to the tank. The gauge shall be marked in increments of 0.5 psig (pounds per square inch, gauge) or less, with a maximum pressure indication of 15 psig or less. Pressurize the tank using an air-pressure pump fitted with a pressure regulator set to limit the pressure to no more than 1 psig above the specified test pressure. Pressurize the tank to a minimum of 3 psig and let stand for 1 hr. Examine for leakage or drop in pressure. Apply a soapy water to the outside of the tank, including fittings and manways. The tank shall show no visible signs of leakage.

Sec. 5.3 Physical and Mechanical Properties of Tank Shell

Physical and mechanical tests shall be conducted in accordance with Sec. 5.3.1 through 5.3.5. Additional tests may be required by the manufacturer's third-party quality control and quality assurance program or by the purchaser.

5.3.1 Specimens. Physical and mechanical tests shall be conducted on specimens cut from laminates that are determined by the engineer to be representative of the materials and methods of fabrication used in the tank.

5.3.2 Conditioning. Unless otherwise specified by the specific test procedure, test specimens shall be conditioned in accordance with Procedure A of ASTM D618.

5.3.3 Glass content. Determine the glass content of the structural layer of the laminate in accordance with ASTM D2584. The specimen shall be prepared by cutting or grinding away the inner surface, interior layer, and exterior surface. Test a minimum of three sets of three specimens each. Sample sets shall be taken from separate, representative locations on the tank or test laminate.

5.3.4 Tensile properties. Determine tensile strength and modulus of elasticity in accordance with one or more of the following methods: ASTM D638 or ASTM D2290. The test specimens shall be the actual thickness of the fabricated laminate and shall not be machined on the surface except at the ends to facilitate uniform gripping. Test at least five specimens in each of the two directions corresponding to the structural axes of the tank (e.g., hoop and axial or longitudinal and meridional).
5.3.5  *Flexural properties.* Determine flexural strength and tangent modulus of elasticity in accordance with ASTM D790. The test specimens shall be the actual thickness of the fabricated laminate and shall not be machined on the surface. Flexural properties shall be determined in at least two orthogonal directions that are chosen to be consistent with the design approach for the tank. Test at least five specimens in each of the two directions corresponding to the structural axes of the tank (e.g., hoop and axial or longitudinal and meridional). If flexural properties are affected by orientation of the tension surface, test five specimens with the inner surface in tension and five specimens with the exterior surface in tension in each directional axis.

**Sec. 5.4  Environmental Resistance**

Environmental resistance tests shall be conducted in accordance with Sec. 5.4.1 through 5.4.3. Additional tests may be required by the manufacturer's third-party quality control and quality assurance program or by the purchaser. If deemed acceptable by the engineer, tests conducted in accordance with ASTM C581 may be used to meet the requirements of this section.

5.4.1  *Specimens.* Resistance to environmental exposure of the FRP laminate shall be determined on specimens cut from laminates that are determined by the engineer to be representative of the materials and methods of fabrication used in the tank. Specimens for testing of mechanical properties after exposure may be cut either before or after exposure in the test media. The edges of exposure specimens shall be coated with paraffinated resin. When tests are conducted in liquids intended for internal containment only, a corrosion-resistant barrier may be added to the exterior surface of the specimens. The number of specimens for exposure testing shall be as specified for the required mechanical tests.

5.4.2  *Immersion tests.* Conduct immersion tests in accordance with Sec. 5.4.2.1 through 5.4.2.9.

5.4.2.1  Immersion periods. Immerse specimens for 30, 90, and 180 days and 1 yr in the required test media. Also prepare and obtain initial test properties on a control set of specimens immediately following fabrication and cure of test laminates.

5.4.2.2  Immersion media. Immersion media shall be representative of the anticipated service environment(s).

5.4.2.3  Immersion temperature. Immersion temperature shall be representative of the anticipated service environment(s).
5.4.2.4 Immersion procedures. Specimens must remain completely immersed during the test interval. Specimens shall not be stacked. Maintain a minimum of ¼ in. between specimens and between the specimen and the container wall. Change test media as often as needed to maintain the original composition and concentration. Use methods to maintain the test temperature within 5°F (3°C) of the specified value during the test. At the end of the immersion interval, remove the specimens and clean and dry them by blotting with a paper towel. Cold tap water may be used to facilitate cleaning. Unless otherwise specified, allow specimens to cool to room temperature before conducting required mechanical tests. Tests shall be completed within 4 hr after removal from the test media.

5.4.2.5 Physical examination. Examine specimens prior to immersion and at the end of each immersion interval. Record visual appearance, including color, texture, and surface features.

5.4.2.6 Measure and record the thickness to the nearest 0.001 in. at two locations on each specimen before and after immersion.

5.4.2.7 Weight change. Measure and record weight to the nearest gram before and after immersion.

5.4.2.8 Hardness. Measure and record Barcol hardness at five locations on each specimen.

5.4.2.9 Flexural properties. Conduct flexural tests for strength and modulus in accordance with Sec. 5.3.5. Plot the test results with respect to time for each immersion interval on a semi-log time plot. Extrapolate flexural strength and modulus to 100,000 hr and report the values as a percentage of initial properties.

5.4.3 Light and water exposure. Submit ten specimens to 360 days of light and water exposure in accordance with ASTM G23, Method I, Type D or DH apparatus. During each operating cycle of 120 min, the specimens are to be exposed to light alone for 102 min and light and water for 18 min. After exposure, test five specimens for flexural properties in accordance with Sec. 5.3.5, exterior surface in tension.

Sec. 5.5 Additional Tests for Underground Tanks

A sample tank for each underground tank model line shall meet the following test requirements. If a manufacturer produces a line of tanks that differ only in shell length, the manufacturer may test the length most representative of the entire line when an analysis shows that length effects are not significant to the performance of the tank. Otherwise, the longest tank shall be tested. For a line of spherical tanks that differ only in diameter, only the largest-diameter tank need be tested.
Table 6  Torques on pipe fittings

<table>
<thead>
<tr>
<th>Nominal Pipe Size, in.</th>
<th>Torques, lb/in. (N-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4</td>
<td>2.000 (226)</td>
</tr>
<tr>
<td>1</td>
<td>2.400 (271)</td>
</tr>
<tr>
<td>1 1/4</td>
<td>2.900 (328)</td>
</tr>
<tr>
<td>1 1/2</td>
<td>3.100 (350)</td>
</tr>
<tr>
<td>2</td>
<td>3.300 (373)</td>
</tr>
<tr>
<td>2 1/2</td>
<td>3.500 (395)</td>
</tr>
<tr>
<td>3</td>
<td>3.600 (407)</td>
</tr>
<tr>
<td>3 1/2</td>
<td>3.700 (418)</td>
</tr>
<tr>
<td>4</td>
<td>3.800 (429)</td>
</tr>
<tr>
<td>6</td>
<td>4.200 (475)</td>
</tr>
<tr>
<td>8</td>
<td>4.600 (520)</td>
</tr>
</tbody>
</table>

* Nominal pipe size requirements are in accordance with ASME B36.10, Standard for Welded and Seamless Wrought Steel Pipe.

5.5.1  Strength of pipe fittings test. A length of pipe shall be threaded into a fitting for pipe connection and shall be tightened to the torque specified in Table 6. The fitting shall not crack or split, and the threads shall not strip.

5.5.2  Bending moment. A 4-ft (1.2-m) length of Schedule 40 steel pipe is to be threaded into the fitting. A force is then to be applied to the top of the pipe. For a cylindrical tank, the force is first to be applied parallel to the longitudinal axis of the tank and then transverse to the longitudinal axis of the tank. For a spherical tank, the force is first to be applied in any one direction and then perpendicular to the direction in which the force was first applied. The applied force is to be increased so that the bending moment is also increased, from zero to 2,000 lb/ft (2,712 N-m) or to the bending capacity of the pipe, whichever is less, in 250-lb/ft (339-N-m) increments. If the Schedule 40 pipe bends before the required bending moment is reached, the test is to be stopped, and the fitting is to be examined for compliance. As a result of the bending moment, the bond between a fitting for a pipe connection and the tank shall not be damaged.

5.5.3  Leakage. After each of the tests specified in Sec. 5.5.2, the tank is to be subjected to a leakage test, as specified in Sec. 5.2.3.2.

5.5.4  Strength of lift lug tests. A lug intended to be used to lift and move a tank shall be subjected for 1 sec to a load equal to twice that imposed by lifting the empty tank. When more than one lug is provided on a tank, the load is to be divided between the lugs in proportion to the loads to which they are subjected.
by lifting the tank as intended. The lug(s) shall not be damaged or damage the tank. Following the test, the tank is to be subjected to a leakage test, as specified in Sec. 5.2.3.2.

5.5.5 Water-load test. A tank shall be (a) placed in a sand bed so that one eighth of the tank diameter is buried and (b) filled to capacity with water for 1 hr. The tank shall not be damaged.

5.5.6 External pressure test. The empty tank is to be installed in a test pit using the specified anchoring system and the specified backfill procedure. The pit is then to be filled with water to such a level that the tank is submerged to its maximum specified burial depth. The tank is to remain submerged for 24 hr. While the tank is still submerged, it is to be subjected for 1 min to a partial internal vacuum of 5.3 in. of mercury (17.9 kPa). The tank shall not be damaged.

5.5.7 Impact and cold exposure. Condition five specimens for 16 hr in a cold box at −29°C (−20°F). After conditioning, remove each specimen one at a time and immediately clamp between two steel rings having an inside diameter of 4¾ in. (108 mm). Drop a 1.18-lb (0.536-kg) steel ball from a height of 6 ft (1.83 m) to strike the exterior surface of the specimen. Specimens shall exhibit no visible signs of cracking or fracture.

Sec. 5.6 Aboveground-Tank Surface Burning Characteristics

The surface burning characteristics shall be determined in accordance with ASTM E84. The results should be of a laminate representative of the laminate of the tank wall, unless otherwise specified by the purchaser.

Sec. 5.7 Retest

If any failure occurs, the FRP tank may be retested to establish conformity in accordance with agreement between the purchaser and the manufacturer.

Sec. 5.8 Inspection and Testing by Purchaser

5.8.1 Inspection at manufacturer’s plant. The purchaser or its agent may inspect the FRP tank and the manufacturing process at the manufacturer’s plant. The extent of the inspection requested and criteria for acceptance shall be specified by the purchaser.

5.8.2 Access to work. The purchaser or its agent shall have free access to those parts of the manufacturer’s plant that are necessary to monitor compliance with this standard. The manufacturer shall make available for the purchaser’s use such test equipment and apparatus and shall provide such assistance as necessary for inspection.

Copyright © 2009 American Water Works Association. All Rights Reserved.
5.8.3 **Responsibility.** Inspection by the purchaser, or lack thereof, shall not relieve the manufacturer of the responsibility to provide materials and perform work in accordance with this standard.

5.8.4 **Tests.** In addition to the tests required by this standard, the purchaser may require other tests to be performed by the manufacturer or conduct its own tests of tank samples or laminate samples representative of the tank. The extent of additional testing and criteria for acceptance shall be specified by the purchaser.

5.8.5 **Rejection.** If the FRP tank fails to meet the criteria for acceptance specified by the purchaser, the tank shall be rejected.

---

**SECTION 6: DELIVERY**

**Sec. 6.1 Marking**

The tank shall carry a plaque, permanently affixed to the outside shell near the inlet or outlet nozzle or other location as required, that shall show the following information with permanently applied letters and numbers at least ¼ in. high:

1. Certification of manufacture and testing in accordance with this standard.
2. Name and location of manufacturer.
3. Date of manufacture.
4. Shipping weight.
5. Capacity.
6. Type and grade.
7. Designed service media and condition.
8. Precautions, if any.

**Sec. 6.2 Packaging and Shipping**

Tanks shall be mounted on cradles or suitable support pads if shipped in a horizontal position or on a suitable skid or pallet if shipped in a vertical position. Cradles and skids shall be padded and secured to the bed of the vehicle in a manner that will prevent damage to the tank during normal handling. The tank shall be secured to the cradle or skid so that there can be no movement of the tank in relation to the skid or cradle. A suitable stiffening member shall be secured at the opening of open-top tanks. Tanks shall be loaded with at least a 2-in. clearance between the tank, including fittings, and the bulkheads or bed of the vehicle.
When two or more tanks are shipped at one time, there shall be sufficient clearance or padding between tanks to prevent contact during transit.

**Sec. 6.3 Handling**

The tank manufacturer shall provide written instructions for handling the tank. The following normal precautions shall be taken in handling the tank at the destination:

6.3.1 **Rigging.** Proper rigging practices shall be observed at all times. Hoisting-equipment operators shall attach a guideline to prevent the tank from swinging without control.

6.3.2 **Damage.** The tank shall not be dropped or allowed to strike any other object. Damage caused by dropping or striking other objects may result in cracking the inner corrosion-resistant liner as well as the exterior of the tank.

6.3.3 **Rolling.** The tank shall not be rolled or slid.

6.3.4 **Working around the tank.** In working around the tank, care should be exercised to prevent tools, scaffolding, or other objects from striking the tank or being dropped inside the tank. Soft-soled shoes shall be worn by workers entering the tank. Ladders used inside or outside in contact with the tank shall be wooden or have cushion protection on both ends and shall not be permitted to scratch or point-load the surface.

6.3.5 **Lifting.** A crane is recommended for use in lifting and erecting the tank. The clearance between the head shackle of the crane and the tank should at least equal the overall length of the tank. If this is not possible, a spreader bar must be used to approximate the same angle in lifting.

6.3.5.1 **Lift lugs.** Tanks shall be equipped with lift lugs and shall be lifted using lift lugs.

6.3.5.2 **Unauthorized lifting devices.** Chains or cables shall not be put around the tank or used for lifting or handling the tank. No fittings other than lift lugs shall be used for lifting.

6.3.6 **Storing.** When the tank is stored on the ground prior to installation, it shall be placed on the shipping cradles and tied down so that it cannot roll because of winds or sloping elevation.

**Sec. 6.4 Installation**

The manufacturer shall provide written instructions for installing the tank. Two copies of the manufacturer's installation instructions shall be provided with each tank, one of which shall be embedded in clear resin on the outside surface of the tank. The installation instructions shall include
1. Location of lifting points and the method of intended lifting.
2. Method of preinstallation inspection or testing, as required by the manufacturer.
3. Type and size of suitable foundation or bedding.
4. Location and type of hold-down attachments.
5. Type and method of backfill for underground tanks.

Sec. 6.5 Affidavit of Compliance

The purchaser may require an affidavit from the manufacturer or supplier that the material provided complies with applicable requirements of this standard.
APPENDIX A

Explanatory Notes to D120

This appendix is for information only and is not a part of ANSI/AWWA D120.

The following notes refer to various sections of ANSI/AWWA D120. These notes are meant to further explain the sections to which they refer.

4.1.1 Note: Filament-wound tanks are normally constructed in combination with contact molding. The primary method used for constructing the tank shell is used to define the type.

4.2.2 Note: Most states recognize NSF International 61 as the authoritative standard for qualifying materials for potable water use. See the foreword of ANSI/AWWA Standard D120 for more information.

4.3.1.4 Note: Additions to the resin may interfere with visual inspection of laminate quality.

4.4.5 Note: Unrestricted vent piping sized in accordance with the following table will prevent backpressure development in tanks from exceeding 2.5 psig (17.2 kPa). As a practical matter, screened vents should be evaluated as to the net unrestricted area available after consideration of the individual woven wires or fabric involved in the screening or filtering action. Net vent area should match or exceed the largest total area of either the inflow or outflow piping lines.

<table>
<thead>
<tr>
<th>Max. Flow (gpm)</th>
<th>Vent Line Diameter (in.)</th>
<th>50 to 100 ft</th>
<th>200 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>100–200</td>
<td>1.25</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>1.25</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>400–500</td>
<td>1.50</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>600–700</td>
<td>2.00</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>800–1,000</td>
<td>2.00</td>
<td>3.00</td>
<td></td>
</tr>
</tbody>
</table>

4.6.2 Note: Barcol hardness is affected by the type and concentration of reinforcing materials and fillers in the surface layer and the test temperature. Laminates with organic surfacing veil may have a Barcol reading lower than 90 percent of the resin manufacturer’s minimum specified hardness for the cured resin. The
minimum acceptable Barcol reading must be established between the purchaser and the manufacturer prior to fabrication.

4.10.1  NOTE 1: The compositions specified for the inner surface and interior layer are intended to achieve optimum chemical resistance.

NOTE 2: Different resin systems may be used within the tank; that is, the resin used for the inner surface may be different from the resin used for the other tank wall layers.

4.10.1.1 NOTE 1: A resin-rich layer with surfacing veil will usually contain less than 20 percent of reinforcing material. A specific limit is not included because of the impracticability of determining this value in the finished product.

NOTE 2: The use of organic materials, such as acrylic and polyester fibers, may give lower readings for the Barcol hardness of the surface. However, this lower Barcol reading does not necessarily indicate uncure of the surface under these circumstances.

4.10.1.3 NOTE 1: During laminate construction, any layer that may have cured beyond exotherm should be tested for acetone sensitivity and, if found nonsensitive, the surface should be prepared by appropriate abrasion methods prior to applying subsequent layers.

4.10.5  NOTE: Wrought fittings for underground tanks may be FRP flanged nozzles or stainless-steel female-threaded pipe couplings. Nonwrought fittings may be flanged nozzles, stainless-steel couplings, or FRP female-threaded pipe couplings meeting the applicable bend tests.

4.10.5.2.2 NOTE: Other flanges agreed on between the manufacturer and the purchaser are acceptable, provided that they produce a tight joint.

4.10.5.3.3 NOTE: Alternative methods for distributing nozzle reinforcement are provided in ASTM D3299 and ASTM D4097.

5.2.3.2 NOTE: Use proper safety precautions when pressurizing a tank with air to protect persons from injury in the event of a sudden rupture of the tank or disengagement of appurtenances. Aerostatic testing should be conducted only by trained personnel using equipment and methods accepted by the tank manufacturer.
APPENDIX B

Pre-installation Site Analysis for Underground Tanks

This appendix is for information only and is not a part of ANSI/AWWA D120.

SECTION B.1: GENERAL

Because many site-specific factors related to soil conditions and drainage affect the operational life of an underground structure, it is necessary to conduct a pre-installation site analysis. The pre-installation site analysis may include but not be limited to soil stability, utilities, depth to the water table, potential flooding, and the presence of or absence of contamination.

SECTION B.2: TANK ANCHORAGE

An underground tank can float if it is submerged in a high water table or if there is flooding when the tank is partially full of water. The tank weight, type of tank cover (i.e., backfill and paving), and height of water around the tank have an effect on whether a tank will float. If a high water table exists, or if flooding can be expected, tanks should be anchored. The presence of these conditions should be identified during the pre-installation site analysis. Tanks can be secured against flotation in several ways. The following are the most common methods used:

1. Burying a concrete slab under the tank, with a 6–12-in. cushion of proper backfill between the bottom of the tank and slab, and anchoring the tank to the slab.

2. Burying concrete deadmen on either side of the tank and anchoring the tank thereto.

3. Burying the tank deeper than normal, subject to the manufacturer’s requirements.

When anchor straps are used, the straps should be installed in accordance with the manufacturer’s instructions on the use of FRP straps and placement at specific locations marked on the tank.
SECTION B.3: PERMEATION

The selection of materials is critical for potable water, wastewater, or reclaimed water service and distribution piping in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants composed of low molecular weight petroleum products or organic solvents or their vapors. Research has documented that pipe materials such as polyethylene, polybutylene, polyvinyl chloride, and asbestos cement; and elastomers, such as used in jointing gaskets and packing glands, are subject to permeation by lower molecular weight organic solvents or petroleum products. If a potable water, wastewater, or reclaimed water tank or pipe made of these or similar materials will be located in or pass through such a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation before selecting materials for use in that area.
APPENDIX C

Accessories for Underground Tanks

This appendix is for information only and is not a part of ANSI/AWWA D120.

SECTION C.1: SHELL MANWAY

One or more fiberglass flanged manways, at least 22 in. in diameter, may be installed on the tank. Larger manways, such as 30 and 36 in. in diameter, in circular or oval configurations are typically available. Manway covers may be fiberglass, stainless steel, or coated steel, as specified by the purchaser, and should be supplied with bolts and gaskets (see appendix D) for watertight protection. Manways and covers should be designed by the manufacturer to safely support service loads, which may include soil load, live load, and the weight of any supported equipment.

SECTION C.2: SHELL MANWAY EXTENSIONS

Buried tanks often require a manway extension to reach grade. Flanged fiberglass extensions compatible with the manway bolt pattern and gasket surface are typically available from the tank manufacturer in various lengths.

SECTION C.3: MANWAY RISER PIPE

A manway riser pipe provides a spacious access down to the tank manway. The standard fiberglass manway riser pipe is 42 or 48 in. in diameter, with lengths ranging from 30 to 54 in. in length.

SECTION C.4: STEEL NPT FITTINGS

Steel NPT fittings are available in 2-, 4-, 6-, and 8-in. half-couplings.
SECTION C.5: TANK LADDERS

Factory-installed aluminum or carbon-steel ladders are available. The ladders should be attached to the tank bottom with FRP mounting fittings and retained at the top with FRP slip fittings on the trunk of the manway to allow for contraction and expansion of the metal ladder.

SECTION C.6: ANCHOR STRAPS

If water could enter the tank hole, the tank installation must be designed to safely resist buoyant forces. A significant portion of the hold-down force results from the soil and pad overburden. When anchor straps are required to provide some of the resistance to buoyancy, they shall be provided by the tank manufacturer. The anchoring-system design must ensure the loads on the hold-down straps and the loads applied to the tank from the hold-down straps do not exceed the allowed load ratings of the tank manufacturer.

SECTION C.7: TURBINE ENCLOSURES

A piping enclosure may be sealed or unsealed to prevent water infiltration in high-water conditions. Fiberglass turbine enclosures are 42 or 48 in. in diameter and a minimum of 2 ft in length. Longer enclosures are available in increments of 1 ft. Fiberglass enclosure penetration kits are available for electrical and piping connections.

SECTION C.8: MANWAY COVERS

Fiberglass manway covers are available in round and square, watertight and nonwatertight configurations.

SECTION C.9: CONNECTION HARDWARE

The accessory supplier should provide connection hardware that is compatible with the accessory and the tank to which it is connected.
APPENDIX D

Flanged-Joint Bolts, Gaskets, and Installation

This appendix is for information only and is not a part of ANSI/AWWA D120.

The bolts and gaskets to be used with flanged pipe, fittings, and appurtenances are to be selected by the purchaser for the particular pressure-service and installation requirements.

SECTION D.1: BOLTS AND NUTS

Size, length, and number of bolts are shown in Tables 2 and 3 of ANSI/AWWA C115/A21.15. Bolts conform to ASME+B18.2.1, Square and Hex Bolts and Screws, Inch Series—Including Hex Cap Screws and Lag Screws. Nuts conform to ASME B18.2.2, Square and Hex Nuts, Inch Series. Bolts may have either square or hex heads and either hex or heavy hex nuts. Bolts and nuts are threaded according to ASME B1.1, Unified Inch Screw Threads (UN and UNR Thread Form), Class 2A, External, and Class 2B, Internal. Bolts and nuts of low-carbon steel conforming to the chemical and mechanical requirements of ASTM+A307, Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength, Grade B, are suitable for use with the flanges described by ANSI/AWWA C115/A21.15 when used with the gaskets described in this appendix. Bolts and nuts should be provided with appropriate corrosion-resistant coatings or materials.

In 1990, the 101st Congress enacted Public Law 101-592, the Fastener Quality Act. This standard requires that fasteners fully comply with this act.

SECTION D.2: GASKETS

Unless otherwise specified by the purchaser, gaskets shall be made of synthetic rubber, or cork, and ⅛ in. (3.18 mm) thick. Gaskets shall conform to the dimensions shown in Table 4. When considering the use of gaskets thinner than ⅛ in. (3.18 mm), or gaskets of materials other than synthetic rubber, or cork, the purchaser

---

1American National Standards Institute, 25 West 43rd St., Fourth Floor, New York, NY 10036.
2American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10017.
3ASTM International, 100 Barr Harbor Dr., West Conshohocken, PA 19428.

Copyright © 2009 American Water Works Association. All Rights Reserved.
should contact the pipe or fitting manufacturer concerning suitability for a particular application. Also available for most pipe and fitting sizes are specially designed gaskets, either ring or full-faced, using one or more annular rings molded into the gasket to improve the joint performance. The manufacturer should be contacted for details.

SECTION D.3: INSTALLATION

The design, assembly, and installation of the flanged piping system are the responsibility of the purchaser. The following suggestions are for general guidance:

a. The use of flanged joints underground is generally not recommended because of the rigidity of the joint.

b. Flange faces should bear uniformly on the gasket, and the bolts should be tightened in a progressively crisscross pattern, such as by first tightening the bottom bolt; then the top bolt; next the bolts at either side; and finally the remaining bolts. This process should be repeated until the bolts are sufficiently tightened.

c. Users of flanged joints should be careful to prevent bending or torsional strains from being applied to flanges or flanged appurtenances. Piping systems must be designed so that piping components connected by flanged joints are properly anchored, supported, or restrained to prevent breakage.

d. For best performance with flat rubber gaskets in 14-in. (356-mm) and larger sizes, ring-type gaskets are recommended rather than the full-face type. For joints utilizing the specially designed gaskets containing one or more molded annular rings, both ring type and full face are recommended for available sizes.

e. Impact wrenches cannot be used in many cases when assembling flanged joints due to the many variations of flange shroud diameters and impact wrench socket dimensions, in combination with nut configurations (heavy or regular hex).

*See Sec. D.3d.*
This page intentionally blank.