

NFPA 22

Standard for Water Tanks for Private Fire Protection

2003 Edition



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An International Codes and Standards Organization

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NFPA 22
Standard for
Water Tanks for Private Fire Protection
2003 Edition

This edition of NFPA 22, *Standard for Water Tanks for Private Fire Protection*, was prepared by the Technical Committee on Water Tanks and acted on by NFPA at its November Association Technical Meeting held November 16–20, 2002, in Atlanta, GA. It was issued by the Standards Council on January 17, 2003, with an effective date of February 6, 2003, and supersedes all previous editions.

This edition of NFPA 22 was approved as an American National Standard on January 17, 2003.

Origin and Development of NFPA 22

In 1909, the NFPA Committee on Gravity Tanks developed the *Standard on Gravity Tanks*. Amendments were considered in 1912 and 1913, and the standard was adopted in 1914. Revised or amended editions were adopted in 1915, 1917, 1918, 1919, 1922, 1926, 1928, 1930, 1931, 1933, 1936, 1941, 1949, and 1950.

The name of the committee was changed to the Committee on Water Tanks and its recommendations resulted in changes adopted in 1957, 1958, 1962, 1965, 1967, 1970, 1971, 1974, 1976, 1978, 1981, and 1987.

Tanks other than gravity tanks (which, at that time, included concrete reservoirs) and valve pits were first covered in 1913, pressure tanks (formerly covered by *Standards for Sprinkler Systems*) were covered in 1915, and tank heating was covered in 1922. The standard title has been periodically amended to reflect the expanded scope of the standard.

The 1993 edition provided new, environmentally friendly requirements for tank-coating systems. Two new chapters were included to cover the design and erection of bolted steel tanks and concrete tanks. Information on fiberglass tanks also was included. These changes, along with other editorial changes, reflected the current information for water storage tank design.

The 1996 edition of NFPA 22 consolidated tank care and maintenance information within a single chapter. Further revisions addressed the corrosion resistance of certain tank components, access into tanks, the monitoring of internal conditions, and the structural stresses to which tanks are subjected. The figures in Appendix B were revised to reflect current practices. Editorial changes were also made.

The 1998 edition further addressed environmental issues. All inspection, testing, and maintenance requirements were removed and added to the appropriate chapter of the 1998 edition of NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

The 2003 edition has been changed to conform to the NFPA *Manual of Style*, 2000 edition. Referenced publications have been updated.

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Committee Scope: This Committee shall have primary responsibility for documents on the design, construction, installation, and maintenance of tanks and accessory equipment supplying water for fire extinguishment, including gravity and pressure tanks, towers and foundations, pipe connections and fittings, valve enclosures and frost protection, and tank heating equipment.

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

Information on referenced publications can be found in Chapter 2 and Annex C.

Chapter 1 Introduction

1.1 Scope. This standard provides the minimum requirements for the design, construction, installation, and maintenance of tanks and accessory equipment that supply water for private fire protection, including the following:

- (1) Gravity tanks, suction tanks, pressure tanks, and embankment-supported coated fabric suction tanks
- (2) Towers
- (3) Foundations
- (4) Pipe connections and fittings
- (5) Valve enclosures
- (6) Tank filling
- (7) Protection against freezing

1.2 Purpose. The purpose of this standard is to provide a basis for the design, construction, operation, and maintenance of water tanks for private fire protection. Nothing in this standard shall prevent the use of systems, methods, or devices that are equivalent in quality, strength, fire resistance, effectiveness, and durability to those prescribed by this standard, provided technical documentation is made available to the authority having jurisdiction that demonstrates equivalency, and the system, method, or device is appropriate for the intended purpose.

1.3 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.3.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.3.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.3.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be

impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.4 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.4.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.4.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.5 Types of Tanks. This standard addresses elevated tanks on towers or building structures, water storage tanks that are at grade or below grade, and pressure tanks.

1.6 Units.

1.6.1 Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The bar unit, which is outside of but recognized by SI, is commonly used in international fire protection. Metric units and their conversion factors are shown in Table 1.6.1.

Table 1.6.1 Metric Unit Conversion Factors

Name of Unit	Unit Symbol	Conversion Factor
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10 ⁵ Pa

Note: For additional conversions and information, see ANSI SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System*.

1.6.2 If a value for measurement in this standard is followed by an equivalent value that is expressed in other units, the first stated value shall be regarded as the requirement. A given equivalent value could be approximate.

1.6.3 SI units in this standard have been converted by multiplying the number of units by the conversion factor and then rounding the result to the appropriate number of significant digits.

1.6.4 Where sizes for pipe, sheet and plate steel, and wire gages are indicated, they are noted in trade sizes and not by hard conversions.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2002 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 2003 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2001 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2002 edition.

NFPA 70, *National Electrical Code*®, 2002 edition.
 NFPA 72®, *National Fire Alarm Code*®, 2002 edition.
 NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 2000 edition.
 NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 2000 edition.

2.3 Other Publications.

2.3.1 ACI Publications. American Concrete Institute, P.O. Box 9094, Farmington Hill, MI 48333-9094.

ACI 318, *Building Code Requirements for Structural Concrete and Commentary*, 2002.

ACI 350R, *Environmental Engineering Concrete Structures*, 2001.

2.3.2 ANSI Publication. American National Standards Institute, Inc., 11 West 42nd Street, 13th Floor, New York, NY 10036.

ANSI SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System*, 1997.

2.3.3 API Publication. American Petroleum Institute, 1220 L Street NW, Washington, DC 20005-4070.

API 5LC, *Specification for CRA Line Pipe*, 3rd ed., 1998.

2.3.4 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers Inc., 1791 Tullie Circle NE, Atlanta, GA 30329-2305.

ASHRAE *Handbook of Fundamentals*, 1993.

2.3.5 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," 1998.

2.3.6 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 6/A 6M, *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*, 2001.

ASTM A 27/A 27M, *Standard Specification for Steel Castings, Carbon, for General Application*, 2000.

ASTM A 36/A 36M, *Standard Specification for Carbon Structural Steel*, 2001.

ASTM A 53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, 2001.

ASTM A 105/A 105M, *Standard Specification for Carbon Steel Forgings for Piping Applications*, 2001.

ASTM A 106, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*, Rev. A, 1999.

ASTM A 108, *Standard Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality*, 1998.

ASTM A 131/A 131M, *Standard Specification for Structural Steel for Ships*, 2001.

ASTM A 139, *Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and over)*, 2000.

ASTM A 181/A 181M, *Standard Specification for Carbon Steel Forgings, for General-Purpose Piping*, 2001.

ASTM A 283/A 283M, *Standard Specification for Low- and Intermediate-Tensile Strength Carbon Steel Plates*, Rev. A, 2000.

ASTM A 285/A 285M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*, 2001.

ASTM A 307, *Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*, 2000.

ASTM A 502, *Standard Specification for Steel Structural Rivets*, 1993.

ASTM A 516/A 516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*, 2001.

ASTM A 572/A 572M, *Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*, 2001.

ASTM A 615/A 615M, *Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement*, 2001.

ASTM A 668/A 668M, *Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use*, 2001.

ASTM A 675/A 675M, *Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties*, Rev. A, 2000.

ASTM A 992/A 992M, *Standard Specification for Steel for Structural Shapes for Use in Building Framing*, 2002.

ASTM A1011, *Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability*, 2001.

ASTM C 578, *Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation*, 2001.

ASTM C 591, *Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation*, 2001.

ASTM D 751, *Standard Test Methods for Coated Fabrics*, 2001.

ASTM D 1171, *Standard Test Method for Rubber Deterioration — Surface Ozone Cracking Outdoors or Chamber (Triangular Specimens)*, 1999.

ASTM D 1183, *Standard Test Methods for Resistance of Adhesives to Cyclic Laboratory Aging Conditions*, 1996.

ASTM D 1751, *Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)*, 1999.

ASTM D 2261, *Standard Test Method for Tearing Strength of Fabrics by the Tongue (Single Rip) Procedure (Constant-Rate-of-Extension Tensile Testing Machine)*, 1996.

2.3.7 AWS Publications. American Welding Society, Inc., 550 NW Le Jeune Road, Miami, FL 33126.

AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*, 1991.

AWS D1.1, *Structural Welding Code — Steel*, 1998.

2.3.8 AWWA Publication. American Wood Preservers Association, 7735 Old Georgetown Avenue NW, Suite 500, Washington, DC 20036.

Standard Specifications of the American Wood Preservers Association by the Empty-Cell Process, July 1, 2001.

2.3.9 AWWA Publications. American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

AWWA C652, *Disinfection of Water-Storage Facilities*, 1992.

AWWA D100, *Welded Steel Tanks for Water Storage*, 1996.

AWWA D102, *Coating Steel Water-Storage Tanks*, 1997.

AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*, 1997.

AWWA D110, *Wire- and Strand-Wound, Circular-Prestressed Concrete Water Tanks*, 1995.

AWWA D115, *Circular-Prestressed Concrete Water Tanks with Circumferential Tendons*, 1995.

AWWA D120, *Standard for Thermosetting Fiberglass-Reinforced Plastic Tanks*, 2001.

2.3.10 NWTI Publication. National Wood Tank Institute, 5500 N. Water St., P.O. Box 2755, Philadelphia, PA 19120.

NWTI Bulletin S82, *Specifications for Tanks and Pipes*, 1982.

2.3.11 SSPC Publications. The Society for Protective Coatings, 40 24th Street, Pittsburgh, PA 15222-4656.

SSPC Systems and Specifications Steel Structures Painting Manual, Volume 2, Chapter 5, 1991.

SSPC SP 6, *Joint Surface Preparation Standard Commercial Blast Cleaning*, 2000.

SSPC SP 8, *Pickling*, 2000.

SSPC SP 10, *Joint Surface Preparation Standard Near-White Blast Cleaning*, 2000.

2.3.12 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Title 29, Code of Federal Regulations, Part 1910 (OSHA).

Federal Standard 191 Method.

Federal Test Method Standard 601.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated stan-

dards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definition.

3.3.1 Holiday. A discontinuity in the coating system that includes, but is not limited to, voids, cracks, pinholes, or scratches.

Chapter 4 General Information

4.1 Capacity and Elevation.

4.1.1* The size and elevation of the tank shall be determined by conditions at each individual property after due consideration of all factors involved.

4.1.2 Wherever possible, standard sizes of tanks and heights of towers shall be as specified in 5.1.3, 6.1.2, 8.1.3, and Section 9.2.

4.1.3 For suction tanks, the net capacity shall be the number of cubic meters (U.S. gallons) between the inlet of the overflow and the level of the vortex plate.

4.2 Location of Tanks.

4.2.1 The location of tanks shall be such that the tank and structure are not subject to fire exposure.

4.2.1.1 If lack of yard room makes this impracticable, the exposed steel work shall be suitably fireproofed or shall be protected by open sprinklers (*see A.12.1.1*).

4.2.1.2 Fireproofing, where necessary, shall be provided for steelwork within 6.1 m (20 ft) of exposures, combustible buildings or windows, and doors from which fire might issue.

4.2.1.3 Where used for supports near combustible construction or occupancy inside the building, steel or iron shall be fireproofed 1.8 m (6 ft) above combustible roof coverings, and within 6.1 m (20 ft) of windows and doors from which fire might issue.

4.2.1.4 Steel beams or braces that join two building columns that support a tank structure shall also be suitably fireproofed where near combustible construction or occupancy.

4.2.1.5 Interior timber shall not be used to support or brace tank structures.

4.2.2 Fireproofing, where required, shall have a fire resistance rating of not less than 2 hours.

4.2.3 Foundations or footings shall furnish adequate support and anchorage for the tower.

4.2.4 If the tank or supporting trestle is to be placed on a building, the building shall be designed and built to carry the maximum loads.

4.3 Tank Materials.

4.3.1 Materials shall be limited to steel, wood, concrete, and coated fabric.

4.3.1.1 The elevated wood and steel tanks shall be supported on steel towers or reinforced concrete towers.

4.3.2 Fiberglass-reinforced plastic tanks shall be permitted only for underground storage of water at atmospheric pressure.

4.3.2.1 Fiberglass tanks shall meet the requirements of AWWAD120, *Standard for Thermosetting Fiberglass-Reinforced Plastic Tanks*, and shall comply with the following:

4.3.2.1.1 The tank shall be located below the frost line to protect against freezing.

4.3.2.1.2 At least 305 mm (12 in.) of pea gravel, crushed stone, or sand shall be backfilled around the tank.

4.3.2.1.3 If the tank is not installed above the maximum ground water level, suitable methods of anchoring the tank shall be permitted so that the buoyancy of the tank when empty does not force it upward.

4.3.2.1.4 The tank shall be designed to resist the pressure of earth against it.

4.4 Workmanship.

4.4.1 In addition to complying with the requirements of this standard, it is expected that the manufacturers of approved structures will also follow the spirit of the standard, by using their experience and ability to create structures that shall prove reliable under all specified conditions.

4.4.1.1 Manufacturers shall replace all parts that are defective due to faulty materials or workmanship and shall replace all parts that fail to comply with this standard.

4.4.2 The contractor's representatives shall provide careful inspection during shop fabrication and field erection.

4.4.2.1 The inspection shall include, but shall not be limited to, a check of the following:

- (1) The thickness of butt-welded plates in tanks and tubular columns
- (2) The appearance of welding in tank plates where a balcony is omitted and in tubular columns and at struts, except near the ladder and base of the structure
- (3) The extent of inaccessible dents and out-of-roundness of tubular columns and struts

4.5 Plans. The contractor shall furnish stress sheets and plans required by the purchaser and the authority having jurisdiction for approval or for obtaining building permits and licenses for the erection of the structure.

4.6 Tank Contractor Responsibility.

4.6.1 Any necessary work shall be handled by experienced contractors.

4.6.1.1 Careful workmanship and expert supervision shall be employed.

4.6.1.2 The manufacturer shall warranty the tank for at least 1 year from the date of completion and final customer acceptance.

4.6.2 Upon completion of the tank construction contract, and after the contractor has tested the tank and made it water-

tight, the tank contractor shall notify the authority having jurisdiction so that the tank can be inspected and approved.

4.6.3 Cleaning Up.

4.6.3.1 During and upon completion of the work, the contractor shall remove or dispose of all rubbish and other unsightly material in accordance with NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*.

4.6.3.2 The condition of the premises shall be as it was before tank construction.

4.7 Inspection of Completed Equipment.

4.7.1 Prior to placing the tank in service, a representative of the tank contractor and a representative of the owner shall conduct a joint inspection of the tank.

4.7.2 Written reports of tank inspections shall be made in triplicate, and a copy that has been signed by the contractors and the owners shall be sent to the authority having jurisdiction.

4.8 Attachments to Tank Structures.

4.8.1 If tank structures are used to support signs, flagpoles, steel stacks, or similar objects they shall be specifically designed for the purpose.

4.8.2* Confined entry requirements signs shall be posted at each shell manway.

4.9 Lightning Protection. To prevent lightning damage to tanks, protection shall be installed in accordance with Section 4-4 of NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

4.10 Strength.

4.10.1 The material, as specified, shall be without defects that affect its strength or service.

4.10.2 The workmanship shall be of such quality that defects or injuries are not produced during manufacture or erection.

4.10.3 Specified unit stresses shall not be exceeded.

4.10.4 The structure and its details shall possess the requisite strength and rigidity.

4.11 National Standards. Materials produced and tested in accordance with the requirements of a recognized national standard and within the mechanical (strength), metallurgical, and chemical limitations of one of the material grades specified in this document shall be permitted.

4.12 Loads.

4.12.1 Dead Load.

4.12.1.1 The dead load shall be the estimated weight of all permanent construction and fittings.

4.12.1.2 The unit weight of steel shall be considered to be 7849 kg/m³ (490 lb/ft³); the unit weight of concrete shall be considered to be 2307 kg/m³ (144 lb/ft³).

4.12.2 Live Load.

4.12.2.1 Under normal conditions, the live load shall be the weight of all the liquid when it overflows the top of the tank.

4.12.2.2 The unit weight of water shall be considered to be 1000 kg/m³ (62.4 lb/ft³).

4.12.2.3 Proper provisions shall be made for temporary stresses during erection.

4.12.2.4 Where roofs have slopes of less than 30 degrees, they shall be designed to support a uniform weight of 122 kg/m² (25 lb/ft²) on the horizontal projection.

4.12.3 Wind Load.

4.12.3.1 Under normal conditions, the wind load or pressure shall be assumed to be 147 kg/m² (30 lb/ft²) on vertical plane surfaces, 88 kg/m² (18 lb/ft²) on projected areas of cylindrical surfaces, and 73 kg/m² (15 lb/ft²) on projected areas of conical and double-curved plate surfaces.

4.12.3.2 Where designing for wind velocities over 161 km/hr (100 mph), all of these specified unit pressures shall be adjusted in proportion to the square of the velocity, assuming that the pressures are for 161 km/hr (100 mph).

4.12.4 Earthquake Load.

4.12.4.1 Earthquake design criteria shall be considered.

4.12.4.2 Specific design criteria are contained in the appropriate chapter for the particular tank, or in local codes, whichever is more stringent.

4.12.4.3 Flat-bottom tanks shall be designed by a method that accounts for the sloshing of the contents (effective mass method).

4.12.5 Balcony, Platform, and Ladder Loads.

4.12.5.1 A vertical load of 454 kg (1000 lb) shall be assumed to be applied to any 0.93 m² (10 ft²) of area on the balcony floor and on each platform, 227 kg (500 lb) applied to any 0.93-m² (10-ft²) area on the tank roof, and 159 kg (350 lb) on each vertical section of ladder.

4.12.5.2 All of the structural parts and connections shall be designed to withstand such loads.

4.12.5.3 These specified loads shall not be required to be combined with snow loading.

4.12.6 Columns and Struts.

4.12.6.1 All steel columns and struts shall be designed in accordance with AWWA D100, *Welded Steel Tanks for Water Storage*.

4.12.6.2 The minimum thickness for any columns in contact with water shall be 6.4 mm (0.25 in.).

4.12.6.3 Tubular sections shall not be flattened to form end connections.

4.12.7 Stress Increases.

4.12.7.1 Where wind or earthquake loads are considered in calculating stresses, the maximum permissible increase in working unit stresses shall be one-third, provided the resulting section is not less than required for dead and live loads alone.

4.12.7.2 Wind and earthquake loads shall not be required to be considered simultaneously.

4.12.8 Roof Construction.

4.12.8.1 The roof shall be designed to withstand the forces anticipated during the erection, inspection, testing, and maintenance of the tank.

4.12.8.2 The maximum allowable uniform live load (in pounds per square foot) and the maximum allowable concen-

trated load (in pounds) shall be identified on the design drawings and tank nameplate.

4.13 Welding. All welding shall be completed in accordance with AWWA D100, *Welded Steel Tanks for Water Storage*, NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, and ASME Boiler and Pressure Vessel Code, Section IX.

4.14 Roofs.

4.14.1* All tanks shall have roofs.

4.14.1.1 OSHA compliant (29 CFR 1910) standard railing shall be placed around the roof manholes and other accessories that require access.

4.14.2 A perimeter roof guardrail is not required on lap-jointed bolted steel tanks when fitted with a manway platform, roof walkway, and guardrails.

4.14.3 Guardrails shall be constructed in accordance with OSHA 29 CFR 1910.

4.15 Roof Vent.

4.15.1 Where the steel roof is essentially airtight, there shall be a substantial vent above the maximum water level.

4.15.2 A vent pipe shall have a cross-sectional area equal to a minimum of one-half the area of the discharge pipe(s) or fill pipe, whichever is the larger.

4.15.3 A corrosion-resistant screen or perforated plate with 9.5-mm (3/8-in.) holes, to exclude birds or other animals, shall be provided and have a net area at least equal to the vent line.

4.15.4 In the case of a screen, this requires a gross area at least one and one-half times the cross-sectional area of the discharge pipe(s) or fill pipe, whichever is larger.

4.15.5 The screen or perforated plate shall be protected against the accumulation of sleet.

4.15.6 The weather hood above the perforated plate or screen, or its equivalent, shall be readily removable.

4.15.7 The overflow pipe shall not be included as vent area.

4.15.8 The vent shall be permitted to be combined with the roof finial.

4.15.9 Equivalent venting shall be permitted to be used, provided the area cannot be obstructed by sleet, and the ingress of birds or other animals shall be prevented.

4.15.10 Where dual service is specified and where local health departments require screening vents against insects, a nonmetallic screen or special fail-safe vent shall be provided to minimize the risk in the event that the insect screens frost over.

4.15.11 A roof vent attached to a flanged neck shall be installed on steel tanks prior to entering the tank.

4.15.11.1 The flanged neck shall be designed to accommodate an adequately sized exhaust fan.

4.16 Test Reports. Copies of mill test reports for steel plates and certificates of compliance for bolts and other structural members shall be maintained at the premises of the vendor and shall be made available for review by the purchaser.

4.17 Acceptance.

4.17.1 After completion of the tank, all coated steel tanks shall be tested for holidays and coating thickness.

4.17.2 Repairs or replacements shall be made as necessary.

Chapter 5 Welded-Steel Gravity Tanks and Suction Tanks

5.1 General.

5.1.1 This chapter shall apply to the design, fabrication, and erection of welded-steel gravity water tanks, including pump suction tanks.

5.1.2 Capacity.

5.1.2.1 The capacity of the tank shall be the number of cubic meters (U.S. gallons) available above the outlet opening.

5.1.2.2 The net capacity between the outlet opening of the discharge pipe and the inlet of the overflow shall be equal to at least the rated capacity.

5.1.2.3 The net capacity for gravity tanks with large plate risers shall be the number of cubic meters (U.S. gallons) between the inlet of the overflow and the designated low-water level line.

5.1.3 Standard Sizes.

5.1.3.1 The standard net capacity sizes of steel tanks shall be as follows:

- (1) 18.93 m³ (5000 gal)
- (2) 37.85 m³ (10,000 gal)
- (3) 56.78 m³ (15,000 gal)
- (4) 75.70 m³ (20,000 gal)
- (5) 94.63 m³ (25,000 gal)
- (6) 113.55 m³ (30,000 gal)
- (7) 151.40 m³ (40,000 gal)
- (8) 189.25 m³ (50,000 gal)
- (9) 227.10 m³ (60,000 gal)
- (10) 283.88 m³ (75,000 gal)
- (11) 378.50 m³ (100,000 gal)
- (12) 567.75 m³ (150,000 gal)
- (13) 757.00 m³ (200,000 gal)
- (14) 1135.50 m³ (300,000 gal)
- (15) 1892.50 m³ (500,000 gal)

5.1.3.2 Tanks of other sizes shall be permitted.

5.1.4 Form. Steel tanks shall be permitted to be of any form desired provided they conform to all requirements of this standard.

5.2 Materials.

5.2.1 Plates, Shapes, and Tubular Columns.

5.2.1.1 Plates. Plate materials shall be of open-hearth, electric furnace, or basic oxygen process steel that conforms to the following ASTM specifications:

- (1) ASTM A 36/A 36M, *Standard Specification for Carbon Structural Steel*
- (2) ASTM A 283/A 283M, *Standard Specification for Low- and Intermediate-Tensile Strength Carbon Steel Plates*, Grades A, B, C, and D

5.2.1.2 Where plates of thicknesses greater than 19.1 mm ($\frac{3}{4}$ in.) are used, ASTM A 283, *Standard Specification for Low- and Intermediate-Tensile Strength Carbon Steel Plates*, Grade D, shall not be used. ASTM A 131, *Standard Specification for Structural Steel for Ships*, Grades A, B, and C; ASTM A 285, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*, Grades A, B, and C; or ASTM A 516, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for*

Moderate- and Lower-Temperature Service, Grades 55 and 60, shall be used as alternatives.

5.2.1.3 Basis of Furnishing Plates. Plates shall be furnished, based on weight, with permissible underrun and overrun in accordance with the tolerance table for plates ordered to weight in ASTM A 6, *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*.

5.2.1.4 Shapes. Structural materials shall be open-hearth, electric furnace, or basic oxygen process steel that conforms to ASTM A 36, *Standard Specification for Carbon Structural Steel*, or ASTM A 131, *Standard Specification for Structural Steel for Ships*, Grades A, B, and D, or ASTM A 992/A 992M-00, *Standard Specification for Steel for Structural Shapes for Use in Building Framing*.

5.2.1.5 Copper-bearing steel that contains approximately 0.20 percent copper shall be permitted to be used. In all other respects, steel shall conform to the specifications of 5.2.1.1, 5.2.1.3, and 5.2.1.4.

5.2.2 Bolts, Anchor Bolts, and Rods.

5.2.2.1 Bolts and anchor bolts shall conform to ASTM A 307, *Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*, Grade A or Grade B.

5.2.2.2 ASTM A 36, *Standard Specification for Carbon Structural Steel*, shall be considered an acceptable alternative material for anchor bolts. Rods shall be open-hearth, electric furnace, or basic oxygen process steel that conforms to ASTM A 36.

5.2.3* Forgings.

5.2.3.1 Steel used for forgings shall be made only by the open-hearth process.

5.2.3.2 Forgings shall conform to the following ASTM specifications:

- (1) ASTM A 105, *Standard Specification for Carbon Steel Forgings for Piping Applications*
- (2) ASTM A 668, *Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use, Class D*
- (3) ASTM A 181, *Standard Specification for Carbon Steel Forgings, for General-Purpose Piping, Class 70*

5.2.4 Castings. Castings shall conform to ASTM A 27, *Standard Specification for Steel Castings, Carbon, for General Application*, Grade 60-30 full annealed.

5.2.5 Reinforcing Steel. Reinforcing steel shall comply with ASTM A 615, *Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement*, Grade 40 or Grade 60.

5.2.6 Filler Metal Electrodes.

5.2.6.1 Manual, shielded metal arc welding electrodes shall conform to the requirements of AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

5.2.6.2 Electrodes shall be of any E60XX or E70XX classification that is suitable for the electric current characteristics, the position of welding, and other conditions of intended use.

5.2.6.3 Electrodes for other welding processes shall be in accordance with applicable AWS specifications for filler metal.

5.3 Earthquake Load.

5.3.1 Tanks shall meet the requirements for resistance to earthquake damage in accordance with the earthquake design provisions of AWWA D100, *Welded Steel Tanks for Water Storage*.

5.3.2 For seismic anchor-bolt loading, the following formula shall be used:

$$T_s = \frac{4M_s}{ND} - \frac{W'}{N}$$

where:

T_s = seismic bolt tension (lb)

M_s = seismic overturning moment (ft lb)

W' = weight of tank shell and portion of roof carried by shell (lb)

N = number of anchor bolts

D = tank diameter (ft)

5.4 Unit Stresses.

5.4.1 General. The maximum stresses in megapascals (pounds per square inch) that are produced by the loads specified in Section 4.12 and Section 5.3, or any combination of them, shall not exceed the values in Table 5.4.1.

5.5 Design Details.

5.5.1 Minimum Thickness.

5.5.1.1 The minimum thickness of any part of the structure shall be 4.8 mm ($\frac{3}{16}$ in.) for parts not in contact with water contents and 6.4 mm ($\frac{1}{4}$ in.) for parts in contact with water contents.

5.5.1.2 The controlling thickness of rolled shapes for the purposes of the foregoing stipulations shall be taken as the mean thickness of the flanges, regardless of web thickness.

5.5.1.3 The minimum thickness of tubular columns and struts shall be 6.4 mm ($\frac{1}{4}$ in.).

5.5.1.4 Round or square bars used for wind bracing shall have a minimum diameter or width of 19.1 mm ($\frac{3}{4}$ in.).

5.5.1.5 Bars of other shapes, if used, shall have a total area at least equal to a 19.1-mm ($\frac{3}{4}$ -in.) round bar.

5.5.1.5.1 Roof plates for suction tanks with cone roofs shall be permitted to be 0.1792 in. (7 gauge) sheet.

5.5.1.6 Cylindrical shell plates in contact with water shall have minimum thicknesses as specified in accordance with Table 5.5.1.6.

5.5.2 Thickness for Corrosion.

5.5.2.1 If interior bracing is required to support the water content, 1.6 mm ($\frac{1}{16}$ in.) additional thickness shall be added to the calculated sections.

5.5.2.2 The sections shall be open to facilitate cleaning and painting.

5.5.2.2.1 Tubular sections shall be hermetically sealed to prevent internal corrosion.

5.5.2.3 The plates of tanks that are to contain salt or alkaline water shall be 1.6 mm ($\frac{1}{16}$ in.) thicker than calculated.

5.5.3 Thickness of Tank Plates.

5.5.3.1 Tank plates shall be designed on the basis of the following maximum membrane tensile stresses, which shall be reduced for the joint efficiencies set forth in AWWA D100, *Welded Steel Tanks for Water Storage*.

Table 5.4.1 Maximum Bending Stress

	psi	MPa
Tension: On net section, rolled steel	15,000	103.43
Tension: Anchor bolts	15,000	103.43
Bending:		
Tension on extreme fibers, except column base plates	15,000	103.43
Column base plates	20,000	137.90
Compression on extreme fibers of rolled sections, and plate girders and built-up members for values as follows:		
$\frac{ld}{bt}$ not in excess of 600	15,000	103.43
$\frac{ld}{bt}$ in excess of 600	9,000,000	62,055
	$\frac{ld}{bt}$	$\frac{(l)(d)}{(b)(t)}$
Pins, extreme fiber	22,500	155.15
Cast steel	11,250	77.57

where l is the unsupported length; d is the depth of the member; b is the width; and t is the thickness of its compression flange; all in in. (mm); except that l shall be assumed to be twice the length of the compression flange of a cantilever beam not fully stayed at its outer end against translation or rotation.

Table 5.5.1.6 Minimum Thickness of Cylindrical Shell Plates

	Diameter							
	<50 ft	(<15.2 m)	50 ft – 120 ft	(15.2 m – 35.6 m)	120 ft – 200 ft	(35.6 m – 61 m)	>200 ft	(>61 m)
Bottom rings	¼ in.	6.4 mm	¼ in.	6.4 mm	⅝ in.	7.9 mm	⅝ in.	9.5 mm
Upper rings	⅜ in.	4.8 mm	¼ in.	6.4 mm	⅝ in.	7.9 mm	⅝ in.	9.5 mm

5.5.3.2* Plate surfaces that are susceptible to complete stress analysis shall be designed on the basis of a maximum membrane tensile stress of 103.43 MPa (15,000 psi).

5.5.3.3 Plate surfaces that are not susceptible to complete stress analysis shall also be designed on the basis of a maximum membrane tensile stress of 103.43 MPa (15,000 psi) after making reasonable allowances for such loads and stresses that cannot be accurately determined.

5.5.3.3.1 The maximum membrane tensile stress shall in no case exceed 75.85 MPa (11,000 psi) when calculated, assuming that the concentrated reactions of supporting members are uniformly distributed between such reactions.

5.5.3.3.2 Therefore, the lowest cylindrical courses of tanks with suspended bottoms and the suspended bottoms themselves shall be designed for a maximum membrane tensile stress of 75.85 MPa (11,000 psi), reduced for the joint efficiencies.

5.5.3.4 As an alternate to 5.5.3.1 and 5.5.3.2, tank shell plates for suction tanks shall be permitted to be designed on the basis of the stresses, material selection, and inspection set forth in Section 14 of AWWA D100, *Welded Steel Tanks for Water Storage*, provided all requirements of Section 14 of the standard are met.

5.5.3.5 Where compressive stresses exist, the selected plate thickness shall prevent local buckling.

5.5.4 Thickness of Flat Bottoms.

5.5.4.1 The thickness of plates in flat bottoms shall be not less than those given in Table 5.5.4(a) and Table 5.5.4(b).

5.5.4.2 Any corrosion allowance specified shall be added to the value from the table.

5.5.5 Accessibility of Bottoms. Grillages shall be designed so that the tank bottom and beams are accessible for inspection and painting.

5.5.6 Net Sections. Net sections shall be used in calculating the tensile stress in plates and members.

5.5.7 Load Location.

5.5.7.1 When calculating the thickness of plates that are stressed by the weight or pressure of the tank contents, the pressure at the lower edge of each ring shall be assumed to act undiminished on the entire area of the ring.

5.5.7.1.1 This requirement shall not apply to plate thickness calculated in accordance with 5.5.3.

5.5.8 Four Way Junctions.

5.5.8.1 In welded tanks, the longitudinal joints in adjacent circumferential courses shall be staggered or shall be aligned.

5.5.8.2 Welded joints that cross each other shall be grooved and welded continuously through the intersections.

5.5.8.3 Permission to use four way junctions shall not apply to plate thickness calculated in accordance with 5.5.3.

5.5.9 Opening Reinforcement.

5.5.9.1 All openings of more than 102 mm (4 in.) in diameter that are located in the shell, suspended bottom, larger steel plate riser, or tubular support shall be reinforced.

5.5.9.2 The reinforcement shall be either the flange of a fitting, an additional ring of metal, excess plate metal above that actually required, or a combination of these methods.

5.5.9.3 The opening diameter shall be considered to be the maximum dimension of the hole cut in the plate perpendicular to the direction of maximum stress.

5.5.9.3.1 Excess plate metal used for joint efficiency shall not meet the requirements for opening reinforcement if the center of the opening is within one opening diameter of any plate seam or point of support attachment.

Table 5.5.4(a) Thickness of Bottom Plates for Flat-Bottom Tanks (in inches)

Type of Support	Length ft	Depth of Water											
		10 ft	12 ft	14 ft	16 ft	18 ft	20 ft	22 ft	24 ft	26 ft	28 ft	30 ft	40 ft
Steel or concrete beams	12	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
	14	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
	16	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
	18	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
	20	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
	24	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
Concrete slab or earth grade		⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
		⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝

Table 5.5.4(b) Thickness of Bottom Plates for Flat-Bottom Tanks (in millimeters)

Type of Support	Length m	Depth of Water											
		3.1 m	3.7 m	4.3 m	4.9 m	5.5 m	6.1 m	6.8 m	7.3 m	7.9 m	8.5 m	9.1 m	12.2 m
Steel or concrete beams	3.7	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	9.5
	4.3	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	9.5	9.5	11.1
	4.9	7.9	7.9	7.9	7.9	7.9	7.9	9.5	9.5	9.5	9.5	9.5	11.1
	5.5	7.9	7.9	7.9	7.9	9.5	9.5	9.5	9.5	11.1	11.1	11.1	12.7
	6.1	7.9	7.9	9.5	9.5	9.5	11.1	11.1	11.1	11.1	12.7	12.7	14.3
	7.3	9.5	9.5	11.1	11.1	11.1	12.7	12.7	12.7	14.3	14.3	14.3	17.5
Concrete slab or earth grade		6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4

5.5.9.4 Welding shall be provided to transmit the full net strength of the reinforcing ring or flange to the plate.

5.5.9.4.1 In computing the net reinforcing area of a fitting, such as a boiler maker's flange or a manhole saddle that has a neck, the material in the neck shall be considered as part of the reinforcement for a distance, measured from the surface of the parent plate or from the surface of an intervening reinforcement plate, that is equal to four times the thickness of the material in the neck.

5.5.10 Roof Supports. The supports for tank roofs that do not contain water shall be designed in accordance with the steel construction specifications of the American Institute of Steel Construction.

5.5.10.1 Rafters that are in contact with a steel roof and that have a slope of less than 51 mm in 305 mm (2 in. in 12 in.) and that consist of beam or channel shapes less than 381 mm (15 in.) deep shall be considered to be adequately braced in the lateral position by friction between the roof plate and the top flange.

5.5.10.2 The roof purlin depth shall be less than $\frac{1}{30}$ of the span length.

5.5.10.3 The maximum slenderness ratio, L/r , for columns that support the roof shall be 175. The spacing between rafters, as measured along the tank circumference, shall not exceed 0.61π m (2π ft).

5.5.11 Welded Joints. The types of joints used and their design shall conform to AWWA D100, *Welded Steel Tanks for Water Storage*.

5.6 Workmanship.

5.6.1 Plate Edges. The plate edges to be welded shall be universal mill edges or shall be prepared by shearing, machining, chipping, or mechanically guided oxygen cutting. Where the edges of plates are oxygen cut, the surface obtained shall be uniform, smooth, and shall be cleaned of slag accumulations before welding.

5.6.1.1 Edges of irregular contour shall be permitted to be prepared by manually guided oxygen cutting.

5.6.2 Rolling. Plates shall be cold-rolled to suit the curvature of the tank and the erection procedure in accordance with Table 5.6.2.

5.6.3 Double-Curved Plates. Plates that are curved in two directions shall be pressed cold or hot or shall be dished with a mortar and pestle die by repeated applications.

Table 5.6.2 Plate Dimensions

Plate Thickness	Minimum Diameter for Plates Not Rolled
9.5 mm ($< \frac{3}{8}$ in.)	12.2 m (40 ft)
9.5 mm to < 12.7 mm ($\frac{3}{8}$ in. to $< \frac{1}{2}$ in.)	18.3 m (60 ft)
12.7 mm to < 15.9 mm ($\frac{1}{2}$ in. to $< \frac{5}{8}$ in.)	36.6 m (120 ft)
15.9 mm ($\frac{5}{8}$ in.) and heavier	Must be rolled for all diameters

5.6.4 Milling Columns. The ends of columns shall be milled to provide a satisfactory bearing unless the design provides sufficient welding to resist the total calculated loads.

5.6.5 Fitting Roofs.

5.6.5.1 The roof shall fit tightly to the top of the tank to prevent the circulation of air over the surface of the water.

5.6.5.2 Where a spider is used, it shall not obstruct the flow of water into the overflow inlet.

5.6.6 Preventing Ice Damage. During the construction, the contractor shall keep the tank, structure, and building roofs free of ice caused by leakage until the tank equipment is made watertight.

5.6.7 Coating for Bottom Plates on Soil or Concrete.

5.6.7.1* The underside of all bottom plates shall be protected against corrosion by one of the following methods.

5.6.7.1.1 Two coats of paint shall be applied after the bottom has been completely welded. When the underside of the tank bottom surface is painted and lime (optional) is added to the base material on the tank underside, the compatibility of the paint and the lime shall be checked with the paint supplier.

5.6.7.1.2 Lime shall be applied to a clean sand base. The pH of the lime/sand mix shall be between 6.5 and 7.5. The chloride content of the under-bottom material shall be less than 300 ppm. The sulfate content shall be less than 1000 ppm.

5.6.7.1.3 Where permitted by environmental authorities, an oiled sand cushion shall be permitted to be used. The sand shall be coated but shall not be running with excess oil.

5.6.7.2* Where the tank bottom is placed on oiled sand, the sand shall be saturated to a depth of 102 mm (4 in.) with a suitable petroleum-base oil.

5.6.8 Testing.

5.6.8.1 Flat Bottoms. Upon completion of the welding of the tank bottom, it shall be tested by one of the following methods and shall be made entirely tight:

- (1) Air pressure or vacuum applied to the joints, using soap suds, linseed oil, or other suitable material for the detection of leaks
- (2) Joints tested by the magnetic particle method

5.6.8.2 General. Upon completion of the tank construction, it shall be filled with water furnished at the tank site by the purchaser using the pressure necessary to fill the tank to the maximum working water level.

5.6.8.2.1 Any leaks in the shell, bottom, or roof (if the roof contains water) that are disclosed by the test shall be repaired by chipping or melting out any defective welds and then re-welding.

5.6.8.2.2 Repair work shall be done on joints only when the water in the tank is a minimum of 0.6 m (2 ft) below the point under repair.

5.6.8.2.3 The tank shall be tested as watertight to the satisfaction of the purchaser's inspector.

5.6.8.3 Disposal of Test Water. The purchaser shall provide a means for disposing of test water up to the tank inlet or drain pipe.

5.7 Accessories.

5.7.1 Connections. Connections shall be provided on the tank for the necessary pipes, braces, frost-casting, and walkway supports.

5.7.2 Roof Anchorage. Each roof plate shall be securely fastened to the top of the tank.

5.7.3 Roof Hatch.

5.7.3.1 An easily accessible roof hatch or roof door having a minimum opening dimension of 610 mm (24 in.) shall be provided in the roof.

5.7.3.2 The hatch cover shall be built of steel plate with a minimum thickness of 4.8 mm ($\frac{3}{16}$ in.).

5.7.3.3 The opening shall have a curb that is a minimum of 102 mm (4 in.) high, and the cover shall have a minimum downward overlap of 51 mm (2 in.).

5.7.3.4 A catch shall be provided to keep the cover closed.

5.7.3.5 A second roof hatch shall be placed 180 degrees from the existing roof hatch with a ladder to access the tank floor.

5.7.4 Ladders — General.

5.7.4.1 Outside and inside steel ladders that are arranged for convenient passage from one to the other and through the roof hatch shall be provided.

5.7.4.2 Ladders shall not interfere with the opening of the hatch cover and shall not incline outward from the vertical at any point.

5.7.4.3 For pedestal-supported tanks, the ladder shall be placed inside an access tube that extends through the center of the tank.

5.7.5 Outside Fixed Shell and Roof Ladder.

5.7.5.1 The outside tank ladder of suction tanks and multiple-column-supported gravity tanks shall be fixed a minimum of 178 mm (7 in.) between the tank side and the centerline of rungs and shall be rigidly bolted or welded to brackets that are spaced a maximum of 3.7 m (12 ft) apart and that are welded to the tank plates.

5.7.5.2 The bottom bracket shall be located a maximum of 1.8 m (6 ft) above the base of the tank cylinder, and the ladder shall extend up the tank shell and radially along the roof, with the top bracket located within approximately 0.61 m (2 ft) of the roof hatch.

5.7.5.3 There shall be a minimum 0.3-m (1-ft) clearance at the sides and front of the ladder at the balcony.

5.7.5.4 All ladders shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

5.7.6 Inside Ladder.

5.7.6.1 The inside fixed ladder provided for passage between the roof hatch and tank bottom shall not be rigidly connected to the bottom plates.

5.7.6.2 A ladder shall extend from the top to the bottom of the inside of the large steel riser pipes and shall be secured to the shell plates by brackets that are spaced a maximum of 3.7 m (12 ft) apart.

5.7.6.2.1 The upper bracket shall be located at the top of the riser.

5.7.6.3 All ladders over 6.1 m (20 ft) high shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

5.7.7 Ladder Bars and Rungs.

5.7.7.1 Ladder side bars shall be not less than 51 mm $\times$ 12.7 mm (2 in. $\times$ $\frac{1}{2}$ in.) or 64 mm $\times$ 9.5 mm (2½ in. $\times$ $\frac{3}{8}$ in.).

5.7.7.2 Side bars shall be spaced at least 406 mm (16 in.) apart. Rungs shall be of at least 19.1-mm ($\frac{3}{4}$ -in.) round or square steel and shall be spaced 305 mm (12 in.) on their centers.

5.7.7.3 The rungs shall be firmly welded to the side bars.

5.7.7.4 Ladders and connections shall be designed to support a concentrated load of 159 kg (350 lb).

5.7.8 Painting Inaccessible Parts.

5.7.8.1 Parts that are inaccessible after fabrication, but that are subject to corrosion, shall be protected by paint before assembly.

5.7.8.1.1 This requirement shall not apply to the overlapping surfaces of single-welded lap joints above the high waterline.

5.7.8.2 Surfaces in watertight joints shall be coated with clear oil or lacquer.

5.7.9 Painting.

5.7.9.1 All interior surfaces of steel tanks that are exposed to water immersion or the vapor phase zone above the high water level shall be cleaned by near white blasting in accordance

with SSPC SP 10, *Joint Surface Preparation Standard Near-White Blast Cleaning*, or pickling in accordance with SSPC SP 8, *Pickling*, and shall be primed in accordance with the requirements for "Inside Paint System No. 1" in AWWA D102, *Coating Steel Water-Storage Tanks*.

5.7.9.2 All exterior surfaces and inside dry surfaces (pedestal tanks) shall be cleaned by commercial blasting in accordance with SSPC SP 6, *Joint Surface Preparation Standard Commercial Blast Cleaning*, or pickling in accordance with SSPC SP 8, *Pickling*, and shall be primed with one coat of lead-free alkyd in accordance with the requirements for "Outside Paint System No. 1" of AWWA D102, *Coating Steel Water-Storage Tanks*.

5.7.9.3 The appropriate primers for other interior and exterior paint systems shall be permitted to be used, provided permission is first obtained from the authority having jurisdiction.

5.7.9.4 After construction, all weld seams, unprimed margins, and any areas where the primer (if preprimed) has been damaged shall be blast-cleaned and patch-primed with the same primer.

5.7.9.5 All finish coat painting for interior surfaces (exposed to stored water) shall be in accordance with the requirements for "Inside Paint System No. 1" of AWWA D102, *Coating Steel Water-Storage Tanks*, using the same basic system throughout.

5.7.9.5.1* Wax coating systems shall not be permitted.

5.7.9.6 Finish coat painting for all exterior and interior surfaces not exposed to stored water shall be in accordance with the requirements for "Outside Paint System No. 1" of AWWA D102, *Coating Steel Water-Storage Tanks*, using two coats of aluminum or alkyd enamel in a color, as specified by the purchaser, to provide a minimum total system dry (not exposed to stored water) film thickness of .09 mm (3.5 mils) for aluminum finishes and .1 mm (4.5 mils) for alkyd enamels.

5.7.9.6.1 As provided for by "Outside Paint System No. 4" of AWWA D102, *Coating Steel Water-Storage Tanks*, the purchaser shall be permitted to specify an additional complete coat of primer for a total minimum system dry film thickness of .13 mm (5.0 mils) for aluminum finishes and of .15 mm (6.0 mils) for alkyd enamels in cases of more severe atmospheric exposures.

5.7.10 Other finish coats shall be permitted to be used where they comply with AWWA D102, *Coating Steel Water-Storage Tanks* (excluding "Inside Paint System No. 5"), and with the approval of the authority having jurisdiction.

5.7.11* Painting Application. All painting shall be applied in accordance with the appropriate requirements of *SSPC Systems and Specifications Steel Structures Painting Manual*, Chapter 5.

5.7.12 The painting and priming systems described in 5.7.9 through 5.7.11 shall be lead free.

Chapter 6 Factory-Coated, Bolted Steel Tanks

6.1 General.

6.1.1* This chapter shall apply to the design, fabrication, and erection of bolted steel water tanks, including pump suction tanks with factory-applied coatings.

6.1.2 Standard Capacity. The standard capacity of bolted tanks varies with the number of panels added to the diameter and ranges from 15.1 m³ to approximately 1900 m³ (4000 gal to approximately 500,000 gal) net capacity.

6.1.2.1 Tanks of other capacities shall be permitted.

6.1.3 Form.

6.1.3.1 Bolted tanks shall be cylindrical.

6.1.3.2 All joints, including vertical, horizontal, shell-to-roof, and shell-to-bottom plates or sheets, shall be field bolted.

6.1.3.3 Coatings shall be factory applied.

6.1.3.4 Bolt holes shall be shop-punched or drilled for field assembly.

6.1.3.5 Joints that are in contact with water and weather-tight joints shall be sealed.

6.2 Plate and Sheet Materials.

6.2.1 Plate and sheet materials shall be of open-hearth, electric furnace, or basic oxygen process steel that conforms to any of the following:

- (1) ASTM A 36, *Standard Specification for Carbon Structural Steel*
- (2) ASTM A 283, *Standard Specification for Low- and Intermediate-Tensile Strength Carbon Steel Plates*, Grade C or Grade D
- (3) ASTM A 1011, *Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High Strength Low-Alloy with Improved Formability*
- (4) ASTM A 572, *Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*, Grade 42 or Grade 50

6.2.2 Plates and sheets shall be furnished on the basis of weight, with permissible underrun and overrun in accordance with the tolerance table for plates ordered to weight in ASTM A 6, *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*.

6.2.3 Structural Shapes.

6.2.3.1 Hot-rolled structural shapes shall conform to ASTM A 36, *Standard Specification for Carbon Structural Steel*, or ASTM A 992/A 992M, *Standard Specification for Steel for Structural Shapes for Use in Building Framing*.

6.2.3.2 Aluminum shapes shall be permitted to be used for portions of the tank that are not in contact with water and shall follow the design criteria in Appendix A of AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*.

6.2.4 Tubular Columns.

6.2.4.1 Steel pipe shall be permitted to be used for tubular columns or other structural members, provided it complies with ASTM A 53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, Type E or Type S, Grade B; ASTM A 139, *Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and over)*, Grade B; and API 5LC, *Specification for CRA Line Pipe*, Grade B, and provided the minimum wall thickness of any such material complies with the design requirements and the minimum thickness requirement of this standard.

6.2.4.2 The allowable underrun shall be subtracted from the nominal wall thickness when calculating the minimum pipe wall thickness.

6.2.4.3 Tubular sections shall not be flattened to form end connections.

6.2.5 Bolts, Anchor Bolts, and Nuts. Bolts, anchor bolts, and nuts shall conform to AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*, and Section 11.4.

6.2.6* Forgings. Steel used for forging shall be made only by the open-hearth process. Forgings shall conform to the following ASTM specifications:

- (1) ASTM A 105, *Standard Specification for Carbon Steel Forgings for Piping Applications*
- (2) ASTM A 668, *Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use*

6.2.7 Filler Metal Electrodes.

6.2.7.1 Manual, shielded metal arc welding electrodes shall conform to the requirements of AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

6.2.7.2 Electrodes shall be of any E60XX or E70XX classification suitable for the electric current characteristics, the position of welding, and other conditions of intended use.

6.2.7.3 Electrodes for other welding processes shall be in accordance with applicable AWS specifications for filler metal.

6.2.8 Gasket.

6.2.8.1 Gasket material shall be of adequate tensile strength and resilience to obtain a leakproof seal at all seams and joints.

6.2.8.2 Gasket material shall be resistant to weather and ozone exposure and shall be in accordance with ASTM D 1171, *Standard Test Method for Rubber Deterioration — Surface Ozone Cracking Outdoors or Chamber (Triangular Specimens)*. Physical requirements shall conform to AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*.

6.2.8.3 Gasket material shall be capable of resisting chlorination exposure in accordance with AWWA C652, *Disinfection of Water-Storage Facilities*.

6.2.9 Sealant.

6.2.9.1 Sealants shall be supplied by the tank manufacturer. Sealants shall remain flexible over a temperature range of -40°C to 76.7°C (-40°F to 170°F).

6.2.9.2 Resistance to hardening and cracking shall be required. The sealant shall be solid with no plasticizers or extenders to cause shrinkage.

6.2.9.3 The sealant shall resist ozone and ultraviolet light and shall not swell or degrade under normal water storage conditions. In addition, the sealant shall be capable of resisting chlorination exposure in accordance with AWWA C652, *Disinfection of Water-Storage Facilities*.

6.3 Earthquake Load.

6.3.1 Tanks shall meet requirements for resistance to earthquake damage in accordance with the earthquake design provisions of AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*. For seismic anchor-bolt loading:

$$T_s = \frac{4M_s}{ND} - \frac{W'}{N}$$

where:

T_s = seismic bolt tension (lb)

M_s = seismic overturning moment (ft lb)

W' = weight of tank shell and portion of roof carried by shell (lb)

N = number of anchor bolts

D = tank diameter (ft)

6.3.2 Unit Stress of Shell Plates. The maximum stresses in pounds per square inch (megapascals) that are produced by the design loads in Section 4.12 shall not exceed the requirements of AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*.

6.4 Design Details.

6.4.1 Minimum Steel Thickness. Steel plates or sheets shall meet the minimum design criteria in accordance with AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*, as well as any additional requirements outlined below.

6.4.1.1 Roof sheets shall have a minimum thickness of 2.4 mm (0.094 in.).

6.4.1.1.1 Sheets on roofs having a slope of 1 in 2.75 or greater for which the tank diameter does not exceed 10.7 m (35 ft) shall be permitted to utilize a minimum thickness of 1.8 mm (0.070 in.), provided a suitable walkway is provided from the ladder to all appurtenances including, but not limited to, the roof hatch(es), roof vent(s), and controls for the water level and temperature.

6.4.1.2 Floor sheets shall have a minimum thickness of 2.7 mm (0.105 in.), provided the tank floor is supported on a granular base, on crushed stone, or on a concrete slab.

6.4.1.3 The minimum thickness of the first full height shell plate and starter ring (if applicable) shall be 4.8 mm (0.1875 in.).

6.4.1.3.1 This minimum thickness shall be permitted to be reduced, provided the design meets the following criteria:

- (1) *Tension on the Net Section.* The tensile stress on the net section of a bolted connection shall not exceed the lesser of the values determined by the following formulas:

$$f_t = 0.5F_y(1.0 - 0.9r + 3rd/s) \leq 0.5F_u$$

$$f_t = \frac{1}{3}F_u$$

where:

f_t = allowable tensile stress (psi)

F_y = published yield strength of the sheet material (psi)

r = force transmitted by the bolt or bolts at the section considered, divided by the tensile force in the member at that section; if r is less than 0.2, it can be taken equal to zero.

d = diameter of the bolt (in.)

s = spacing of the bolts perpendicular to the line of stress (in.)

F_u = ultimate strength of the sheet material (psi)

- (2) *Shell Thickness.* The thickness of cylindrical shell plates stressed by the pressure of the tank contents shall be calculated by the following formula:

$$t = \frac{2.6 HDSG}{f_t(S-d)}$$

where:

- t = shell plate thickness (in.)
 H = height of liquid from the top capacity line to the point of overflow to the bottom of the shell course being designed (ft)
 D = tank diameter (ft)
 S = bolt spacing in line perpendicular to line of stress (in.)
 G = specific gravity of liquid (1.0 for water)
 f_t = allowable tensile stress (psi)
 d = bolt-hole diameter (in.)

6.4.1.4 The minimum thickness of the upper rings of shell plates shall be 2.7 mm (0.105 in.).

6.4.1.4.1 This minimum thickness shall be permitted to be reduced to no less than 2.4 mm (0.094 in.), provided that the design meets the criteria of 6.4.1.3.1.

6.5 Fabrication.

6.5.1 Parts shall be fabricated in accordance with AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*, practices and tolerances.

6.5.2 Welding shall be limited to the shop installation of nozzles, vents, manway connections, and subassemblies. Field welding shall not be permitted.

6.5.3 Coatings shall be applied in accordance with AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*.

6.5.4 All tank components shall be given a mark number for ease of assembly.

6.5.5* All coated parts shall be protected from damage during shipment.

6.6 Erection.

6.6.1 Bolted tanks shall be erected in accordance with the manufacturers' drawings, instructions, and AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*, procedures to facilitate inspection for leaks.

6.6.1.1 Bolted steel floor plates shall be positioned directly on a minimum 102-mm (4-mil) polyethylene base that is arranged to allow waterflow from the center of the tank to the perimeter of the tank.

6.6.1.2 The polyethylene sheets shall be placed over the sloped base and shall be lapped a minimum of 457 mm (18 in.) on top of one another (the higher sheet overlapping the adjacent sheet) to allow drainage from the underside of the tank.

6.6.1.3 Polyethylene sheeting shall not be required for tanks with concrete slabs that also serve as the tank floor, provided the provisions of Section 10.6 have been met.

6.6.2 The erector shall exercise care to properly install all parts of the tank including, but not limited to, gaskets and sealants.

6.6.3 Care in handling coated parts shall be exercised.

6.6.3.1 Any sections that experience damage to the factory-applied coatings shall be repaired or replaced in accordance with the manufacturers' instructions.

6.6.3.2 Damaged parts shall be replaced.

6.6.4* The completed tank shall be tested by filling it with water, and any detected leaks shall be repaired in accordance with AWWA D103, *Factory-Coated Bolted Steel Tanks for Water Storage*.

Chapter 7 Pressure Tanks

7.1 General.

7.1.1 Service. Pressure tanks shall be permitted to be used for limited private fire protection services, such as those covered by the following NFPA standards:

- (1) NFPA 13, *Standard for the Installation of Sprinkler Systems*
- (2) NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*
- (3) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

7.1.2 Pressure tanks shall not be used for any other purpose.

7.1.2.1 Pressure tanks approved by the authority having jurisdiction shall be permitted to be used for other purposes.

7.1.3 Capacity. The capacity shall be approved by the authority having jurisdiction.

7.1.4 Water and Air Pressure.

7.1.4.1 Pressure tanks shall be kept with a supply of water to meet the demand of the fire protection system as calculated in Chapter 14 of NFPA 13, *Standard for the Installation of Sprinkler Systems*, for the duration required by Chapter 11 of NFPA 13.

7.1.4.1.1 The pressure shall be sufficient to push all of the water out of the tank while maintaining the necessary residual pressure required by Chapter 14 of NFPA 13, at the top of the system.

7.1.4.1.2 Where otherwise approved by the authority having jurisdiction, this requirement shall not apply.

7.1.5* Air Lock. Methods used for the prevention of air lock shall be approved by the authority having jurisdiction in each case.

7.1.6 Location. Pressure tanks shall be located above the top level of sprinklers.

7.1.6.1 Subject to the approval of the authority having jurisdiction, tanks shall be permitted to be located in the basement or elsewhere.

7.1.6.2 Subject to the approval of the authority having jurisdiction, tanks shall be permitted to be buried in accordance with the requirements of 7.1.10.

7.1.7 Construction.

7.1.7.1* General. Pressure tanks shall be constructed in accordance with the *ASME Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," Section VIII, Division 1, Unfired Pressure Vessels.

7.1.7.1.1 This requirement shall not apply where otherwise specified herein.

7.1.7.2 Tests. Tests shall be performed as follows:

7.1.7.2.1 Each pressure tank shall be tested in accordance with the *ASME Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," before painting.

7.1.7.2.1.1 The hydrostatic test pressure shall be a minimum of 10.3 bar (150 lb/in.²).

7.1.7.2.2 In addition to the ASME tests, each pressure tank shall be filled to two-thirds of its capacity and tested at the normal working pressure with all valves closed and shall not lose more than 0.03 bar ($\frac{1}{2}$ lb/in.²) pressure in 24 hours.

7.1.7.2.3 A certificate signed by the manufacturer that certifies that the foregoing tests have been made shall be filed with the authority having jurisdiction.

7.1.7.2.4 A repetition of the tests specified in 7.1.7.2.1 through 7.1.7.2.3 shall be required after the tank has been set in place and connected. Where conditions do not allow shipping the tank after it is assembled, these tests shall be conducted following its assembly in the presence of a representative of the authority having jurisdiction.

7.1.7.3 Supports.

7.1.7.3.1 The supports shall be steel or reinforced concrete and shall be located in a manner that prevents sagging or vibration and that properly distributes the loads caused by the weight of the vessel when full of water.

7.1.7.3.2 Stresses in steel supports shall not exceed those permitted by Section 12.4 for steel towers.

7.1.7.3.3 Horizontal tanks shall have at least one support near each end of the tank that is located so that combined stresses in any part of the tank do not exceed those specified in 12.4.6.

7.1.7.4 Painting. Tanks shall be cleaned and painted inside and outside in accordance with the requirements of 5.7.9 through 5.7.12. An ASME Specifications for Material stamp and an ASME Standard Pressure Vessel stamp shall not be rendered illegible.

7.1.8 Marking.

7.1.8.1 General. All stamps required by the ASME specification shall be applied.

7.1.8.1.1 The nameplate or water-level marking shall be securely fastened without obliterating any lettering.

7.1.8.1.2 If screws are used, they shall not penetrate more than one-half of the tank plate thickness.

7.1.8.2 Nameplate. A metal nameplate with raised or stamped letters and numbers that are large enough to be easily read that bears the following information shall be provided:

- (1) Name and location of manufacturer
- (2) Year of assembly
- (3) Length and diameter
- (4) Total capacity [m³ (gal)]
- (5) Working pressure [bar (lb/in.²)]

7.1.8.3 Water-Level Indicator.

7.1.8.3.1 The nameplate shall also serve as the water-level indicator by bearing an easily observed raised arrow.

7.1.8.3.2 The tank plate shall be marked " $\frac{2}{3}$ capacity line" in raised or stamped lettering behind the gauge glass and shall

be located in such a position that the arrow is at the water level when the tank is two-thirds full. For horizontal tanks, the two-thirds capacity line is $\frac{63}{100}$ of the diameter above the bottom of the tank.

7.1.8.3.3 Where the design water level is at a point other than the $\frac{2}{3}$ level, the nameplate shall be so lettered and positioned behind the gauge glass accordingly.

7.1.9 Housing.

7.1.9.1 Where subject to freezing, the tank shall be located in a substantial noncombustible housing.

7.1.9.2 The tank room shall be large enough to provide free access to all connections, fittings, and manholes, with at least 457 mm (18 in.) around the rest of the tank.

7.1.9.3 The distance between the floor and any part of the tank shall be at least 0.91 m (3 ft).

7.1.9.4 The floor of the tank room shall be watertight and shall be arranged to drain outside the enclosure.

7.1.9.5 The tank room shall be adequately heated to maintain a minimum temperature of 4.4°C (40°F) and shall be equipped with ample lighting facilities.

7.1.10 Buried Tanks. Where necessary due to lack of space or other conditions, pressure tanks shall be permitted to be buried, provided the requirements of 7.1.10.1 through 7.1.10.7 are satisfied.

7.1.10.1 The tank shall be located below the frost line to protect against freezing.

7.1.10.2 The end of the tank, and at least 457 mm (18 in.) of its shell, shall project into the building basement or into a pit in the ground provided with protection against freezing.

7.1.10.3* There shall be adequate space for inspection, maintenance, and use of the tank manhole for interior inspection.

7.1.10.4 The exterior surface of the tank shall be cleaned and painted in accordance with 7.1.7.4, and additional protection shall be provided as follows:

7.1.10.4.1 An approved cathodic system of corrosion protection shall be provided.

7.1.10.4.2 At least 305 mm (12 in.) of sand shall be backfilled around the tank.

7.1.10.5 The tank shall be located above the maximum ground water level so that the buoyancy of the tank, when empty, does not force it upward. The tank shall be permitted to be anchored to a concrete base as an alternative.

7.1.10.6 The tank shall be designed with strength to resist the pressure of earth to which it is subjected.

7.1.10.7 A manhole shall be located on the vertical centerline of the tank end as close as possible to the knuckle but remaining clear of it.

7.2 Pipe Connections and Fittings.

7.2.1 Openings.

7.2.1.1 A manhole and all openings needed for the connection of the piping and fittings specified in the following articles shall be provided.

7.2.1.2 The manhole and threaded openings shall conform in design with the *ASME Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels."

7.2.1.3 The manhole shall be placed below the water level.

7.2.2 Tank Discharge.

7.2.2.1 The discharge pipe shall be sized to supply the required amount of water for the fire protection system, but shall not be less than 102 mm (4 in.) in size in any case.

7.2.2.2 The discharge pipe shall be connected to the bottom of the tank by means of a fitting that projects 51 mm (2 in.) above the bottom to form a settling basin and to prevent sediment from passing into the system.

7.2.2.3 A listed horizontal swing-check valve and a listed indicating valve shall be located in the discharge pipe, directly under or near the tank.

7.2.2.4 The pipe shall be adequately supported.

7.2.3 Filling Pipe.

7.2.3.1 The water-filling pipe shall be at least 38 mm (1½ in.) in size, shall be run separately from the filling pump or other acceptable source of supply, and shall be adequately supported and protected from mechanical injury.

7.2.3.2* The filling pipe shall be connected to the top or bottom of the tank as required by the authority having jurisdiction.

7.2.3.3 A listed horizontal bronze-seat swing-check valve and a renewable-disc globe valve shall be provided in the pipe near the tank.

7.2.3.4 The globe valve shall be placed between the check valve and the tank.

7.2.4 Air Pipe.

7.2.4.1 The air supply pipe shall be at least 25.4 mm (1 in.) in size, well supported, and protected from breakage.

7.2.4.2 It shall be connected to the tank above the water level.

7.2.4.3 A reliable horizontal bronze-seat swing-check valve and listed renewable-disc globe valve shall be provided in the pipe near the tank.

7.2.4.4 The globe valve shall be placed between the tank and the check valve.

7.2.5 Water-Level Gauge.

7.2.5.1 A 19.1-mm (¾-in.) water-level gauge with a listed valve at each end shall be provided with the center of the glass tube at the normal water level.

7.2.5.2 The gauge glass shall be not over 305 mm (12 in.) long for horizontal tanks or 457 mm (18 in.) long for vertical tanks.

7.2.5.3 Listed angle globe valves with renewable discs shall be installed in the connections from the gauge to the tank and shall be independent of the shutoff valves that are a part of the gauge fittings.

7.2.5.4 The water-level gauge shall be connected through valves into the tank.

7.2.5.5 A petcock shall be provided for draining the glass.

7.2.5.6 All fittings and nipples shall be of brass, not less than 19.1 mm (¾ in.) in size.

7.2.5.6.1 The nipple that extends into the tank shall be permitted to be 12.7 mm (½ in.) in size.

7.2.5.7 The glass gauge tube shall be protected from mechanical injury by a guard that consists of at least three 4.8-mm (⅜-in.) brass rods.

7.2.5.8 The valves on the water-level gauge connections shall be opened only when ascertaining the amount of water in the tank.

7.2.6 Air-Pressure Gauge.

7.2.6.1 A listed 114-mm (4½-in.) dial, double-spring gauge shall be connected into the air chamber between the tank and any valve, generally to the line between the upper end of the water-level gauge and the tank.

7.2.6.2 The pressure gauge shall have a maximum range equivalent to twice the normal working pressure when installed and shall be controlled by a valve that is arranged to drain.

7.2.6.3 A plugged outlet at least 6.4 mm (¼ in.) in size shall be provided between the valve and the gauge for the inspector's gauge.

7.2.7 Safety Appliances.

7.2.7.1 A brass relief valve not less than 19.1 mm (¾ in.) in size that is set to operate at a pressure that is 10 percent in excess of the normal tank pressure shall be placed in the air-supply pipe between the check valve and the air compressor.

7.2.7.2 There also shall be a brass relief valve not less than 38.1 mm (1½ in.) in size at the filling pump that is set to relieve pressures that are 10 percent in excess of the pressure at the pump when the tank is under normal working pressure.

7.2.7.3 No safety appliances shall be installed between the tank and other valves.

7.2.8 Emergency Drain.

7.2.8.1 Provisions shall be made to drain each tank independently of all other tanks and the sprinkler system by means of a pipe that is not less than 38.1 mm (1½ in.) in size.

7.2.8.1.1 The drain valve shall be a globe valve with a renewable disc and shall be located near the tank.

7.2.8.2 Use of drains other than those shown in Figure B.1(a) and Figure B.1(b) below the pressure tank, after shutting off other water supplies, shall not be permitted under any condition, as collapse of the pressure tank can result.

7.2.9 Water Filling Supply.

7.2.9.1 The filling supply or pump shall be reliable and shall be capable of replenishing the water that is required to be maintained in the tank with the required air pressure restored in not more than 4 hours.

7.2.9.2 A relief valve shall be provided at the pump, as specified in 7.2.7.

7.2.10 Air Compressor.

7.2.10.1 An air compressor capable of delivering not less than 16 ft³/min (0.45 m³/min) of free air for tanks of 28.39 m³ (7500 gal) total capacity, and not less than 0.57 m³/min (20 ft³/min) for larger sizes, shall be provided.

7.2.10.2 The compressor shall be located in the tank house.

7.2.10.2.1 The compressor shall be permitted to be located elsewhere if permitted by the authority having jurisdiction.

7.2.10.3 A safety valve shall be provided, as specified in 7.2.7.

7.2.11 Arrangement. All pipe connections and valves, including the manhole, the emergency drain valve, and all valves on the discharge pipe, shall be arranged for convenient manipulation.

7.2.12* Watertight Intersections at Roofs and Floors. The intersections of all piping with the building roof and concrete or waterproof floors shall be watertight.

7.2.13 Fire Protection. The tank shall be protected by automatic sprinklers if combustible contents or construction could heat the tank in the event of a fire.

Chapter 8 Wood Gravity Tanks and Suction Tanks

8.1 General.

8.1.1 This chapter shall apply to the design, fabrication, and erection of wood gravity water tanks, including pump suction tanks.

8.1.2 Capacity.

8.1.2.1 The capacity of the tank is the number of cubic meters (U.S. gallons) available above the outlet opening.

8.1.2.2 The net capacity between the outlet opening of the discharge pipe and the inlet of the overflow shall be at least equal to the rated capacity.

8.1.3* Standard Sizes. The standard net capacity sizes of wood tanks shall be as follows:

- (1) 18.93 m³ (5000 gal)
- (2) 37.85 m³ (10,000 gal)
- (3) 56.78 m³ (15,000 gal)
- (4) 75.70 m³ (20,000 gal)
- (5) 94.63 m³ (25,000 gal)
- (6) 113.55 m³ (30,000 gal)
- (7) 151.40 m³ (40,000 gal)
- (8) 189.25 m³ (50,000 gal)
- (9) 227.10 m³ (60,000 gal)
- (10) 283.88 m³ (75,000 gal)
- (11) 378.50 m³ (100,000 gal)

8.1.4 Strength.

8.1.4.1 The materials as specified shall have no defects other than those that are permitted by the grading rules for the lumber specified in 8.2.2.

8.1.4.2 The use of second-hand materials, including such materials as hoops and lumber, shall not be permitted.

8.1.4.3 The workmanship shall be of such quality that defects or injuries are not produced during manufacture or erection.

8.1.4.4* Unit stresses, as specified in Section 8.4, shall not be exceeded except where additionally reinforced.

8.1.4.5 The structure and its details shall possess the requisite strength and rigidity.

8.2 Material.

8.2.1 Lumber — General. All lumber shall be well-seasoned and free from rot, sap, loose or unsound knots, worm holes, and shakes in accordance with National Wood Tank Institute Bulletin S82, *Specifications for Tanks and Pipes*.

8.2.2 Lumber — Staves and Bottom.

8.2.2.1 Untreated lumber in the staves and bottom shall be thoroughly air-dried (below 17 percent moisture content) “all heart” or “tank stock” without any sapwood after shaping. Acceptable untreated species, in order of preference, shall be redwood, western yellow cedar, southern white cedar (dismal swamp), western red cedar, and Douglas fir (coast type).

8.2.2.2* Western yellow cedar, redwood, or southern white cedar (dismal swamp) shall be used, as the increased serviceability ordinarily more than offsets the slightly greater cost of the complete installation.

8.2.2.3 Treatment.

8.2.2.3.1 Acceptable treated species shall include all those specified in 8.2.2.1 and yellow pine, all without sapwood restriction.

8.2.2.3.2 Treatment shall consist of a 96-kg/m³ to 128-kg/m³ (6-lb/ft³ to 8-lb/ft³) retention of creosote or pentachlorophenol that is applied by means of the empty-cell process after shop fabrication, in accordance with the American Wood Preservers Association.

8.2.3 Timber Supports. Wooden dunnage beams, where used, shall be a dense grade of southern pine or Douglas fir or shall be a construction heart-untreated redwood or red cypress (coast type).

8.2.3.1 Structural grades of other species shall be permitted to be used, provided they are treated with 96-kg/m³ to 128-kg/m³ (a 6-lb/ft³ to 8-lb/ft³) retention of creosote or pentachlorophenol that is applied by means of the empty-cell process in accordance with the standard specifications of the American Wood Preservers Association. (See 8.4.1 and 8.5.8.)

8.2.3.2 Wood dunnage beams shall be at least 102 mm × 152 mm (4 in. × 6 in.) nominal size.

8.2.4 Hoops.

8.2.4.1 Hoops shall be round bars of steel.

8.2.4.2 The steel bars shall conform to ASTM A 36, *Standard Specification for Carbon Structural Steel*, ASTM A 502, *Standard Specification for Steel Structural Rivets*, or ASTM A 675, *Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties*.

8.2.4.3 Steel shall be made only by the open-hearth or electric-furnace processes.

8.2.5 Hoop Lugs. The lugs shall be malleable iron, cast steel, or fabricated steel and shall have equal or greater ultimate strength than the steel hoop with which they are used that is in accordance with ASTM A 36, *Standard Specification for Carbon Structural Steel*, ASTM A 502, *Standard Specification for Steel Structural Rivets*, or ASTM A 675, *Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties*.

8.2.6 Steel Shapes. The steel for structural shapes shall conform to ASTM A 36, *Standard Specification for Carbon Structural Steel*.

8.3 Loads.

8.3.1 Dead Load. The dead load shall be the estimated weight of all permanent construction and fittings.

8.3.2 Live Load.

8.3.2.1 Under normal conditions, the live load shall be the weight of all the liquid when it overflows the top of the tank.

8.3.2.2 The unit weight of water shall be considered to be 1000 kg/m^3 (62.4 lb/ft^3).

8.3.2.3 Proper provision shall be made for temporary stresses during erection.

8.3.2.4 Where roofs have a slope of less than 30 degrees, they shall be designed to support a uniform weight of 122 kg/m^2 (25 lb/ft^2) on the horizontal projection.

8.3.3 Wind Load.

8.3.3.1 Under normal conditions, the wind load or pressures shall be assumed to be 147 kg/m^2 (30 lb/ft^2) on vertical plane surfaces, 88 kg/m^2 (18 lb/ft^2) on projected areas of cylindrical surfaces, and 73 kg/m^2 (15 lb/ft^2) on projected areas of conical and double-curved plate surfaces.

8.3.3.2 When designing for wind velocities over 161 km/hr (100 mph), all of these specified unit pressures shall be adjusted in proportion to the square of the velocity, assuming that the pressures are for velocities of 161 km/hr (100 mph).

8.3.4 Earthquake Load. Tank structures shall meet local requirements for resisting earthquake damage.

8.3.5 Balcony and Ladder Loads.

8.3.5.1 A vertical load of 1000 lb (454 kg) shall be assumed to be applied to any 10 ft^2 (0.93 m^2) of area on the balcony floor and on each platform; 500 lb (227 kg) shall be assumed to be applied to any 10 ft^2 (0.93 m^2) of area on the tank roof; and 350 lb (159 kg) shall be assumed to be applied on each vertical section of ladder.

8.3.5.2 All structural parts and connections shall be designed to withstand such loads.

8.3.5.3 The loads specified shall not be combined with snow loading.

8.4 Unit Stresses.

8.4.1* General. The following stresses in megapascals (pounds per square inch) shall apply particularly to wood tanks and shall not be exceeded.

8.4.1.1 Tension Hoops.

8.4.1.1.1 The unit stress for tension hoops made of steel in accordance with ASTM A 675, *Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties*, shall be 103.43 MPa ($15,000 \text{ lb/in.}^2$) (use with hydrostatic load and neglect initial tension).

8.4.1.1.2 Steel in accordance with ASTM A 36, *Standard Specification for Carbon Structural Steel*, or ASTM A 502, *Standard Specification for Steel Structural Rivets*, shall have a unit stress of 137.90 MPa ($20,000 \text{ lb/in.}^2$).

8.4.1.2 Timber. The allowable working stresses for timbers referenced in 8.2.3 and 8.5.8 shall be as specified in Table 8.4.1.2.

8.4.2 Wind and Earthquake Allowance.

8.4.2.1 For stresses that are due to the combination of wind or earthquake with other loads, the working unit stresses specified in 8.4.1 through 8.4.1.2 shall be permitted to be increased by $33\frac{1}{3}$ percent.

8.4.2.2 Wind and earthquake loads shall not be required to be considered simultaneously.

8.4.2.3 In no case shall the strength of the member be less than that required for dead and live loads alone.

8.5 Details of Design.

8.5.1 Lumber Thickness. The lumber in the staves and in the bottom shall be at least $2\frac{1}{2} \text{ in.}$ (64 mm) (nominal), dressed to not less than 54 mm ($2\frac{1}{8} \text{ in.}$) thickness for tanks less than 6.1 m (20 ft) in depth or diameter; for larger tanks, the lumber shall be at least 76 mm (3 in.) (nominal), dressed to not less than 60 mm ($2\frac{3}{8} \text{ in.}$) thickness.

8.5.2 Hoop Sizes. Hoops shall not be smaller than the pitch diameter of 19.1-mm ($\frac{3}{4}\text{-in.}$) thread. No more than two sizes of hoops shall be used on a tank.

8.5.3* Hoop Schedules.

8.5.3.1 A hoop shall be assumed to support one-half the length of the stave to the two adjacent hoops.

8.5.3.2* Other schedules shall be acceptable, provided the unit stresses specified in Section 8.4 are not exceeded.

8.5.4 Hoops at Bottom.

8.5.4.1 One hoop shall be placed at approximately the center of the bottom planks of tanks with diameters of 5.8 m (19 ft) or less.

8.5.4.1.1 The stress in this hoop shall not exceed one-half the allowable unit tension, with the excess strength provided to accommodate the swelling of the bottom planks.

8.5.4.2 On tanks with diameters of over 5.8 m (19 ft), two hoops of equal size shall be placed opposite the tank bottom.

8.5.4.2.1 The stress in the upper hoop shall be limited as specified in 8.5.4.1.1.

8.5.5 Hoops at Top. The top hoops shall be placed 76 mm (3 in.) below the bottom of the flat cover joists or 76 mm (3 in.) below the top of the staves if the flat cover is omitted.

8.5.5.1 The maximum spacing of hoops shall not exceed 533 mm (21 in.).

8.5.6 Hoop Lugs.

8.5.6.1 The ends of the hoop sections shall be connected by malleable iron, cast steel, or fabricated steel lugs and shall have equal or greater ultimate strength than the steel hoop with which they are used that is in accordance with ASTM A 36, *Standard Specification for Carbon Structural Steel*, or ASTM A 502, *Standard Specification for Steel Structural Rivets*.

8.5.6.2 The lugs shall be designed so that water cannot be pocketed.

8.5.6.3 The hoops shall be so located on the tank that the lugs form fairly uniform spiral lines.

8.5.7 Main Supports. Steel I-beams or reinforced concrete beams shall be used for the main supports where the dunnage beams rest.

Table 8.4.1.2 Working Stresses for Timber (Select Grade)

Species	Allowable Stress							
	Bending				Compression Perpendicular to Grain		Compression Parallel to Grain; Short Columns	
	In Extreme Fiber		Horizontal Shear		MPa	psi	MPa	psi
	MPa	psi	MPa	psi				
Cedar, western red	6.21	900	0.55	80	1.38	200	4.83	700
Cedar, northern and southern white	5.17	750	0.48	70	1.21	175	3.79	550
Douglas fir (western Washington and Oregon)	11.03	1600	0.62	90	2.38	345	8.10	1175
Douglas fir (western Washington and Oregon), dense grade	12.07	1750	0.72	105	2.62	380	8.89	1290
Douglas fir (Rocky Mountain type)	7.58	1100	0.57	85	1.90	275	5.52	800
Pine, southern yellow	11.03	1600	0.76	110	2.38	345	8.10	1175
Pine, southern yellow, dense	12.07	1750	0.83	120	2.62	380	8.89	1290
Pine, white, sugar, western white, western yellow	6.21	900	0.57	85	1.72	250	5.17	750
Pine, Norway	7.58	1100	0.57	85	2.07	300	5.52	800
Redwood	8.27	1200	0.48	70	1.72	250	6.90	1000
Spruce, red, white, Sitka	7.58	1100	0.57	85	1.72	250	5.52	800

8.5.8 Spacing of Supports.

8.5.8.1 The maximum distance in the clear between the beams where the tank bottom rests shall not exceed 533 mm (21 in.).

8.5.8.2 The maximum distance between the outer edge of the outer dunnage beam and the inside surface of the tank staves measured on a line perpendicular to the beam at its midpoint shall not exceed 356 mm (14 in.).

8.5.9 Air Circulation Under Tank Bottom. Tank supports shall be designed to allow the free circulation of air under the tank bottom and around the ends of the staves.

8.6 Workmanship.

8.6.1* Lumber Edges and Surfaces. Planks for the staves and bottom shall be planed on both sides.

8.6.1.1 The edges of the staves and bottom planks shall be machine-planed or sawed.

8.6.1.2 The edges of staves shall be cut to obtain full bearing at the joints.

8.6.1.3 The last stave to be placed in the tank shall be carefully planed to the required size.

8.6.2 Croze.

8.6.2.1 The croze shall be cut at right angles to the centerline of the staves.

8.6.2.2 The edges of the bottom planks shall be beveled on the underside and smoothed off on the upper side by planing to obtain a tight joint at the croze.

8.6.2.3 The depth and width of the croze shall be at least 19.1 mm ($\frac{3}{4}$ in.) and 54 mm ($2\frac{1}{8}$ in.), respectively, for 76-mm (3-in.) nominal staves, and 15.9 mm ($\frac{5}{8}$ in.) and 51 mm (2 in.), respectively, for 64-mm ($2\frac{1}{2}$ -in.) nominal staves.

8.6.3 Chime.

8.6.3.1 The chime shall be of uniform depth and shall be not less than 76 mm (3 in.).

8.6.3.2 Before erection, the chimes of staves shall be fastened with at least two nails or staples at least 32 mm ($1\frac{1}{4}$ in.) long.

8.6.3.3 Nails or staples shall be coated with zinc or copper, or they shall be of other material that is highly resistant to corrosion.

8.6.4 Dowels. The edges of each bottom plank shall be bored with holes not over 5 ft (1.5 m) apart for wooden dowels not less than 12.7 mm ($\frac{1}{2}$ in.) in diameter for planks up to 64 mm ($2\frac{1}{2}$ in.) nominal, and 15.9 mm ($\frac{5}{8}$ in.) in diameter above that thickness.

8.6.5 Splices.

8.6.5.1 Finger joint splices shall be used in a stave or in a bottom plank where permitted by the authority having jurisdiction.

8.6.5.2 Such joints in adjacent staves or bottom planks shall be staggered a minimum of 0.61 m (2 ft).

8.6.6 Joints at Bottom. The joints between staves shall not be closer than 12.7 mm (½ in.) to a joint between the bottom planks.

8.6.7 Extra Staves. One or more extra staves shall be shipped with each tank.

8.6.8 Marking of Staves. The proper hoop spacing shall be plainly marked on at least six staves before shipment.

8.6.9 Clearance at Supports.

8.6.9.1 The distance between the ends of dunnage beams and the inside surface of the staves shall be not less than 25.4 mm (1 in.) or more than 76 mm (3 in.).

8.6.9.2 The supports shall be of such depth that the clearance beneath the ends of staves is not less than 25.4 mm (1 in.) at any point.

8.6.10 Hoop Forming. Hoops shall be cut to the proper length and shall be bent in the shop to the radius of the tank.

8.6.11 Hoop Threads. The nut threads shall fit tightly and shall be U.S. Standard.

8.6.12 Hoop Tightening. Care shall be taken when setting up the nuts on the hoops to prevent an excessive initial stress in the hoops. The threads of the nuts shall be fully engaged.

8.6.13 Removal of Rubbish. All waste lumber and rubbish shall be removed from the inside of the tank and from the flat cover, if provided, before filling to prevent possible obstruction of piping.

8.7 Accessories.

8.7.1 Roof — General.

8.7.1.1 Where the tank is located outdoors, it shall have a flat wooden cover over the top and a conical roof above the wooden cover.

8.7.1.1.1 The flat cover shall not be required, and the conical cover shall be made self-supporting, provided the approval of the detailed design is first obtained from the authority having jurisdiction.

8.7.1.2 Roofs shall be constructed as shown in Figure B.1(c) and Figure B.1(d), or shall be in accordance with other designs approved by the authority having jurisdiction.

8.7.1.3 Roof boards shall be of not less than 25.4 mm (1 in.) nominal thickness or 9.5-mm (⅜-in.) exterior grade plywood that is laid without spacing between.

8.7.1.4 If plywood is used, the end joints shall be made over roof joists, or ply clips shall be used to support the edges.

8.7.1.5 Shiplap or matched joints shall be used on boards in the flat cover, unless plywood is used.

8.7.1.6 The joint between the tank staves and roof shall be tight.

8.7.1.7 Nails or staples shall be heavily galvanized or shall be of nonferrous metals.

8.7.2 Flat Cover.

8.7.2.1 The flat cover, if provided, shall rest on parallel joists and shall be spaced not over 914 mm (36 in.) on centers.

8.7.2.2 The nominal size of the joists shall be at least 51 mm × 152 mm (2 in. × 6 in.) for lengths up to 5.5 m (18 ft); 76 mm × 152 mm (3 in. × 6 in.) for lengths up to 6.7 m (22 ft); and 76 mm × 203 mm (3 in. × 8 in.) for lengths up to 9.2 m (30 ft).

8.7.2.3 The full section of all joists at their ends shall be solidly supported by resting in slots that are cut entirely through the staves or by other means that are approved by the authority having jurisdiction.

8.7.3* Conical Roof.

8.7.3.1 The conical roof shall be supported by 51-mm × 102-mm (2-in. × 4-in.) rafters spaced not over 914 mm (36 in.) apart around the top of the tank.

8.7.3.2 Although the rafter and header type of construction is considered preferable, other types of roof construction shall be acceptable, provided approval of the design is first obtained from the authority having jurisdiction.

8.7.3.3 The roof shall be covered with galvanized iron, at least 27-kg (60-lb) asphalt, asbestos, or equivalent fire-resistive roofing and shall be securely fastened in place.

8.7.3.3.1 Prepared asphalt roofing shall be laid with at least 64-mm (2½-in.) laps, properly cemented, and using 19.1-mm (¾-in.) galvanized roofing nails with at least 12.7-mm (½-in.) heads and large washers spaced not over 76 mm (3 in.) on centers, or 1.27-mm (0.050-in.) nonferrous staples 12.7 mm (½ in.) in length for 30-kg (65-lb) covering and 19.1 mm (¾ in.) for 41-kg (90-lb) covering.

8.7.4 Roof Anchorage. All parts of the roof and cover shall be securely fastened together and shall be anchored to the tank staves to prevent extreme winds from blowing them loose.

8.7.5 Roof Hatches.

8.7.5.1 A hatch not less than 508 mm × 559 mm (20 in. × 22 in.) shall be built in the conical roof and shall be accessible from the tank ladder.

8.7.5.1.1 The hatch shall be placed high enough on the conical roof that entrance to the flat roof is reasonably easy when the cover for the flat roof hatch is in place.

8.7.5.2 The four sides of the hatch shall be of not less than 38.1-mm (1½-in.) dressed stock and shall be raised not less than 76 mm (3 in.) above the roof boards.

8.7.5.2.1 The top of the hatch cover shall be made of not less than 25.4-mm (1-in.) dressed and matched boards or 9.5-mm (⅜-in.) exterior grade plywood, and shall be covered with the same material as specified for the roof.

8.7.5.2.2 The edges of the hatch cover shall be of not less than 38.1-mm (1½-in.) dressed stock and shall lap down over the raised sides of the hatch.

8.7.5.2.3 The hatch cover shall be arranged to open freely by sliding upward on two 12.7-mm (½-in.) guide rods that are securely bolted to the roof, one on each side of the cover.

8.7.5.2.4 A substantial handle shall be bolted to the lower side of the cover.

8.7.5.3 Other forms of hatch covers shall be acceptable, provided approval is first obtained from the authority having jurisdiction.

8.7.5.4 A hatch of not less than 508 mm × 559 mm (20 in. × 22 in.) shall be built in the flat cover, if provided, and shall be located directly beneath the hatch in the conical roof.

8.7.5.4.1 The hatch cover shall be made of 25.4-mm (1-in.) dressed and matched boards or 9.5-mm (3/8-in.) exterior grade plywood, and shall be of sufficient size to prevent it from falling through the hatch.

8.7.6 Ladders — General.

8.7.6.1 Inside and outside ladders that are arranged for convenient passages from one to the other and through the roof hatch shall be provided.

8.7.6.2 Ladders shall not interfere with the opening of the hatch cover.

8.7.6.3 All ladders exceeding 6.1 m (20 ft) shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

8.7.7 Outside Ladders.

8.7.7.1 A steel ladder that extends from the balcony to the roof shall be provided on the outside of the tank.

8.7.7.1.1 The sides of the ladder shall extend 457 mm (18 in.) above the top of the tank and downward in an arch to the roof or cover where the ends shall be securely fastened.

8.7.7.1.2 The ladder shall be placed at least 0.91 m (3 ft) to one side of the tower ladder if a balcony is provided. (*See 8.7.9.*)

8.7.7.2 The outside ladder shall have flat side bars of not less than 51-mm × 12.7-mm (2-in. × 1/2-in.) or 64-mm × 9.5-mm (2 1/2-in. × 3/8-in.), spaced at least 406 mm (16 in.) apart, and shall have at least 19.1-mm (3/4-in.) round or square rungs, spaced 305 mm (12 in.) on centers.

8.7.7.2.1 The rungs shall be firmly welded to the side bars. The ladder shall be securely fastened by brackets at a location that is at least 178 mm (7 in.) between the side of the tank and the centerline of the rungs.

8.7.7.2.2 The upper brackets shall be placed not more than 305 mm (12 in.) below the top of the tank staves, and the lower end of the ladder shall be securely fastened to the balcony (*see 8.7.9*); in the absence of a balcony, the lower end of the ladder shall be fastened to the tower ladder.

8.7.7.2.3 The brackets shall be designed to support a load of 159 kg (350 lb) on the ladder and shall be securely fastened to the tank with through bolts not less than 9.5 mm (3/8 in.) in diameter.

8.7.8 Inside Ladder.

8.7.8.1 A wooden ladder that is made of the same type of wood as the tank shall be provided on the inside of the tank and shall extend from the hatch to the tank bottom with a slope of approximately 10 degrees from the vertical.

8.7.8.2 Inside ladders of up to 4.9 m (16 ft) in height shall have 51-mm × 102-mm (2-in. × 4-in.) side pieces.

8.7.8.2.1 Ladders over 4.9 m (16 ft) shall have 51-mm × 152-mm (2-in. × 6-in.) side pieces.

8.7.8.2.2 All side pieces shall be spaced at least 406 mm (16 in.) apart. Rungs shall be 32 mm × 76 mm (1 1/4 in. × 3 in.) spaced 305 mm (12 in.) on centers.

8.7.8.2.3 Rungs shall be securely spiked with noncorrosive nails into slots of not less than 19.1 mm (3/4 in.) and shall be not more than 25.4 mm (1 in.) in depth.

8.7.8.2.4 The ladder shall be securely fastened at the upper and lower ends with noncorrosive nails.

8.7.9 Balcony — General.

8.7.9.1 A wooden or steel balcony shall be placed around the base of the tank where the tank bottom is elevated more than 7.6 m (25 ft) above the main building roof.

8.7.9.2 For tanks with a diameter in excess of 4.7 m (15 ft 6 in.), the width of the balcony shall be 607 mm (24 in.) and, for smaller tanks, the width shall be not less than 457 mm (18 in.).

8.7.10 Balcony Floor.

8.7.10.1 Where the balcony is made of wood, the planks shall be at least 51-mm (2-in.) nominal dressed lumber of good quality and shall be spaced 12.7 mm (1/2 in.) apart.

8.7.10.2 The planks shall be laid crosswise on stringers, or lengthwise on cross beams, and spaced not over 1.2 m (4 ft) apart.

8.7.10.3 Where the balcony is made of steel, it shall be built of at least 6.4-mm (1/4-in.) plate and shall be provided with drain holes.

8.7.11 Balcony Clearance.

8.7.11.1 A clearance of not less than 76 mm (3 in.) nor more than 127 mm (5 in.) at any point shall be provided between the balcony and the tank staves.

8.7.11.2 The clearance in the inside angles of polygonal balconies with plank laid lengthwise shall be limited to a maximum of 127 mm (5 in.) by means of properly supported filler pieces.

8.7.12 Balcony Supports. The balcony supports shall be built of structural steel shapes.

8.7.12.1 Reinforced concrete supports shall be permitted to be used where the tank is located on a concrete tower.

8.7.13 Balcony Railing.

8.7.13.1 A railing of 1067 mm (42 in.) in height shall be placed around the balcony and shall be rigid.

8.7.13.2 The top rail and posts shall be made of not less than 1 1/2-in. pipe or of angle iron not lighter than 51 mm × 51 mm × 9.5 mm (2 in. × 2 in. × 3/8 in.).

8.7.13.3 An intermediate rail shall be provided.

8.7.13.4 The maximum spacing of rail posts shall be 2.4 m (8 ft).

8.7.13.5 The railing shall be designed to withstand a 91-kg (200-lb) load in any direction at any point on the top rail.

8.7.13.6 A toe board shall be provided where needed.

8.7.14 Balcony Opening. Where a hole is cut in the balcony for the tower ladder, it shall be at least 457 mm × 607 mm (18 in. × 24 in.).

8.7.15 Painting Inaccessible Parts. Portions of steelwork that are inaccessible after erection shall be painted before assembly.