



Member of the FM Global Group

Approval Standard for Steel Tanks for Fire Protection

Class Number 4020

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Foreword

The FM Approvals certification mark is intended to verify that the products and services described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

- a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and
- b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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1 INTRODUCTION

1.1 Purpose

- 1.1.1 This standard states Approval requirements for steel tanks used for fire protection.
- 1.1.2 Approval criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

- 1.2.1 This standard shall be used to measure and assess the ability of ground supported, flat bottom steel suction tanks to provide a highly reliable source of water for fire protection at anticipated rates and durations in emergency situations. Such tanks shall be permitted to utilize either bolted or welded shell plate designs as submitted by the manufacturer.
 - 1.2.1.1 The standard shall also be used to measure and assess the ability of steel gravity tanks on steel towers (also referred to as elevated tanks in this document) to provide fire protection water as noted above. Such tanks shall utilize welded steel plate designs as submitted by the manufacturer.
- 1.2.2 The items addressed by this standard are limited to the tank proper, its foundation, penetrations and related appurtenances. Excluded from the scope of this standard are pumps, pump houses, internal and external piping and any item not specifically addressed.
- 1.2.3 This standard is not intended to determine the suitability for all end use conditions of a product as conditions under which tanks are used vary widely. This standard therefore, does not evaluate every condition or environment to which a suction tank might be exposed.
- 1.2.4 All tanks addressed in this standard shall be fabricated from carbon steel. All ground-supported suction tanks shall be cylindrical in shape. Elevated tanks shall be permitted to be elliptical, hemispherical or conical in shape.

1.3 Basis for Requirements

- 1.3.1 The requirements of this standard are based on experience, research and testing and/or the standards of FM Approvals and other organizations. The advice of manufacturers, users, trade associations and loss control specialists was also considered.
- 1.3.2 Meeting the requirements qualifies a product as an FM Approved ground supported, flat bottom bolted or welded steel suction tank or elevated steel gravity tank, as applicable. Requirements prohibit component substitution without prior authorization by FM Approvals.
- 1.3.3 The requirements of this standard reflect current design, fabrication and erection procedures used throughout the industry. These requirements are intended primarily as guides and strict conformity is not always mandatory. Ground supported, flat bottom bolted or welded steel suction tanks or elevated steel gravity tanks having characteristics not anticipated by this standard may be FM Approved if performance equal or superior to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, ground supported, flat bottom bolted or welded steel suction tanks or elevated steel gravity tanks that meet all the requirements identified in this standard may not be FM Approved if other conditions that adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for Approval

Approval is based upon a satisfactory evaluation of the product and the manufacturer in the following major areas:

- the structural integrity of the tanks to withstand anticipated design conditions;
- the ability of the manufacturer to properly design, fabricate and erect bolted or welded steel tanks in accordance with industry practices and the requirements of FM Approvals;
- the ability to provide a highly reliable and durable structure for the storage of water for fire protection purposes and;
- an initial in-house Facilities and Procedures Audit inspection of the manufacturer's quality control program.

1.5 Basis for Continued Approval

Continued Approval is based upon a satisfactory evaluation of the manufacturer in the following areas:

- the ability to design, fabricate and erect bolted or welded steel suction tanks in accordance with industry and Approval requirements;
- the continued use of acceptable quality control procedures as determined by on-going Facilities and Procedures Audits;
- satisfactory field experience and;
- re-examination, as necessary, of production samples for continued conformity to requirements.

1.6 Effective Date

1.6.1 The effective date of an Approval Standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products FM Approved under a previous edition shall comply with the new version by the effective date or else forfeit Approval. The effective date shall apply to the entire Approval Standard, or, where so indicated, only to specific paragraphs of the standard.

1.6.2 The effective date for this standard is July 1, 2011 for compliance with all requirements.

1.7 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-97, "Standard for Use of the International System of Units (SI): The Modern Metric System."

1.8 Applicable Documents

The following are standards, test methods, and practices referenced in the examinations conducted per this standard. The revision of each standard is current at the date of publication of this standard shall be used unless shown otherwise.

American Concrete Institute ACI 318-(08), “Building Code Requirements for Reinforced Concrete”.

American Iron and Steel Institute, Steel Plate Engineering Data, Volumes 1 and 2, December 1992.

American Institute of Steel Construction, Inc. “Manual of Steel Construction” (05) 13th edition.

American Society of Mechanical Engineers (ASME), “Boiler and Pressure Vessel Code, Section IX”, 2007.

American Society for Testing and Materials (ASTM)

ASTM D 1751, 05 “Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)”

American Society of Civil Engineers (ASCE)

ASCE 7-10, “Minimum Design Loads for Buildings and Other Structures”

American Water Works Association (AWWA)

AWWA D 100 -05, “AWWA Standard for Welded Carbon Steel Tanks for Water Storage”

AWWA D 102- 06, “AWWA Standard for Coating Steel Water Storage Tanks”

AWWA D-103-09, “AWWA Standard for Factory Coated Bolted Steel Tanks for Water Storage”

FM Global Property Loss Prevention Data Sheets

Data Sheet 1-2, April 2010, “Earthquakes”

Data Sheet 1-28, September 2009, “Wind Design”

Data Sheet 1-54, January 2009, “Roof Loads for New Construction”

Data Sheet 3-2, May 2010, “Water Tanks for Fire Protection”

National Fire Protection Association

NFPA 22- 2008, “Standard for Water Tanks for Private Fire Protection”

1.9 Definitions

For purposes of this standard, the following terms apply:

<i>Anchor Bolt Chair</i>	<i>An assembly secured to both the tank and the foundation to prevent a tank from overturning when subjected to a seismic or wind load. The anchor bolt chair transfers the overturning or uplift forces from the tank shell to the anchor bolt and into the foundation.</i>
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<i>Contractor</i>	<i>See manufacturer.</i>
<i>Dead Load</i>	The estimated weight of all permanent construction and fittings.
<i>Earthquake Load</i>	The estimated forces applied to the tank as a result of an anticipated seismic event, as defined in FM Global Property Loss Prevention Data Sheet 1-2.
<i>Earthquake Zone</i>	Geographic areas based on the severity and frequency of an anticipated seismic event.
<i>FM Approved Tank Design</i>	The specific combination of design parameters, material specifications, geometries, components and notes as shown in the design documents that were reviewed as part of the Approval process.
<i>Freeboard</i>	The distance from the inlet of the overflow or weir box to the top of the tank shell.
<i>Gravity Tank</i>	A water tank which is typically installed on a tower or elevated such that the stored water has an elevation considerably higher than that of the sprinkler system it supplies so as to provide the water at the needed pressure.
<i>Interior Insulation</i>	Insulation provided to prevent heat loss from the tank. It is installed between a tank liner and the interior surface of the tank shell plates.
<i>Liner</i>	A one piece flexible membrane that serves to prevent water from leaking from a bolted tank. The use of flexible liners reduces or eliminates the need for placing a waterproof sealant where mating steel surfaces meet (such as at bolt holes and where adjacent shell plates overlap).
<i>Live Load</i>	The estimated weight of all temporary construction or attachments to the tank, including snow.
<i>Manufacturer</i>	The entity that obtains Approval recognition and listing. The manufacturer may subcontract various aspects of their Approval but shall be responsible for the design, fabrication and where applicable the installation or erection of the FM Approved tank design(s). The manufacturer may also be referred to in this standard as the contractor or tank fabricator.
<i>Net Capacity</i>	The volume of water, in gallons (cubic meters) available for fire protection. For purposes of this standard, it shall be computed as the volume of water located between the inlet of the overflow and the bottom of the anti-vortex plate.
<i>Nominal Capacity</i>	The net capacity rounded off to the standard or published capacity.
<i>Suction Tank</i>	A water tank that is typically flat bottomed and has a water level at approximately the same elevation as the sprinkler system it supplies and slightly above that of the fire pump. Water is supplied to the sprinkler system at the necessary volume and pressure using a fire pump.
<i>Tank Fabricator</i>	<i>See manufacturer.</i>
<i>Wind Load</i>	The estimated forces applied to the tank resulting from a specified wind speed.

1.10 Nomenclature

The following nomenclature shall be used throughout this standard:

C	Value used in determining overturning due to wind
C _f	Force coefficient
D	Diameter of the cylindrical portion of the tank shell, ft (m)
F _u	Published minimum ultimate tensile stress of the steel under consideration, lbs/in ² (MPa)
F _y	Published minimum yield stress of the steel under consideration, lbs/in ² (MPa)
G	Wind gust factor
H	Height of the cylindrical portion of the tank shell, ft (m)
I	Importance factor
J	Value used to determine whether there is uplift during a seismic event
K _z	Wind pressure exposure coefficient evaluated at height z of the centroid of the projected area
L	Laterally unsupported column length, in (mm)
L _u	Maximum unbraced length of the compression flange, ft (m)
MCE	Maximum Considered Earthquake
M _{EQ}	Overturning moment applied to the bottom of the tank shell due to earthquake, ft-lbs (N-m)
M _w	Overturning moment applied to the bottom of the tank shell due to wind, ft-lbs (N-m)
N	Number of foundation bolts
P _w	Wind pressure, lbs/ft ² (kPa)
S	Spacing between anchor bolts, ft (m)
T	Calculated - tensile load per bolt, lbs (N)
T _a	Allowable tensile load per bolt, lbs (N)
TCL	Top capacity level – the water level defined by the lip of the overflow
V	3 second peak gust wind speed, miles/hour (km/hr)
V _a	Allowable shear load per bolt, lbs (N)

V_{EQ}	Calculated shear load per bolt, lbs (N)
W'	Total weight of the tank shell plus that portion of the roof supported by the shell, lbs (N)
d_a	Actual (provided) freeboard, ft (m)
d_{sl}	Calculated or required sloshing wave height, ft (m)
f_b	Calculated bending stress, lbs/in ² (MPa)
q_z	Wind pressure evaluated at height z of the centroid of the projected area, lbs/ft ² (kPa)
r	Least radius of gyration, in (mm)
w_t	Weight of the tank shell per foot of circumference, lbs/ft (N/m)
w_L	Weight of the tank contents per foot of circumference that may be used to resist the shell overturning moment, lbs/ft (N/m)
z	Height above finished grade, ft (m)

2 GENERAL INFORMATION

2.1 Product Information

- 2.1.1 Steel tanks for fire protection are used to provide a reliable source of water at desired rates and durations under anticipated design conditions.
- 2.1.2 Ground supported, flat bottom steel tanks consist of a floor, cylindrical shell and a roof fabricated from steel plates joined together, all of which rest upon a foundation. Tanks are filled with water from an outside source. Water is withdrawn in emergency situations through piping connected to a suction pump. Accessory items are provided to monitor the water level, gain access for inspection and repair and to prevent positive and negative pressures which could impair the structural integrity of the tank. Consideration shall be given to tank heating equipment and/or insulation in colder regions to keep the water from freezing.
- 2.1.3 Steel gravity tanks are similar to suction tanks except that they consist of a storage vessel supported by either multiple columns attached directly to the tank shell or by a support cone and tubular tower. A multiple column tank consists of a roof, shell and suspended bottom. A single pedestal tank consists of a roof, shell and support cone.

2.2 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to

Materials Director
FM Approvals
1151 Boston-Providence Turnpike
PO Box 9102

Norwood, MA 02062
U.S.A.

The manufacturer shall provide the following preliminary information with any request for Approval consideration:

- A complete list of all models, types, sizes, and options for the products or services being submitted for Approval consideration;
- General assembly drawings, complete set of manufacturing drawings, materials list, anticipated marking format, piping and electrical schematics, nameplate format, brochures, sales literature, spec. sheets, installation, operation and maintenance procedures; and
- The number and location of manufacturing facilities.
- All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

- 2.3.1 Following authorization of an Approval examination, the manufacturer shall submit calculations and drawings.
- 2.3.2 Requirements for calculations and drawings may vary depending on design features or the results of prior or similar examinations.

2.4 Design Loads

- 2.4.1 Tanks are designed to withstand the dead load of all permanent construction, a water load filled to just overflowing, a roof live (snow) load and a wind load. In addition, tanks that are located in areas in which a seismic event is likely to occur are also designed to withstand the anticipated earthquake loads.
- 2.4.2 The **dead load** shall be the estimated weight of all permanent construction and fittings. The unit weights used shall be 490 lbs/ft³ (7850 kg/m³) for steel and 150 lbs/ft³ (2400 kg/m³) for concrete except for special materials where the weight is known to be greater.
- 2.4.3 The **water load** shall be the weight of all the water when the tank is filled to the high water level (inlet of the overflow or top of the weir box) and shall be considered as 62.4 lbs/ft³ (1000 kg/m³).
- 2.4.4 The **live load** is an allowance for the weight resulting from a snow loading. The live load shall be considered over the horizontal projection of the tank when the roof slope is less than 30 degrees (7 in 12). On roofs with a greater slope, the live load may be reduced in accordance with FM Global Loss Prevention Data Sheet 1-54.
- 2.4.5 It is recommended that tanks submitted for Approval be designed based on a roof live load of 25 lbs/ft² (1.2 kPa). Consideration of lower roof live loads shall be given for specific locations in warm weather areas where the lowest one day mean temperature is 5°F (-15°C) or warmer and local experience indicates that a smaller load may be used. The minimum roof live load shall be 15 lbs/ft² (0.75 kPa). Conversely, when tanks are designed for specific locations in cold weather areas, greater roof live loads may be required. Refer to the snow maps taken from FM Global Loss Prevention Data Sheet 1-54 for guidance in selecting the proper loading.
- 2.4.5.1 In cases where a tank is to be erected in a locale that requires a snow load greater than that originally FM Approved, revised drawings and calculations shall be submitted to FM Approvals for review and Approval.

2.4.5.2 In cases where a tank is to be erected in a locale that requires a snow load less than that originally FM Approved, the FM Approved roof design shall be utilized unless revised drawings and calculations are submitted to FM Approvals for review and Approval.

2.4.6 A **wind load** shall be considered for all designs submitted for Approval. The resulting pressure shall be based upon a minimum wind speed of 90 miles per hour (145 km/hr) and a wind Exposure C. The wind speed referenced in this document shall be considered as a (three) 3 second peak gust wind speed. Many codes, Authorities Having Jurisdiction or other documents (including FM Global Loss Prevention Data Sheet 1-28 and ASCE 7) require that wind loadings be based on the three (3) second peak gust wind speed which is greater than the fastest mile wind speed. See Table 2.4.6 for a correlation between 3 second peak wind gusts and fastest mile wind speeds. Approval shall be permitted to be granted for Exposure D.

Table 2.4.6

<i>Saffir-Simpson</i>	<i>3 Second Peak Gusts</i>	<i>Fastest Mile Speeds</i>
Category 1	88-115 mph (39-51 m/s)	74-99 mph (33-44 m/s)
Category 2	115-133 mph (51-60 m/s)	100-117 mph (45-52 m/s)
Category 3	133-158 mph (60-70 m/s)	118-139 mph (53-62 m/s)
Category 4	158-187 mph (70-84 m/s)	140-169 mph (63-76 m/s)
Category 5	>187 mph (>84 m/s)	>170 mph (>76 m/s)

2.4.6.1 The wind pressure shall be calculated using the following formula:

$$P_w = q_z G C_f \geq 30 C_f \text{ where } q_z = 0.00256 K_z V^2 \text{ and } G = 1.0 \text{ and } I = 1.15$$

2.4.6.2 The following force coefficients, C_f shall be used:

<i>Type of Surface</i>	<i>C_f</i>
a) Vertical plane surfaces	1.0
b) Projected areas of cylindrical surfaces	0.6
c) Projected areas of conical and double curved plate surfaces	0.5

2.4.6.3 The wind pressure exposure coefficient, K_z , shall be permitted to be calculated in accordance with ASCE 7 or the following coefficients shall be used.

<i>Height above finished grade, ft (m)</i>	<i>Exposure C</i>	<i>Exposure D</i>
0 to 50 ft (15.2)	1.09	1.27
50 to 100 ft (15.2) to 30.5)	1.27	1.43
Over 100 ft (30.5)	See ASCE 7	

2.4.6.4 Certain locations, particularly along coastal areas subjected to high wind events, may require a tank to be designed for wind loadings for wind speeds greater than 90 miles per hour (145 km/hr). In such cases, the wind speed shall be increased in multiples of 5 miles per hour (8 km/hr). Refer to the wind maps taken from FM Global Loss Prevention Data Sheets 1-28.

- 2.4.6.5 The wind pressures defined by the above shall be applied to the vertical projected areas of the tank. The wind speed, Exposure type and notation that the wind pressures are based on a 3 second peak gust shall be shown on the design drawings.
- 2.4.6.6 In cases where a tank is to be erected in a location that requires a wind speed greater than that originally FM Approved, revised drawings shall be submitted to FM Approvals for review and Approval.
- 2.4.7 An **earthquake load** shall be considered for all tanks located in FM Global Earthquake Zones 50-year through 500-year. The method to be used takes into account impulsive and convective (sloshing) actions of the liquid in flexible steel tanks fixed to rigid or flexible foundations. For details, see paragraph 2.19 of this Standard.
- 2.4.7.1 FM Approvals recognizes five (5) earthquake zones: 50-year; 100-year; 250-year; 500-year; and >500-year. With this methodology, Earthquake Zone 50-year is the most severe. These earthquake zones are unique to FM Global and FM Approvals and do not necessarily correlate with the zoning of other code bodies such as the AWWA. Refer to the earthquake maps contained in FM Global Loss Prevention Data Sheet 1-2 to determine the applicable earthquake zone. An approximate correlation is shown in Table 2.4.7-1.

Table 2.4.7-1

<i>New FM Earthquake Zone Designation</i>	<i>Return Period of Damaging Ground Motion</i>
50-year	Up to 50 years
100-year	51 to 100 years
250-year	101 to 250 years
500-year	251 to 500 years
>500-year	>500 years

- 2.4.7.2 Tanks erected in FM Global Earthquake Zone >500-year do not require a seismic analysis to comply with this standard but may be required by other codes or regulations. Tanks that are analyzed for erection in a particular zone may be erected in other, less severe earthquake zones. For example, a tank Approved for Earthquake Zone 50-year shall be permitted to be erected in any of the zones. A tank Approved for Earthquake Zone 250-year shall be permitted to be erected only in Earthquake Zones 250-year, 500-year or >500-year.
- 2.4.7.3 When tanks have been seismically designed, the Approval Guide listing shall show the FM Earthquake Zone Designation(s) where the tank is permitted to be erected (see Table 2.4.7-1).

2.5 Individual Tank Designs

- 2.5.1 A complete set of design drawings and qualifying calculations shall be submitted for review for each FM Approved tank design.
- 2.5.2 Changes to an FM Approved tank design, including but not limited to, material specifications, capacities, allowable stresses, shell plates, roof supports, tank bottoms, accessories, corrosion protection, foundations, welding, general notes and drawings, earthquake zones, foundation bolts, alternative design parameters, tank heating and insulation shall not be permitted unless otherwise stated in this Approval Standard or the individual Approval reports.
- 2.5.3 Subsequent fabrication and erection of FM Approved tank designs shall be permitted if in accordance with the FM Approved design documents and Approval report(s). FM Approvals shall be notified, and agree to in writing, of any changes in the design parameters, the tank proper, penetrations and accessories unless specifically allowed otherwise in this Approval Standard or individual Approval report(s).

2.6 Materials

- 2.6.1 All materials incorporated into any FM Approved steel tank shall be new, previously unused, in first class condition, and shall comply with all the requirements of this standard.
- 2.6.2 All steel incorporated into any FM Approved steel tank shall have their properties verified for compliance to the material specifications. Verification shall be in the form of a mill test report that lists the physical, dimensional and chemical properties of the material. Steel materials of an unidentified specification shall be tested by a qualified testing laboratory and found to be in compliance with all physical, dimensional and chemical requirements of this Standard prior to use.
- 2.6.3 Allowable design stresses shall be based on the published yield stress of the material. Increasing allowable design stresses based on the results of mill test reports shall not be allowed.
- 2.6.4 Use of materials other than those contained in AWWA D103 (for bolted tanks) or AWWA D100 (welded and elevated tanks) shall be handled on a case-by-case basis. Materials specifications shall be submitted to FM Approvals.
- 2.6.5 All material specifications, minimum and maximum thicknesses and size requirements for bolts, anchor bolts, rods, reinforcing steel, plates, sheets, structural shapes, forgings, pins, filler metals, electrodes and components not specifically addressed in this Standard shall be as specified in the applicable AWWA standard.

2.7 Standard Capacities

- 2.7.1 The standard capacities for tanks submitted for Approval shall be in increments of 10,000 US gallons (37.8 m³). Approval of other capacities shall be considered on a case-by-case basis.
- 2.7.2 The net capacity shall be the volume of water between the bottom of the anti-vortex plate and the TCL. All tanks shall have a minimum freeboard of 2 in. (50 mm).

- 2.7.3 The net capacity shall be at least 99% of the nominal published capacity except as allowed in paragraph 2.7.4.
- 2.7.4 Tanks designed for Earthquake Zones 50-year, 100-year, 250-year and 500-year shall have a net capacity of at least 97% of the nominal published capacity. This is allowed due to the extra freeboard required at the top of the tank to accommodate the height of the sloshing wave in an effort to minimize damage to the roof support system during a seismic event (see paragraph 2.19.3).

2.8 Unit Stresses

- 2.8.1 Except for roof supports and other exceptions specifically provided for elsewhere in this standard, all steel members shall be designed such that the resulting maximum stresses produced by any design load or combination of design loads shall not exceed their allowable values as specified in AWWA D100 for welded and elevated tanks and AWWA D-103 for bolted tanks. Allowable unit stress values, wherever stated in this standard, shall be reduced by any applicable joint efficiencies as detailed in AWWA D100.
- 2.8.2 Consideration shall be given for stresses produced by the combination of wind with dead and live loads or by wind alone or produced by the combination of earthquake with dead and live loads, or by earthquake alone. In such cases, the allowable unit stresses shall be permitted to be increased 33⅓% provided that the resulting section is not less than that required for dead and live loads alone. Wind and earthquake loads do not need to be considered simultaneously.
- 2.8.2.1 For the design of concrete foundations, consideration shall be given for the increase in design stresses when including either wind or earthquake with dead and live loads. An increase of 33⅓% for both allowable concrete and reinforcing steel stresses as permitted by ACI 318 shall be used, provided that the foundation design is not less than that required for the combination of dead and live loads alone.
- 2.8.3 In the design of welded tanks, consideration shall be given for increased allowable stresses of certain items if the alternative design basis contained in AWWA D100, is followed (see paragraph 2.20).

2.9 Shell Plates

- 2.9.1 The minimum thickness for all welded steel tank cylindrical shell plates shall be ¼ in. (6.4 mm). The minimum thickness for all bolted steel tank cylindrical shell plates shall be 0.094 in. (2.4 mm).
- 2.9.2 All tank shell plates shall be cold rolled to the proper curvature to suit the configuration of the tank.
- 2.9.3 The thickness of cylindrical shell plates stressed by the pressure of the tank contents shall be calculated by the formulas shown in AWWA D100 and AWWA D-103. For welded tanks, built to AWWA D100 the joint efficiency shall be 0.85 for tanks that are not designed using the alternative design method.
- 2.9.4 All openings in the tank shell greater than 4 in. (100 mm) in diameter and subject to hydrostatic pressure shall be reinforced in accordance with AWWA D100 or AWWA D103.
- 2.9.5 Intermediate shell girders (wind stiffeners) shall be permitted to be installed as a means of stiffening the tank shell for wind loading. The maximum unstiffened height and the method of

determining the minimum section modules shall be determined in accordance with AWWA D103 (bolted tanks) or AWWA D100 (welded and elevated tanks) as applicable.

2.10 Roof Supports

- 2.10.1 All tanks shall have roofs. When the roof is supported by rafters arranged in a radial pattern, they shall be located such that when measured along the tank circumference, the spacing between rafters shall not exceed 6 ft 3 in. (1.9 m). They shall be placed above the overflow water level, such that no part of the rafters or support clips are in contact with the water.
- 2.10.2 Designs shall be in accordance with the steel construction specifications of the American Institute of Steel Construction, except as noted in this Standard. Consideration shall be given to roof rafter depth less than $f_b/600,000$ provided the roof slope is $\frac{3}{4}$ in 12 or greater.
- 2.10.2.1 The roof rafters shall utilize an allowable bending stress which shall be the greater of 15,000 lbs/in² (103 MPa) or $0.4F_y$, unless the rafter compression flange is laterally supported. Friction between the roof plate and the top flange of the rafter shall not be considered as a means of providing lateral support of the rafter compression flange for purposes of this standard. When the compression flange is provided with lateral support, the allowable rafter bending stress may be increased to $0.6F_y$. In such cases, the unbraced length of the rafter compression flange shall not exceed the maximum allowable unbraced length of the compression flange, L_U , as shown in the AISC Manual of Steel Construction.
- 2.10.2.2 Columns supporting roofs shall be designed as secondary members. The maximum slenderness ratio, L/r , for columns supporting rafters shall be 175. The maximum permissible compressive stress shall be determined as shown in AWWA D-100 and D103.
- 2.10.2.3 Consideration shall be given to column cap plates and column base plates designed to utilize an allowable bending stress of 20,000 lbs/in² (140 MPa).
- 2.10.2.4 The minimum thickness of all roof support members shall be $\frac{3}{16}$ in. (5 mm).
- 2.10.2.5 When the roof slope is less than 1 in 2.75 (20°), the minimum thickness of flat roof sheets shall be 0.094 in (2.4 mm). Roof sheets shall be permitted to be thinner than 0.094 in (2.4 mm) if the roof sheet is corrugated and placed perpendicular to the roof support beams. Such roofs shall be fastened to the roof supports in each trough using minimum 0.25 in (6 mm) diameter self-tapping screws. The minimum thickness of the corrugated sheets shall be based on the material, section properties, span and applied live load.
- 2.10.3 Consideration shall be given to roofs made from other types of materials if in accordance with AWWA D100 and AWWA D103.
- 2.10.4 For rafter design guidelines, see Appendix C of this Standard.

2.11 Tank Bottoms

- 2.11.1 Flat bottom, ground supported welded tanks – the minimum thickness for all welded steel tank bottom plates shall be $\frac{1}{4}$ in. (6.4 mm). Lap welded tank bottoms need only be welded on the top side with a continuous, full height fillet weld on all seams. Plates under the bottom ring of cylindrical shells shall have the outer ends of lap joints depressed to form a smooth bearing for all

shell plates. The minimum lap shall be 1in. (25 mm). Butt joints shall be welded from the top side using a suitable backing strip or equivalent means to ensure at least 90% joint fusion.

2.11.1.1 Tank bottoms shall utilize either lap joint construction or butt joint construction. All three-plate laps or three-plate joints in the tank bottom shall be at least 12 in. (300 mm) from each other and from the tank shell.

2.11.1.2 The bottom edge of the lowest course of shell plates and the bottom plates shall be joined by a continuous fillet weld, ¼ in. (6 mm) minimum, on both sides of the plate. After trimming, the bottom plate shall extend a minimum of 1 in. (25 mm) beyond the toe of the weld.

2.11.1.3 All openings in the tank bottom greater than 4 in. (100 mm) in diameter shall be reinforced in accordance with AWWA D100.

2.11.2 Flat bottom, ground supported bolted tanks – the minimum thickness for all bolted steel tank bottom plates shall be 0.094 in. (2.4 mm). When a concrete mat has been provided for the foundation, the steel bottom plates may be omitted provided that the bottom course of shell has been anchored or cast into the concrete. When this occurs, a flexible, continuous waterproof sealant shall be installed at the mating surface between the steel plate and concrete foundation. Openings in the tank floor plates, if provided, shall be fabricated in accordance with AWWA D103.

2.11.2.1 When tanks are provided with a rubber or flexible liner, the tank bottom shall be permitted to be a bed of sand placed within a concrete ringwall.

2.11.2.2 When a tank is provided with a rubber or flexible liner and is to be erected within Earthquake Zones 50-year, 100-year, 250-year or 500-year, either a concrete mat or steel bottom plate shall be required. When a steel bottom plate has not been provided, see Paragraph 2.18 for guidelines on the use of foundation bolts.

2.11.3 Elevated tanks provided with a suspended bottom shall be elliptical, hemispherical or conical in shape. The bottoms on single pedestal tanks shall utilize a support cone.

2.12 Accessories for Tanks

2.12.1 Accessories for flat-bottom suction tanks shall be provided in accordance with the following. The criteria is consistent with NFPA 22. All accessories shall be fabricated from galvanized steel or as otherwise Approved or acceptable to FM Approvals. All accessory items shall be provided by the tank manufacturer.

2.12.1.1 A **shell manhole** shall be provided in the 1st ring of the tank. The minimum size shall be 24 in. (600 mm) in diameter for circular manholes and 18 in. × 22 in. (450 mm × 550 mm) for elliptical shaped manholes. All portions including the neck, bolting and cover shall be designed to withstand the weight and pressure of the tank contents. Fillet welds between the manway neck and cover flange shall be equal or greater than the minimum material thickness of the neck or flange.

2.12.1.2 A **roof vent** located above the maximum water level and near the center of the roof. The screened area of the vent shall have an area at least 1½ times the cross-sectional area of the suction line or fill line, whichever is larger. The screening shall have either ⅜ in. (10 mm) or ½ in. (13 mm) openings and be fabricated from a corrosion resistant metal. The overflow pipe shall not be considered as part of the roof vent.

- 2.12.1.3 A **roof manway** located near the center of the roof. It shall have a removable cover, have a minimum dimension of 20 in. (500 mm) or be at least 20 in. (500 mm) in diameter, and have a 4 in. (100 mm) minimum curb height. The roof manway is optional when a flanged roof vent is provided.
- 2.12.1.4 A **roof hatch** located near the outside tank ladder. It shall have a clear opening dimension of at least 24 in. (600 mm) in one direction and 15 in. (380 mm) in the other direction, or have a minimum diameter of 24 in. (600 mm). It shall be provided with a hinged cover and hasp suitable for a lock. It shall have a 4 in. (100 mm) minimum curb and the cover shall have a downward overlap of at least 2 in. (50 mm). As an alternative, a gasketed watertight cover may be provided in lieu of the 4 in. (100 mm) curb and 2 in. (50 mm) overlap.
- 2.12.1.5 A **fill line** capable of filling the tank in less than eight (8) hours. It shall have a minimum diameter of 2 in. (50 mm). If an over the top fill line is utilized, the water shall be directed downward as it discharges from the pipe. If an automatic fill line is used, it shall be located so as to discharge into a different quadrant (more than 90° away) from the suction line. Fill lines that penetrate the tank roof shall be provided with a watertight seal. As an alternative, the automatic fill line shall be oriented such that the water discharges a minimum of 15 ft (4.6 m), measured horizontally, from any part of the anti-vortex plate.
- 2.12.1.6 A **suction line** that is sized according to the anticipated rating of the suction pump. Normally, the suction line penetrates the tank shell and is terminated with a 90° elbow pointing downward. An anti-vortex plate is attached to the inlet and shall be located 6 in. (150 mm) or one-half the suction line diameter, whichever is greater, above the tank floor. The anti-vortex plate shall be fabricated from 1/4 in. (6 mm) minimum thickness steel with each side of the plate, or its diameter, at least twice the diameter of the suction line. Alternatively, the suction line may penetrate the tank bottom. In such cases, it shall extend at least 4 in. (100 mm) above the tank bottom. The anti-vortex plate, sized as described above, shall be located 6 in. (150 mm) or one-half the diameter of the suction line, whichever is greater, above the rim of the inlet. All anti-vortex assemblies shall be securely attached to either the suction line or the tank bottom.
- 2.12.1.7 An **overflow** pipe at least one pipe size larger than the fill line, terminating at the top with a weir box or other appropriate intake. When a stub overflow is utilized, it shall project at least 12 in. (300 mm) beyond the tank shell. When an overflow to ground is utilized, it shall be placed down the outside of the tank, be supported at proper intervals, terminate with an elbow and discharge over a drainage inlet or splash block. The discharge end of the overflow shall be covered with corrosion resistant metal screening having either 3/8 in. (10 mm) or 1/2 in. (13 mm) openings. The overflow shall be sized to provide a capacity at least equal to the pumping rate with a water level not more than 6 in. (150 mm) above the weir.
- 2.12.1.8 A **domestic suction line** for plant use is optional. Design drawings shall clearly state the elevation of this line and the resulting capacity available for fire protection purposes. The capacity available for fire protection shall be determined as the volume of water between the domestic suction inlet to the antivortex plate. When a domestic suction line has been provided, a bottom drain line flush with the tank bottom shall also be provided.
- 2.12.1.9 **Relief and test lines** are optional. If they are capable of discharging while the suction pump is operating, they shall be located such that they discharge into a different quadrant (more than 90° away) from the suction line.
- 2.12.1.10 A **water level gauge** shall be provided as a means of monitoring the water level in the tank. An exterior gauge board with a target is preferred. Alternatively, a high water/low water level electric alarm shall be permitted to be used. When used, the high level alarm