

NFPA 22
Standard for
Water Tanks
for Private
Fire Protection
1996 Edition



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There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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NFPA 22
Standard for
Water Tanks for Private Fire Protection
1996 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 the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 22 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 22

In 1909, the NFPA Committee on Gravity Tanks presented a *Standard on Gravity Tanks* that, with amendments considered in 1912 and 1913, 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 Committee name was changed to the Committee on Water Tanks and their recommendations resulted in changes adopted in 1957, 1958, 1962, 1965, 1967, 1970, 1971, 1974, 1976, 1978, 1981, and 1987.

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

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

The 1996 edition of NFPA 22 consolidated information regarding tank care and maintenance into a separate chapter. Further revisions address corrosion resistance of certain tank components, access into tanks, monitoring of internal conditions, and the structural stresses to which tanks are subjected. Appendix B figures were also revised to reflect current practices. A number of editorial changes were also incorporated.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

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.

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.

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NOTE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 15.

Chapter 1 Introduction

1-1 Scope. This standard includes the minimum requirements for the design, construction, installation, and maintenance of tanks and accessory equipment supplying water for private fire protection, including gravity, suction, pressure, and embankment-supported coated fabric suction tanks, towers, foundations, pipe connections and fittings, valve enclosures, tank filling, and 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 is intended to restrict new technologies or alternate arrangements, providing the level of safety prescribed by the standard is not lowered.

1-3 Types of Tanks. This standard addresses elevated tanks on towers or building structures, grade or below grade water storage tanks, and pressure tanks.

1-4 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Holiday. A discontinuity in the coating system including but not limited to voids, cracks, pinholes, or scratches.

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.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Shall. Indicates a mandatory requirement.

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

1-5 Capacity and Elevation.

1-5.1 The size and elevation of the tank shall be determined by conditions at each individual property after due consideration of all factors involved. Where tanks are to supply sprinklers, see separately published NFPA standards; also see NFPA 13, *Standard for the Installation of Sprinkler Systems*.

1-5.2 Wherever possible, standard sizes of tanks and heights of towers shall be used as given in 3-1.3, 4-1.2, 6-1.3, and Section 7-2.

1-6 Location of Tanks.

1-6.1 The location chosen shall be such that the tank and structure will not be subject to fire exposure from adjacent buildings. If lack of yard room makes this impracticable, the exposed steel work shall be suitably fireproofed or protected by open sprinklers. (See A-10-1.1.) Fireproofing where necessary shall include steel work within 20 ft (6.1 m) of combustible buildings or windows and doors from which fire might issue.

1-6.2 Where used for supports near combustible construction or occupancy inside the building, steel or iron shall be fireproofed 6 ft (1.8 m) above combustible roof coverings, and within 20 ft (6.1 m) of windows and doors from which fire might issue. (See A-10-1.1.) Steel beams or braces joining two building columns that support a tank structure shall also be suitably fireproofed where near combustible construction or occupancy. Interior timber shall not be used to support or brace tank structures.

1-6.3 Fireproofing, where required, shall have a fire resistance rating of not less than two hours.

1-6.4 Foundations or footings shall furnish adequate support and anchorage for the tower.

1-6.5 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.

1-7 Tank Materials. Materials shall be limited to steel, wood, concrete, and coated fabric. The elevated wood and steel tanks shall be supported on steel or reinforced concrete towers.

1-7.1 Fiberglass-reinforced plastic tanks shall be permitted only for underground atmospheric storage. Fiberglass tanks shall meet the requirements of UL 1316, *Glass Fiber Reinforced Plastic Underground Storage Tanks for Petroleum Products*, or ASTM D 4021, *Standard Specification of Glass Fiber Reinforced Polyester Underground Petroleum Storage Tanks*, and shall be subject to the following:

(a) For protection against freezing, the tank shall be located below the frost line.

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

(c) The tank shall be above the maximum ground water level so that the buoyancy of the tank when empty will not force it upward. Suitable methods of anchoring the tank also shall be permitted.

(d) The tank shall be designed to resist the pressure of earth against it.

1-8 Workmanship.

1-8.1 It is expected that manufacturers of approved structures shall follow not only the letter but the spirit of this standard, employing their experience and ability to make structures that shall prove reliable under all specified conditions. Manufacturers shall replace all parts that are found to be defective from faulty materials or workmanship or that are not in accordance with this standard.

1-8.2 The contractor's representatives shall provide careful inspection during shop fabrication and field erection. The inspection shall include, but not be limited to, the following items:

- (a) The thickness of butt-welded plates in tanks and tubular columns.
- (b) 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.
- (c) The extent of inaccessible dents and out-of-roundness of tubular columns and struts.

1-9 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 erection of the structure.

1-10 Engineer's Authority.

1-10.1 The engineer shall have the power to reject materials and workmanship that do not conform to this standard. In the case of a dispute, the contractor shall be permitted to appeal to the authority having jurisdiction.

1-10.2 Rejection. The acceptance of any material or finished member by the engineer shall not be a bar to their subsequent rejection if they are found to be defective. Rejected material and workmanship shall be replaced promptly or repaired by the contractor.

1-10.3 Facilities for Inspection. Material and workmanship at all times shall be subject to the inspection of engineers representing the purchaser.

1-11 Tank Contractor Responsibility.

1-11.1 Any necessary work shall be handled by experienced contractors. Careful workmanship and expert supervision shall be employed. The manufacturer shall warranty the tank for at least one year from the date of completion and final customer acceptance.

1-11.2 Upon completion of the tank construction contract, and after the contractor has tested the tank and made it watertight, the tank contractor shall notify the authority having jurisdiction so the tank can be inspected and given the necessary formal approval.

1-11.3 Cleaning Up. Upon completion of the work, the contractor shall remove or dispose of all rubbish and other unsightly material caused by his operations, and shall leave the premises in as good a condition as he found them.

1-12 Inspection of Completed Equipment.

1-12.1 A joint inspection of the tank shall be conducted by a representative of the tank contractor and a representative of the owner prior to placing the tank in service.

1-12.2 Written reports of these 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.

1-13 Attachments to Tank Structures. Tank structures shall not be used to support signs, flagpoles, steel stacks, or similar objects unless particularly designed for the purpose.

1-14 Lightning Protection. To prevent lightning damage to tanks, protection shall be installed to conform to Section 4-4 of NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

1-15 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). One unit (bar), outside of, but recognized by SI, is commonly used in international fire protection. These units are listed in Table 1-15 with conversion factors.

Table 1-15

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 ASTM E 380, *Standard for Metric Practice*.

1-15.1 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated shall be regarded as the requirement. A given equivalent value could be approximate.

1-15.2 The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

Chapter 2 General Information

2-1 Strength. The material as specified shall be without defects affecting its strength or service. The workmanship shall be of a quality that defects or injuries are not produced during manufacture or erection. Unit stresses as specified shall not be exceeded. The structure and its details shall possess the requisite strength and rigidity.

2-2 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.

2-3 Loads.

2-3.1 Dead Load. The dead load shall be the estimated weight of all permanent construction and fittings. The unit weight of steel shall be considered 490 lb/ft³ (7849 kg/m³) and of concrete, 144 lb/ft³ (2307 kg/m³).

2-3.2 Live Load. Under normal conditions, the live load shall be the weight of all the liquid when overflowing the top of the tank. The unit weight of water shall be considered 62.4 lb/ft³ (1000 kg/m³). Proper provisions must be made for temporary stresses during erection. Where roofs

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

2-3.3 Wind Load. Under normal conditions, the wind load or pressure shall be assumed to be 30 lb/ft² (147 kg/m²) on vertical plane surfaces, 18 lb/ft² (88 kg/m²) on projected areas of cylindrical surfaces, and 15 lb/ft² (73 kg/m²) on projected areas of conical and double curved plate surfaces. Where designing for wind velocities over 100 mph (161 km/hr), all of the above mentioned unit pressures shall be adjusted in proportion to the square of the velocity, assuming that the above pressures are for 100 mph (161 km/hr).

2-3.4 Balcony, Platform, and Ladder Loads. A vertical load of 1000 lb (454 kg) shall be assumed to be applied to any 10 ft² (0.93 m²) of area on the balcony floor and on each platform; 500 lb (227 kg) applied to any 10-ft² (0.93-m²) area on the tank roof; and 350 lb (159 kg) on each vertical section of ladder. All of the structural parts and connections shall be designed to withstand such loads. The above loading shall not need to be combined with snow loading.

2-3.5 Columns and Struts. All steel columns and struts shall be designed in accordance with AWWA D100, *Standard for Welded Steel Tanks for Water Storage*. The minimum thickness for any columns in contact with water shall be 0.25 in. (6.4 mm). Tubular sections shall not be flattened to form end connections.

2-3.6 Stress Increases. Where wind or earthquake loads are considered in calculating stresses, the maximum permissible increase in working unit stresses shall be one-third, provided that the resulting section is not less than required for dead and live loads alone. Wind and earthquake loads shall not need to be considered simultaneously.

2-3.7 The roof shall be designed to withstand the forces anticipated during the erection, inspection, testing, and maintenance of the tank. The maximum allowable uniform live load (psf) and the maximum allowable concentrated load (lb) shall be identified on the design drawings and tank nameplate. (See 2-3.4.)

2-4 Welding. All welding shall be completed in accordance with AWWA D100, *Standard for Welded Steel Tanks for Water Storage*.

2-5 Roofs. All tanks shall have roofs.

2-6 Roof Vent.

2-6.1 Where the steel roof is essentially airtight, there shall be a substantial vent above the maximum water level. A vent pipe shall have a cross-sectional area at least equal to one-half the area of the discharge pipe(s) or fill pipe, whichever is the larger. A corrosion-resistant screen or perforated plate with $\frac{3}{8}$ -in. (9.5-mm) holes, to exclude birds or other animals, shall be provided and have a net area at least equal to the vent line. 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 the larger. The screen or perforated plate shall be protected against accumulation of sleet. The weather hood, or equivalent, over the perforated plate or screen shall be readily removable. The overflow pipe shall not be included as vent area. The vent shall be permitted to be combined with the roof finial. 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.

2-6.2 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 these insect screens frost over.

2-7 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.

2-8 Acceptance. After completion of the tank, all coated steel tanks shall be tested for holidays and coating thickness. Repairs or replacements shall be made as necessary.

Chapter 3 Welded Steel Gravity and Suction Tanks

3-1 General.

3-1.1 This chapter shall apply to the design, fabrication, and erection of welded steel gravity water tanks, including pump suction tanks.

3-1.2 Capacity. The capacity of the tank shall be the number of U.S. gallons (m³) available above the outlet opening. 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. For gravity tanks with large plate risers, the net capacity shall be the number of U.S. gallons (m³) between the inlet of the overflow and the designated low-water level line. For suction tanks, the net capacity shall be the number of U.S. gallons (m³) between the inlet of the overflow and the level of the vortex plate.

3-1.3 Standard Sizes. The standard sizes of steel tanks are: 5000 gal (18.93 m³), 10,000 gal (37.85 m³), 15,000 gal (56.78 m³), 20,000 gal (75.70 m³), 25,000 gal (94.63 m³), 30,000 gal (113.55 m³), 40,000 gal (151.40 m³), 50,000 gal (189.25 m³), 60,000 gal (227.10 m³), 75,000 gal (283.88 m³), 100,000 gal (378.50 m³), 150,000 gal (567.75 m³), 200,000 gal (757.00 m³), 300,000 gal (1135.50 m³), and 500,000 gal (1892.50 m³) net capacity. Tanks of other sizes shall be permitted.

3-1.4 Form. Steel tanks shall be permitted to be of any form desired provided they conform to this standard throughout.

3-2 Materials.

3-2.1 Plates, Shapes, and Tubular Columns.

3-2.1.1 Plates. Plate materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to the following ASTM specifications: A 36; A 283, Grades A, B, C, and D except that where plates of thickness greater than $\frac{3}{4}$ in. (19.1 mm) are used, A 283, Grade D steels shall not be specified; as alternatives, A 285, Grades A, B, and C; A 516, Grades 55 and 60; A 442, Grades 55 and 60; or A 131, Grades A, B, and C shall be used.

Table 3-4.1 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 of:		
$\frac{ld}{bt}$ not in excess of 600	15,000	103.43
$\frac{ld}{bt}$ in excess of 600	9,000,000	62,055
	$\frac{ld}{bt}$	$\frac{(l)(d)}{(b)(t)}$
in which l is the unsupported length and d 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 taken as twice the length of the compression flange of a cantilever beam not fully stayed at its outer end against translation or rotation.		
Pins, extreme fiber	22,500	155.15
Cast steel	11,250	77.57

3-2.1.2 Basis of Furnishing Plates. Plates shall be furnished on the weight basis with permissible underrun and overrun according to the tolerance table for plates ordered to weight published in ASTM A 6, *Specifications for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use*.

3-2.1.3 Shapes. Structural materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to ASTM A 36 or A 131, Grade A, B, and D.

3-2.1.4 Copper-bearing steel with a content of about 0.20 percent copper shall be permitted to be used. In other particulars the steel shall conform to the specifications enumerated above.

3-2.2 Bolts, Anchor Bolts, and Rods. Bolts and anchor bolts shall conform to ASTM Specification A 307, Grade A or Grade B. ASTM A 36 shall be considered an acceptable alternate material for anchor bolts. Rods shall be open-hearth, electric furnace, or basic oxygen process steel, conforming to ASTM A 36.

3-2.3 Forgings. Forgings shall conform to the following ASTM specifications. Steel shall be made only by the open-hearth process.

Forgings for Piping Components — A 105.

Forgings for General Use — A 668 — Class D.

NOTE: For forgings intended for welding, supplementary requirements need to be specified.

Forgings for General Purpose Piping — A 181 — Class 70.

3-2.4 Castings. Castings shall conform to ASTM Specifications A 27, Grade 60-30 full annealed.

3-2.5 Reinforcing Steel. Reinforcing steel shall comply with ASTM Specification A 615, Grade 40 or Grade 60.

3-2.6 Filler Metal Electrodes. Manual, shielded metal-arc-welding electrodes shall conform to the requirements of AWS A5.1, *Specifications for Covered Carbon Steel Arc-Welding Electrodes*. Electrodes shall be any E60XX or E70XX classification suitable for the electric current characteristics, the position of welding, and other conditions of intended use. Electrodes for other welding processes shall conform to applicable AWS specifications for filler metal.

3-3 Earthquake Load. Tanks shall meet requirements for resisting earthquake damage by complying with the earthquake design provisions of AWWA D100 (AWS D5.2), *Standard for Welded Steel Tanks for Water Storage*.

3-4 Unit Stresses.

3-4.1 General. The maximum stresses in psi (MPa) produced by the foregoing loads, or any combination of them, shall not exceed the values in Table 3-4.1.

3-5 Details of Design.

3-5.1 Minimum Thickness.

3-5.1.1 The minimum thickness of any part of the structure shall be $\frac{3}{16}$ in. (4.8 mm) for parts not in contact with water contents and $\frac{1}{4}$ in. (6.4 mm) for parts in contact with water contents. 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. The minimum thickness of tubular columns and struts shall be $\frac{1}{4}$ in. (6.4 mm). Round or square bars used for wind bracing shall have a minimum diameter or width of $\frac{3}{4}$ in. (19.1 mm). Bars of other shapes, if used, shall have a total area at least equal to a $\frac{3}{4}$ -in. (19.1-mm) round bar.

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

3-5.1.2 Cylindrical shell plates in contact with water shall have minimum thicknesses as specified in Table 3-5.1.2.

3-5.2 Thickness for Corrosion. If interior bracing is required to support the water content, it shall always have $\frac{1}{16}$ in. (1.6 mm) additional thickness added to the calculated sections. The sections shall be open to facilitate cleaning and painting, except in the case of tubular sections,

Table 3-5.1.2 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	$\frac{1}{4}$ in.	6.4 mm	$\frac{1}{4}$ in.	6.4 mm	$\frac{3}{16}$ in.	7.9 mm	$\frac{3}{8}$ in.	9.5 mm
Upper rings	$\frac{3}{16}$ in.	4.8 mm	$\frac{1}{4}$ in.	6.4 mm	$\frac{3}{16}$ in.	7.9 mm	$\frac{3}{8}$ in.	9.5 mm

NOTE: For SI units: 1 in. = 25.4 mm.

which shall be hermetically sealed to prevent internal corrosion. The plates of tanks that will contain salt or alkaline water shall be $\frac{1}{16}$ in. (1.6 mm) thicker than calculated.

3-5.3 Thickness of Tank Plates. 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 (AWS D5.2), *Standard for Welded Steel Tanks for Water Storage*.

3-5.3.1 Plate surfaces susceptible to complete stress analysis shall be designed on the basis of a maximum membrane tensile stress of 15,000 psi (103.43 MPa). Such plate surfaces include those not stressed by the concentrated reaction of supporting members or riser pipes.

3-5.3.2 Plate surfaces not susceptible to complete stress analysis shall also be designed on the basis of a maximum membrane tensile stress of 15,000 psi (103.43 MPa) after making reasonable allowances for such loads and stresses that cannot be accurately determined. The maximum membrane tensile stress shall in no case exceed 11,000 psi (75.85 MPa) when calculated, assuming that the concentrated reactions of supporting members are uniformly distributed between such reactions. Thus, the lowest cylindrical courses of tanks with suspended bottoms and the suspended bottoms shall be designed for a maximum membrane

tensile stress not to exceed 11,000 psi (75.85 MPa) reduced for the joint efficiencies.

3-5.3.3 As an alternate to 3-5.3.1 and 3-5.3.2, 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 Appendix C of AWWA D100 (AWS D5.2), *Standard for Welded Steel Tanks for Water Storage*, provided all requirements of that Appendix are met.

3-5.3.4 Where compressive stresses exist, plate thickness shall be chosen to prevent local buckling.

3-5.4 Thickness of Flat Bottoms. The thicknesses of plates in flat bottoms shall be not less than those given in Tables 3-5.4(a) and 3-5.4(b).

3-5.5 Accessibility of Bottoms. Grillages shall be designed so that the tank bottom and beams will be accessible for inspection and painting.

3-5.6 Net Sections. Net sections shall be used in calculating the tensile stress in plates and members.

3-5.7 Load Location. In calculating the thickness of plates (except as specified in 3-5.3) 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

Table 3-5.4(a) Thickness of Bottom Plates for Flat-Bottom Tanks (English Units)

Type of Support	(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
		in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Steel or concrete beams	12	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$
	14	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$
	16	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$
Distance in clear between beams in inches	18	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$
	20	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$
	24	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{11}{16}$
Concrete slab or earth grade		$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$

Table 3-5.4(b) Thickness of Bottom Plates for Flat-Bottom Tanks (SI Units)

Type of Support	(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
		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
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
Distance in clear between beams in inches	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

area of the ring. In welded tanks the longitudinal joints in adjacent circumferential courses shall be either staggered or in alignment. Welded joints crossing each other shall be grooved and welded continuously through the intersections.

3-5.8 Opening Reinforcement.

3-5.8.1 All openings over 4 in. (102 mm) in diameter in the shell, suspended bottom, or larger steel plate riser or tubular support shall be reinforced. This reinforcement shall be either the flange of a fitting, an additional ring of metal, excess plate metal above that actually required, or combinations of these, except that excess plate metal due to joint efficiency shall not be counted if the center of the opening is within one opening diameter of any plate seam or point of support attachment. For the purposes of this standard, the opening diameter shall be taken as the maximum dimension of the hole cut in the plate perpendicular to the direction of maximum stress.

3-5.8.2 Sufficient welding shall be provided to transmit the full net strength of the reinforcing ring or flange to the plate. In computing the net reinforcing area of a fitting, such as a boiler maker's flange or a manhole saddle having a neck, the material in the neck shall be considered as part of the reinforcing for a distance, measured from the surface of the parent plate or that of an intervening reinforcement plate, equal to four times the thickness of the material in the neck.

3-5.9 Roof Supports. The supports for tank roofs not containing water shall be designed in accordance with steel construction specifications of the American Institute of Steel Construction.

Exception No. 1: Rafters in contact with a steel roof and having a slope of less than 2 in. in 12 in. (51 mm in 305 mm) and consisting of beam or channel shapes less than 15 in. (381 mm) deep shall be considered as adequately laterally braced by friction between the roof plate and the top flange.

Exception No. 2: The roof purlin depth shall be less than $1/30$ of the span length.

Exception No. 3: The maximum slenderness ratio L/R for columns supporting roof shall be 175. The spacing between rafters as measured along the tank circumference shall not exceed 2π feet (0.61π m).

3-5.10 Welded Joints. The types of joints used and their design shall conform to AWWA D100 (AWS D5.2), *Standard for Welded Steel Tanks for Water Storage*.

3-6 Workmanship.

3-6.1 Plate Edges. The plate edges to be welded shall be universal mill edges or be prepared by shearing, machining, chipping, or mechanically guided oxygen cutting, except that edges of irregular contour can be prepared by manually 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.

3-6.2 Rolling. Plates shall be cold rolled to suit the curvature of the tank and the erection procedure in accordance with Table 3-6.2.

3-6.3 Double-Curved Plates. Plates that are curved in two directions shall be pressed cold or hot or be dished with a "mortar and pestle" die by repeated applications.

Table 3-6.2 Plate Dimensions

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

3-6.4 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.

3-6.5 Fitting Roofs. The roof shall fit tightly to the top of the tank to prevent circulation of air over the surface of the water. Where a spider is used, it shall not obstruct the flow of water into the overflow inlet.

3-6.6 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.

3-6.7 Coating for Bottom Plates on Soil or Concrete. (See also Sections 9-1 and 9-2.)

3-6.7.1 The underside of all bottom plates shall be protected against corrosion by one of the following methods:

- apply two coats of paint after the bottom has been completely welded, or
- erect bottom on oil-saturated sand cushion.

3-6.7.2* Where the tank bottom is placed on oiled sand, the sand shall be saturated to a depth of 4 in. (102 mm) with a suitable petroleum-base oil.

3-6.8 Testing.

3-6.8.1 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:

- Air pressure or vacuum applied to the joints, using soap suds, linseed oil, or other suitable material for the detection of leaks.
- The joints tested by the magnetic particle method.

3-6.8.2 General. Upon completion of the tank, it shall be filled with water furnished at the tank site by the purchaser at proper pressure to fill the tank to the maximum working water level. Any leaks in the shell, bottom, or roof (if the roof contains water) disclosed in the test, shall be repaired by chipping or melting out any defective welds and then rewelding. No repair work shall be done on any joints unless the water in the tank is at least 2 ft (0.6 m) below the point being repaired. The tank shall be watertight under test to the satisfaction of the purchaser's inspector.

3-6.8.3 Disposal of Test Water. The purchaser shall provide a means for disposing of test water up to the tank inlet or drain pipe.

3-7 Accessories.

3-7.1 Connections. Connections shall be provided on the tank for the necessary pipes, braces, frost-casting, and walkway supports.

3-7.2 Roof Anchorage. Each roof plate shall be securely fastened to the top of the tank.

3-7.3 Roof Hatch. An easily accessible roof door or hatch having a minimum opening dimension of 24 in. (610 mm) shall be provided in the roof. The hatch cover shall be built of steel plate at least $\frac{3}{16}$ in. (4.8 mm) thick. The opening shall have a curb at least 4 in. (102 mm) high, and the cover shall have a downward overlap of at least 2 in. (51 mm). A substantial catch shall be provided to keep the cover closed.

An additional roof hatch or flanged vent with a removable cover having a minimum opening dimension or diameter of 24 in. (610 mm) and a neck 4 in. (102 mm) minimum height shall be provided at, or near, the center of the tank. The opening shall be constructed so that an exhaust fan can be bolted to the hatch if required for ventilation during painting. The flange shall be drilled with at least four $\frac{13}{16}$ -in. (20.6-mm) diameter holes on a 30 $\frac{1}{4}$ -in. (768-mm) diameter bolt circle.

3-7.4 Ladders — General. Outside and inside steel ladders arranged for convenient passage from one to the other and through the roof hatch shall be provided. Ladders shall not interfere with the opening of the hatch cover and shall not incline outward from the vertical at any point. For pedestal-supported tanks, the ladder shall be placed inside an access tube extending through the center of the tank.

3-7.5 Outside Fixed Shell and Roof Ladder. The outside tank ladder of suction and multiple-column-supported gravity tanks shall be fixed at least 7 in. (178 mm) between the tank side and the centerline of rungs and rigidly bolted or welded to brackets not over 12 ft (3.7 m) apart that are welded to the tank plates. The bottom bracket shall not be more than 6 ft (1.8 m) 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 within approximately 2 ft (0.61 m) of the roof hatch. There shall be at least a 1-ft (0.3-m) clearance at the sides and front of the ladder at the balcony. All ladders shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

3-7.6 Inside Ladder.

3-7.6.1 The inside fixed ladder provided for passage between the roof hatch and tank bottom shall not be rigidly connected to the bottom plates.

3-7.6.2 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 spaced not over 12 ft (3.7 m) apart. The upper bracket shall be located at the top of the riser.

3-7.6.3 All ladders exceeding 20 ft (6.1 m) shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

3-7.7 Ladder Bars and Rungs. Ladder side bars shall be not less than 2 in. $\times$ $\frac{1}{2}$ in. (51 mm $\times$ 12.7 mm) or 2 $\frac{1}{2}$ in. $\times$ $\frac{3}{8}$ in. (64 mm $\times$ 9.5 mm). Side bars shall be spaced at least 16 in. (406 mm) apart. Rungs shall be at least $\frac{3}{4}$ in. (19.1 mm) round or square steel spaced 12 in. (305 mm) on centers. The rungs shall be firmly welded to the side bars. Ladders and connections shall be designed to support a concentrated load of 350 lb (159 kg).

3-7.8 Repainting. (See 14-1.8.)

3-7.9 Painting Inaccessible Parts. Parts inaccessible after fabrication, but subject to corrosion, shall be protected by paint before assembly. Surfaces in watertight joints shall be coated with clear oil or lacquer.

Exception: This requirement shall not be applicable to the overlapping surfaces of single-welded lap joints above the high water line.

3-7.10 Painting.

3-7.10.1 All interior surfaces of steel tanks 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-SP10 or Pickling in accordance with SSPC-SP8, and shall be primed in accordance with the requirements for Inside Paint System No. 1 in AWWA D102, *Standard for Painting Steel Water Storage Tanks*.

3-7.10.2 All exterior surfaces and inside dry surfaces (pedestal tanks) shall be cleaned by commercial blasting in accordance with SSPC-SP6 or Pickling in accordance with SSPC-SP8, 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, *Standard for Painting Steel Water Storage Tanks*.

3-7.10.3 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.

3-7.10.4 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.

3-7.10.5 All finish coat painting for interior (wet) surfaces shall be in accordance with the requirements for Inside Paint Systems No. 1 of AWWA D102, *Standard for Painting Steel Water Storage Tanks*, utilizing the same basic system throughout.

3-7.10.6 All exterior and inside dry finish coat painting shall be in accordance with the requirements for Outside Paint System No. 1 of AWWA D102, *Standard for Painting Steel Water Storage Tanks*, utilizing two coats of aluminum or alkyd enamel in a color as specified by the purchaser to provide a minimum total system dry film thickness of 3.5 mils (87 μ m) for aluminum finishes and 4.5 mils (112 μ m) for alkyd enamels. As provided for by Outside Paint System No. 4 of AWWA D102, the purchaser shall be permitted to specify an extra complete coat of primer for a total minimum system dry film thickness of 5.0 mils (125 μ m) for aluminum finishes and 6.0 mils (150 μ m) for alkyd enamels for the more severe atmospheric exposures.

3-7.11 Other finish coats shall be permitted to be used if they comply with AWWA D102 (excluding Inside Paint System No. 5) and with approval from the authority having jurisdiction.

3-7.12* Painting Application. All painting shall be accomplished in accordance with the appropriate requirements of SSPC *Systems and Specifications Steel Structure Painting Manual*, "Paint Application Specification No. 1 — Shop, Field, and Maintenance Painting."

3-7.13 The painting and priming systems described in 3-7.10 through 3-7.12 shall be lead free.

Chapter 4 Factory-Coated, Bolted Steel Tanks

4-1 General.

4-1.1* This chapter shall apply to the design, fabrication, and erection of bolted steel water tanks including pump suction tanks with factory-applied coatings.

4-1.2 Standard Capacity. The standard capacity of bolted tanks varies with the number of panels added to the diameter ranging from 4000 gal to approximately 500,000 gal (15.1 m³ to 1892.7 m³) net capacity. Tanks of other capacities shall be permitted.

4-1.3 Form. Bolted tanks shall be cylindrical. All joints, including vertical, horizontal, shell-to-roof, and shell-to-bottom plates or sheets, shall be field bolted. Coatings shall be factory applied. Bolt holes shall be shop-punched or drilled for field assembly. All joints in contact with water and weather-tight joints shall be sealed.

4-2 Materials.

4-2.1 Plate and Sheet. Plate and sheet shall be open-hearth, electric furnace, or basic-oxygen-process steel conforming to any of the following ASTM specifications: A 36; A 283, Grade C or Grade D; A 570, Grade 30, Grade 33, Grade 36, Grade 40, or Grade 45; A 572, Grade 42 or Grade 50; A 607, Grade 50; or A 715, Grade 50.

4-2.1.1 Basis of Furnishing Plates and Sheets. Plates and sheets shall be furnished on the weight basis with permissible underrun and overrun according to the tolerance table for plates ordered to weight published in ASTM A 6, *Specifications for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use*.

4-2.2 Structural Shapes. Hot-rolled structural shapes shall conform to ASTM A 36, *Specifications for Structural Steel*. Aluminum shapes shall be permitted to be used for portions of the tank not in contact with water and shall follow the design criteria in Appendix A of AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*.

4-2.3 Tubular Columns. Steel pipe shall be permitted to be used as tubular columns or other structural members, provided it complies with specifications ASTM A 139, Grade B; ASTM A 53, Type E or S, Grade B; API 5L, 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. For the purposes of this standard, the allowable underrun shall be subtracted from the nominal wall thickness when calculating the minimum pipe wall thickness. Tubular sections shall not be flattened to form end connections.

4-2.4 Bolts, Anchor Bolts, and Nuts. Bolts, anchor bolts, and nuts shall conform to AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage* and Section 9-4.

4-2.5 Forgings. Forgings shall conform to the following ASTM specifications. Steel shall be made only by the open-hearth process:

ASTM A 105, *Forgings for General Purpose Piping and Piping Components*

ASTM A 668, *Class E. Forgings for General Use*

NOTE: Forgings intended for welding must have supplementary requirements.

4-2.6 Filler Metal Electrodes. Manual, shielded metal-arc-welding electrodes shall conform to the requirements of AWS A5.1, *Specifications for Covered Carbon Steel Arc-Welding Electrodes*. Electrodes shall be any E60XX or E70XX classification suitable for the electric current characteristics, the position of welding, and other conditions of intended use. Electrodes for other welding processes shall conform to applicable AWS specifications for filler metal.

4-2.7 Gasket. Gasket material shall be of adequate tensile strength and resilience to obtain a leak-proof seal at all seams and joints. Gasket material shall be resistant to weather and ozone exposure and shall conform to ASTM D 1171, *Test Method for Rubber Deterioration — Surface Ozone Cracking Outdoors or Chamber (Triangular Specimens)*. Physical requirements shall conform to AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*. In addition, the gasket material shall be capable of resisting the chlorination exposure as required by AWWA C652, *Disinfection of Water-Storage Facilities*.

4-2.8 Sealant. Sealants shall be supplied by the tank manufacturer. Sealants shall remain flexible over a temperature range of -40°F to +170°F (-40°C to 76.7°C). Resistance to hardening and cracking shall be required. The sealant shall be solid with no plasticizers or extenders to cause shrinkage. 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 the chlorination exposure as required by AWWA C652, *Disinfection of Water-Storage Facilities*.

4-3 Earthquake Loads. Tanks shall meet requirements for resisting earthquake damage by complying with the earthquake design provisions of AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*.

4-4 Unit Stress of Shell Plates. The maximum stress in pounds per in.² produced by the design loads in Section 2-3 shall not exceed the requirements of AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*.

4-5 Design Details.

4-5.1 Minimum Steel Thickness. Steel plates or sheets shall meet the minimum design criteria according to AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*, as well as any additional requirements outlined below.

4-5.1.1 Roof sheets shall have a minimum thickness of 0.094 in. (2.4 mm).

Exception: Sheets on roofs having a slope of 1 in 2.75 or greater for which the tank diameter does not exceed 35 ft (10.7 m) shall be permitted to utilize a minimum thickness of 0.070 in. (1.8 mm), provided that 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 water level and temperature.

4-5.1.2 Floor sheets shall have a minimum thickness of 0.105 in. (2.7 mm) provided the tank floor is supported on a granular base, crushed stone, or concrete slab.

4-5.1.3 The minimum thickness of the first full height shell plate and starter ring (if applicable) shall be 0.1875 in. (4.8 mm).

Exception: This minimum thickness shall be permitted to be reduced provided that the design meets the following criteria:

(a) *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:

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

$$f_t = 1/3 F_u$$

Where:

f_t = the allowable tensile stress, in psi

F_y = the published yield strength of the sheet material, in psi

r = the 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 = the diameter of the bolt in in.

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

F_u = the ultimate strength of the sheet material in psi

(b) *Shell thickness:* The thickness of cylindrical shell plates stressed by pressure of the tank contents shall be calculated by the formula:

$$t = \frac{2.6 H D S G}{f_t [S-d]}$$

Where:

t = the shell plate thickness in in.

H = the height of liquid from the top capacity line just to overflow to the bottom of the shell course being designed, in ft

D = the tank diameter, in ft

S = the bolt spacing in line perpendicular to line of stress, in in.

G = the specific gravity of liquid (1.0 for water)

f_t = the allowable tensile stress, in psi [See 5-5.1.3(a)]

d = the bolt-hole diameter in in.

4-5.1.4 The minimum thickness of upper rings of shell plates shall be 0.105 in. (2.7 mm).

Exception: This minimum thickness shall be permitted to be reduced to no less than 0.094 in. (2.4 mm) provided that the design meets the criteria of the exception to 4-5.1.3.

4-6 Fabrication.

4-6.1 Parts shall be fabricated in accordance with AWWA D103 practices and tolerances.

4-6.2 Welding shall be limited to shop installation of nozzles, vents, manways connections, and subassemblies. Field welding shall not be permitted.

4-6.3 Coatings shall be applied in accordance with AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*.

4-6.4 All tank components shall be given a mark number for ease of assembly.

4-6.5* All coated parts shall be protected from damage during shipment.

4-7 Erection.

4-7.1 To facilitate inspection for leaks, bolted tanks shall be erected in accordance with manufacturer's drawings, instructions, and AWWA D103 procedures. Bolted steel floor plates shall be positioned directly on a minimum 4 mil (102 mm) polyethylene base arranged to allow water flow from the center of the tank to the perimeter of the tank. The polyethylene sheets shall be placed over the sloped base and shall be lapped a minimum of 18 in. (457 mm) on top of one another (the higher sheet overlapping the adjacent sheet) to allow for drainage from the underside of the tank.

Exception: Polyethylene sheeting shall not be required for tanks with concrete slabs that also serve as the tank floor provided the provisions of Section 8-6 have been complied with.

4-7.2 The erector shall exercise care in properly installing all parts of the tank, including but not limited to gaskets and sealants.

4-7.3 Care in handling coated parts shall be exercised. Any sections that experience damage to the factory-applied coatings shall be repaired or replaced in accordance with the manufacturer's instructions. Excessively damaged parts shall be replaced.

4-7.4* The completed tank shall be tested by filling with water, and any leaks detected shall be repaired in accordance with AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*.

Chapter 5 Pressure Tanks

5-1 General.

5-1.1 Service. Pressure tanks shall be permitted to be used for limited private fire protection services, such as those covered by the following NFPA standards:

NFPA 13, *Standard for the Installation of Sprinkler Systems*

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

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

Pressure tanks shall not be used for any other purpose unless approved by the authority having jurisdiction.

5-1.2 Capacity. The capacity shall be approved by the authority having jurisdiction.

5-1.3 Air Pressure and Water Level. Unless otherwise approved by the authority having jurisdiction, the tank shall be kept two-thirds full of water, and an air pressure of at least 75 lb/in.² (5.2 bars) by the gauge shall be maintained. As the last of the water leaves the pressure tank, the residual pressure shown on the gauge shall not be less than zero and shall be sufficient to give not less than 15 lb/in.² (1.0 bars) pressure at the highest sprinkler under the main roof of the building.

Exception: Other pressures and water levels might be required for hydraulically designed systems. See NFPA 13, *Standard for the Installation of Sprinkler Systems*, for guidance.

5-1.4* Airlock. Methods used for prevention of airlock shall be approved by the authority having jurisdiction in each particular case.

5-1.5 Location. Pressure tanks shall be located above the top level of sprinklers.

Exception No. 1: Subject to the approval of the authority having jurisdiction, tanks shall be permitted to be located in the basement or elsewhere. (See 5-1.8.)

Exception No. 2: Subject to the approval of the authority having jurisdiction, tanks shall be permitted to be buried in accordance with the requirements of 5-1.9.

5-1.6 Construction.

5-1.6.1 General. Except as herein specified to the contrary, pressure tanks shall be constructed in accordance with the *Rules for the Construction of Unfired Pressure Vessels*, Section VIII, Division 1, Unfired Pressure Vessels of the ASME Boiler and Pressure Vessel Code. This code shall permit the fusion process of welding with certain regulations for strength, qualification of welders, and tests.

5-1.6.2 Tests.

(a) Each pressure tank shall be given the tests specified by the ASME Rules before painting, except that the hydrostatic test pressure shall in no case be less than 150 lb/in.² (10.3 bars).

(b) In addition to the ASME tests, each pressure tank shall be filled two-thirds full and tested at the normal working pressure with all valves closed and shall not lose more than 1/2 lb/in.² (0.03 bars) pressure in 24 hours.

(c) A certificate signed by the manufacturer shall be filed with the authority having jurisdiction, certifying that the foregoing tests have been made.

(d) A repetition of the above tests might be required after the tank has been set in place and connected. In all cases where conditions do not permit shipping the tank assembled, the above tests shall be conducted after erection in the presence of a representative of the authority having jurisdiction.

5-1.6.3 Supports. The supports shall be steel or reinforced concrete and shall be located so as to prevent sagging or vibration and to properly distribute the loads due to the weight of the vessel completely full of water. Stresses in steel supports shall not exceed those permitted by Section 10-4 for steel towers. For horizontal tanks there shall be at least one support near each end of the tank so located that combined stresses in any part of the tank shall not exceed those specified in 10-4.6.

5-1.6.4 Painting. Tanks shall be cleaned and painted inside and outside in accordance with the requirements of 3-7.10, 3-7.11, 3-7.12, and 3-7.13. An ASME Specifications for Material stamp and an ASME Standard Pressure Vessel stamp shall not be rendered illegible.

5-1.7 Marking.

5-1.7.1 General. All stamps required by the ASME specification shall be applied. The nameplate or water-level marking (see 5-1.7.2 and 5-1.7.3) shall be securely fastened without obliterating any lettering. If screws are used, they shall not penetrate the tank plate more than one half its thickness.

5-1.7.2 Nameplate. A metal nameplate with raised or stamped letters and numbers of sufficient size to be easily read containing the following information shall be provided:

Name and location of manufacturer;
Year of erection;
Length and diameter;

Total capacity [gal (m³);
Working pressure [lb/in.² (bars)].

5-1.7.3 Water-Level Indicator. The nameplate shall also serve as the water-level indicator by bearing an easily observed raised arrow. The tank plate shall be marked "2/3 capacity line" in raised or stamped lettering behind the gauge glass in a position such that the arrow will be at the water level when the tank is two-thirds full. For horizontal tanks the two-thirds capacity line is 63/100 of the diameter above the bottom.

Exception: Where the design water level is at some point other than the 2/3 level, the nameplate shall be so lettered and positioned behind the gauge glass accordingly.

5-1.8 Housing. Where subject to freezing, the tank shall be located in a substantial noncombustible housing. The tank room shall be large enough to provide free access to all connections, fittings, and manhole, with at least 18 in. (457 mm) around the rest of the tank. The distance between the floor and any part of the tank shall be at least 3 ft (0.91 m).

The floor of the tank room shall be watertight and arranged to drain outside of the enclosure. The tank room shall be adequately heated to maintain a minimum temperature of 40°F (4.4°C) and shall be equipped with ample lighting facilities.

5-1.9 Buried Tanks. Where lack of space or other conditions require it, pressure tanks shall be permitted to be buried if the requirements of 5-1.9.1 through 5-1.9.6 are satisfied.

5-1.9.1 For protection against freezing, the tank shall be below the frost line.

5-1.9.2 The end of the tank, and at least 18 in. (457 mm) of its shell, shall project into the building basement or a pit in the ground with protection against freezing. There shall be adequate space for inspection and maintenance and use of the tank manhole for interior inspection (see Figure B-1).

5-1.9.3 The exterior surface of the tank shall be cleaned and painted in accordance with 5-1.6.4, and additional protection shall be provided as follows:

(a) An approved cathodic system of corrosion protection shall be provided, and

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

5-1.9.4 The tank shall be above the maximum ground water level so that buoyancy of the tank when empty will not force it upward. The tank shall be permitted to be anchored to a concrete base as an alternative.

5-1.9.5 The tank shall be designed with strength to resist the pressure of earth against it.

5-1.9.6 A manhole shall be located preferably on the vertical centerline of the tank end as close to the knuckle as possible while still being able to clear it (see Figure B-1).

5-2 Pipe Connections and Fittings.

5-2.1 Openings. A manhole and all openings needed for connection of the piping and fittings specified in the following articles shall be provided. The manhole and threaded openings shall conform in design with the ASME Rules for the Construction of Unfired Pressure Vessels. The manhole shall be placed below the water level.

5-2.2 Tank Discharge. The discharge pipe shall be sized to supply the required amount of water for the fire protection system, but shall not be less than 4 in. (102 mm) in size in any case. The discharge pipe shall be connected to the bottom of the tank by means of a fitting that projects 2 in. (51 mm) above the bottom to form a settling basin and prevent sediment from passing into the system. A listed horizontal swing check-valve and a listed indicating valve shall be located in the discharge pipe, directly under or near the tank. The pipe shall be adequately supported.

5-2.3 Filling Pipe. The water-filling pipe shall be at least 1½ in. (38 mm) in size, run separately from the filling pump or other acceptable source of supply, and shall be adequately supported and protected from mechanical injury. It shall be connected to the top or bottom of the tank as required by the authority having jurisdiction. (See *Figures B-1 and B-2.*) A listed horizontal bronze-seat swing-check valve and a renewable-disc globe valve shall be provided in the pipe near the tank. The globe valve shall be placed between the check valve and the tank.

5-2.4 Air Pipe. The air supply pipe shall be at least 1 in. (25.4 mm) in size, well supported, and protected from breakage. It shall be connected to the tank above the water level (see *Figures B-1 and B-2.*) A reliable horizontal bronze-seat swing-check valve and listed renewable-disc globe valve shall be provided in the pipe near the tank. The globe valve shall be placed between the tank and the check valve.

5-2.5 Water-level Gauge. A ¾-in. (19.1-mm) 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. The gauge glass shall be not over 12 in. (305 mm) long for horizontal tanks or 18 in. (457 mm) long for vertical tanks. Listed angle globe valves with renewable discs shall be installed in the connections from the gauge to the tank independent of the shutoff valves that are a part of the gauge fittings. The water-level gauge shall be connected through valves into the tank (see *Figures B-1 and B-2.*) A petcock shall be provided for draining the glass. All fittings and nipples shall be of brass, not less than ¾ in. (19.1 mm) in size, except that the nipple extending into the tank shall be permitted to be ½ in. (12.7 mm) in size.

5-2.5.1 The glass gauge tube shall be protected from mechanical injury by a guard consisting of at least three ⅜-in. (4.8-mm) brass rods.

5-2.5.2 The valves on the water-level gauge connections shall be opened only when ascertaining the amount of water in the tank.

5-2.6 Air-pressure Gauge. A listed 4½-in. (114-mm) 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 (see *Figures B-1 and B-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 arranged to drain. A plugged outlet at least ¼ in. (6.4 mm) in size shall be provided between the valve and the gauge for the inspector's gauge.

5-2.7 Safety Appliances. A brass relief valve not less than ¾ in. (19.1 mm) in size set to operate at a pressure 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. There also shall be a brass relief valve not less than 1½ in. (38.1 mm) in size at the filling pump set to relieve pressures 10 percent in excess of the pressure at the pump when the tank is under normal working pressure. No safety appliances shall be installed between the tank and other valves.

5-2.8 Emergency Drain. Provisions shall be made to drain each tank independently of all other tanks and the sprinkler system by a pipe not less than 1½ in. (38.1 mm) in size. The drain valve shall be a globe valve with renewable disc and shall be located near the tank. (See *Figures B-1 and B-2.*)

5-2.8.1 Use of a drain other than those shown in *Figures B-1 and B-2* 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.

5-2.9 Water Filling Supply. The filling supply or pump shall be reliable and shall be capable of replenishing the water required to be maintained in the tank with the required air pressure restored in not more than four hours. A properly designed relief valve shall be provided at the pump, as specified in 4-2.7.

5-2.10 Air Compressor. An air compressor capable of delivering not less than 16 ft³/min (0.45 m³/min) of free air for tanks of 7500 gal (28.39 m³) total capacity, and not less than 20 ft³/min (0.57 m³/min) for larger sizes, shall be provided. The compressor shall be located in the tank house, unless otherwise permitted by the authority having jurisdiction. A safety valve shall be provided, as specified in 4-2.7.

5-2.11 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.

5-2.12 Watertight Intersections at Roofs and Floors. The intersections of all piping with the building roof and concrete or waterproof floors shall be watertight. (See *11-1.1.*)

5-2.13 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 6 Wood Gravity and Suction Tanks

6-1 General.

6-1.1 This chapter shall apply to the design, fabrication, and erection of wood gravity water tanks, including pump suction tanks.

6-1.2 Capacity. The capacity of the tank is the number of U.S. gallons (m³) available above the outlet opening. 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.

6-1.3 Standard Sizes. The standard sizes of wood tanks are 5000 gal (18.93 m³), 10,000 gal (37.85 m³), 15,000 gal (56.78 m³), 20,000 gal (75.70 m³), 25,000 gal (94.63 m³), 30,000 gal (113.55 m³), 40,000 gal (151.40 m³), 50,000 gal (189.25 m³), 60,000 gal (227.10 m³), 75,000 gal (283.88 m³), and 100,000 gal (378.50 m³) net capacity. Tanks of other sizes are built.

6-1.4 Strength. The materials as specified shall have no defects other than those permitted by the grading rules for the lumbers listed in 6-2.2. The use of second-hand materials, including hoops, lumber, etc., shall not be permitted. The workmanship shall be of a quality that defects or injuries are not produced during manufacture or erection. Unit stresses, as specified in 6-4.1, shall not be exceeded except where additionally reinforced. (See 6-6.3.) The structure and its details shall possess the requisite strength and rigidity.

6-2 Material.

6-2.1 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*.

6-2.2 Lumber—Staves and Bottom.

6-2.2.1 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 shall be redwood, western yellow cedar, southern white cedar (dismal swamp), western red cedar, and Douglas fir (coast type), the varieties being arranged in the order of preference.

6-2.2.2 Western yellow cedar, redwood, or southern white cedar (dismal swamp) shall be preferable, as the increased serviceability will ordinarily more than offset the slightly greater cost of the complete installation. Fir and red cedar deteriorate rapidly, especially if the water is overheated during the heating season. (See 13-1.9.)

6-2.2.3 Acceptable treated species shall include all those listed in 6-2.2.1 and yellow pine, all without sapwood restriction. Treatment shall consist of a 6-lb/ft³ to 8-lb/ft³ (96-kg/m³ to 128-kg/m³) retention of creosote or pentachlorophenol applied after shop fabrication, according to the American Wood Preservers Association, by the empty-cell process.

6-2.3 Timber Supports. Wooden dunnage beams, where used, shall be a dense grade of southern pine or Douglas fir or a construction heart-untreated redwood or red cypress (coast type), except that structural grades of other species can be used if treated with a 6-lb/ft³ to 8-lb/ft³ (96-kg/m³ to 128-kg/m³) retention of creosote or pentachlorophenol applied by the empty-cell process according to the standard specifications of the American Wood Preservers Association. (See 6-4.1 and 6-5.8.) Wood dunnage beams shall be at least 4 in. × 6 in. (102 mm × 152 mm) nominal size.

6-2.4 Hoops. Hoops shall be round bars of steel. The steel bars shall conform to ASTM A 675, A 36, or A 502. Steel shall be made only by the open-hearth or electric-furnace processes.

6-2.5 Hoop Lugs. The lugs shall be malleable iron, cast steel, or fabricated steel and shall have equal or greater ultimate strength than the ASTM A 675, A 36, or A 502 steel hoop they are used with.

6-2.6 Steel Shapes. The steel for structural shapes shall conform to ASTM A 36 structural steel.

6-3 Loads.

6-3.1 Dead Load. The dead load shall be the estimated weight of all permanent construction and fittings.

6-3.2 Live Load. Under normal conditions, the live load shall be the weight of all the liquid when overflowing the top of the tank. The unit weight of water shall be considered as 62.4 lb/ft³ (1000 kg/m³). Proper provision shall be made for temporary stresses during erection. Where roofs have a slope of less than 30 degrees, they shall be designed to support a uniform weight of 25 lb/ft² (122 kg/m²) on the horizontal projection.

6-3.3 Wind Load. Under normal conditions, the wind load or pressures shall be assumed to be 30 lb/ft² (147 kg/m²) on vertical plane surfaces, 18 lb/ft² (88 kg/m²) on projected areas of cylindrical surfaces, and 15 lb/ft² (73 kg/m²) on projected areas of conical and double-curved plate surfaces. When designing for wind velocities over 100 mph (161 km/hr), all of the above mentioned unit pressures shall be adjusted in proportion to the square of the velocity assuming that the above pressures are for 100 mph (161 km/hr).

6-3.4 Earthquake Load. Tank structures shall meet local requirements for resisting earthquake damage.

6-3.5 Balcony and Ladder Loads. A vertical load of 1000 lb (454 kg) shall be assumed to be applied to any 10 ft² (0.93 m²) of area on the balcony floor and on each platform; 500 lb (227 kg) applied to any 10 ft² (0.93 m²) area on the tank roof; and 350 lb (159 kg) on each vertical section of ladder. All of the structural parts and connections shall be designed to withstand such loads. The above loadings shall not be combined with snow loading.

6-4 Unit Stresses.

6-4.1 General. The following stresses in pounds per square inch (MPa) shall apply particularly to wood tanks and shall not be exceeded. (See Section 10-4 for unit working stresses for steel supporting construction.)

6-4.1.1 Tension Hoops. The unit stress for tension hoops of ASTM A 675 steel shall be 15,000 lb/in.² (103.43 MPa) (use with hydrostatic load and neglect initial tension). ASTM A 36 or A 502 steel shall be 20,000 lb/in.² (137.90 MPa).

6-4.1.2 Timber. The allowable working stresses for timbers mentioned in 6-2.3 and 6-5.8 shall be as specified in Table 6-4.1.2.

6-4.2 Wind and Earthquake Allowance. For stresses due to a combination of wind or earthquake with other loads, the above working unit stress shall be permitted to be increased by 33⅓ percent. Wind and earthquake loads shall not need to be considered simultaneously. In no case shall the strength of the member be less than that required for dead and live loads alone.

6-5 Details of Design.

6-5.1 Lumber Thickness. The lumber in the staves and the bottom shall be at least 2½ in. (64 mm) (nominal) dressed to not less than 2⅞ in. (54 mm) thickness for tanks less than 20 ft (6.1 m) in depth or diameter, and for larger tanks at least 3 in. (76 mm) (nominal) dressed to not less than 2⅞ in. (60 mm) thickness.

Table 6-4.1.2 Working Stresses for Timber (Select Grade)

Species	Allowable Stress psi (MPa)			
	Bending In extreme fiber	Hori- zontal shear	Compres- sion perpendic- ular to grain	Compres- sion parallel to grain; short columns
Cedar, western red	900 (6.21)	80 (0.55)	200 (1.38)	700 (4.83)
Cedar, northern and southern white	750 (5.17)	70 (0.48)	175 (1.21)	550 (3.79)
Douglas fir (Western Washington and Oregon)	1600 (11.03)	90 (0.62)	345 (2.38)	1175 (8.10)
Douglas fir (Western Washington and Oregon), dense grade	1750 (12.07)	105 (0.72)	380 (2.62)	1290 (8.89)
Douglas fir (Rocky Mountain type)	1100 (7.58)	85 (0.57)	275 (1.90)	800 (5.52)
Pine, southern yellow	1600 (11.03)	110 (0.76)	345 (2.38)	1175 (8.10)
Pine, southern yellow, dense	1750 (12.07)	120 (0.83)	380 (2.62)	1290 (8.89)
Pine, white, sugar, western white, western yellow	900 (6.21)	85 (0.57)	250 (1.72)	750 (5.17)
Pine, Norway	1100 (7.58)	85 (0.57)	300 (2.07)	800 (5.52)
Redwood	1200 (8.27)	70 (0.48)	250 (1.72)	1000 (6.90)
Spruce, red, white, Sitka	1100 (7.58)	85 (0.57)	250 (1.72)	800 (5.52)

6-5.2 Hoop Sizes. Hoops shall not be smaller than the pitch diameter of $\frac{3}{4}$ -in. (19.1-mm) thread. No more than two sizes of hoops shall be used on a tank.

6-5.3* Hoop Schedules. A hoop shall be assumed to support one half of the length of the stave to the two adjacent hoops. Typical hoop schedules for standard size tanks are shown in Figure A-6-5.3, based on the area at the root of the cut threads. Other schedules shall be satisfactory provided the unit stress as stated in Section 6-4 is not exceeded. (See Figure 6-5.3 for hoop spacing for wood tanks.)

6-5.4 Hoops at Bottom.

6-5.4.1 One hoop shall be placed approximately at the center of the bottom planks of tanks with diameters of 19 ft (5.8 m) or less. The stress in this hoop shall not exceed one half the allowable unit tension, the excess strength being provided to take care of the swelling of the bottom planks.

6-5.4.2 On tanks with diameters of over 19 ft (5.8 m) two hoops of equal size shall be placed opposite the tank bottom. The stress in the upper hoop shall be limited as stated above.

6-5.5 Hoops at Top. The top hoops shall be placed 3 in. (76 mm) below the bottom of the flat cover joists or 3 in. (76 mm) below the top of the staves if the flat cover is omitted. The maximum spacing of hoops shall not exceed 21 in. (533 mm).

6-5.6 Hoop Lugs. 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 ASTM A 36 or A 502 steel hoop they are used with. The lugs shall be designed so that water shall not be pocketed. The hoops shall be so located on the tank that the lugs come in fairly uniform spiral lines.

6-5.7 Main Supports. Steel I-beams or reinforced concrete beams shall be used for the main supports where the dunnage beams rest.

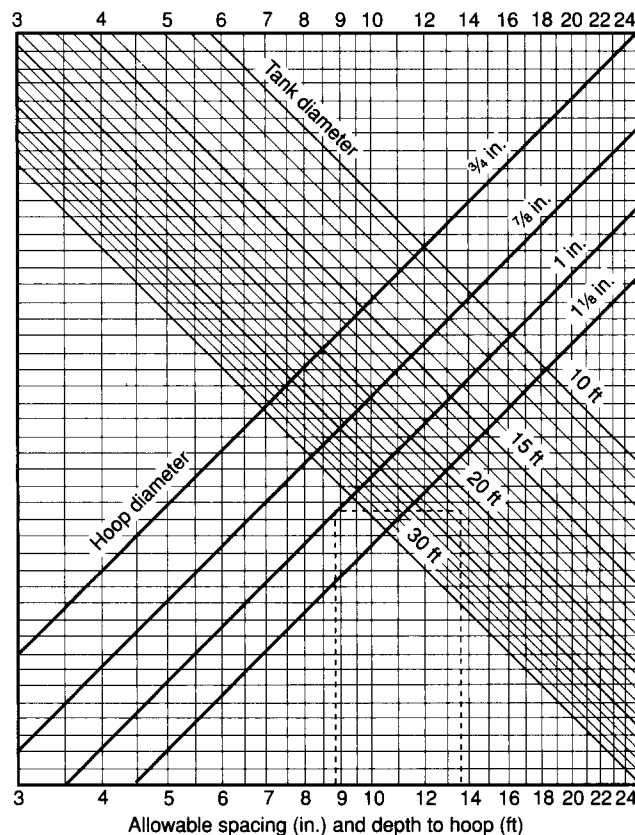


Figure 6-5.3 Hoop spacing diagram for wood tanks.

6-5.8 Spacing of Supports. The maximum distance in the clear between the beams where the tank bottom rests shall not exceed 21 in. (533 mm). The maximum distance between the outer edge of the outer dunnage beam and inside surface of the tank staves measured on a line perpendicular to the beam at its midpoint shall not exceed 14 in. (356 mm).

6-5.9 Air Circulation under Tank Bottom. Tank supports shall be designed to allow a free circulation of air under the tank bottom and about the ends of the staves.

6-6 Workmanship.

6-6.1 Lumber Edges and Surfaces. Planks for the staves and bottom shall be planed on both sides. The edges of the staves and bottom planks shall be machine-planed or sawed. Edges of staves shall be cut to obtain full bearing at joints. A fore plane can be used for smoothing up the edges. The last stave to be placed in the tank shall be carefully planed to the required size.

6-6.2 Croze. The croze shall be cut at right angles to the centerline of the staves. 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. The depth and width of the croze shall be at least $\frac{3}{4}$ in. (19.1 mm) and $2\frac{1}{8}$ in. (54 mm), respectively, for 3-in. (76-mm) nominal staves, and $\frac{7}{8}$ in. (15.9 mm) and 2 in. (51 mm) for $2\frac{1}{2}$ -in. (64-mm) nominal staves.

6-6.3 Chime. The chime shall be of uniform depth and not less than 3 in. (76 mm). Before erection, the chimes of staves shall be fastened with at least two nails or staples at

least 1¼ in. (32 mm) long. Nails or staples shall be coated with zinc or copper, or shall be of other material highly resistant to corrosion.

6-6.4 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 ½ in. (12.7 mm) in diameter for planks up to 2½ in. (64 mm) nominal and ⅝ in. (15.9 mm) in diameter above that thickness.

6-6.5 Splices. Finger joint splices shall be used in a stave or bottom plank if permitted by the authority having jurisdiction. Such joints in adjacent staves or bottom planks shall be staggered a minimum of 2 ft (0.61 m).

6-6.6 Joints at Bottom. The joints between staves shall not come nearer than ½ in. (12.7 mm) to a joint between the bottom planks.

6-6.7 Extra Staves. One or more extra staves shall be shipped with each tank.

6-6.8 Marking of Staves. The proper hoop spacing shall be plainly marked on at least six staves before shipment.

6-6.9 Clearance at Supports. The distance between the ends of dunnage beams and the inside surface of the staves shall be not less than 1 in. (25.4 mm) or more than 3 in. (76 mm). The supports shall be of such depth that the clearance beneath the ends of staves is not less than 1 in. (25.4 mm) at any point.

6-6.10 Hoop Forming. Hoops shall be cut to proper length and shall be bent in the shop to the radius of the tank.

6-6.11 Hoop Threads. The threads shall have a tight fit in the nuts and shall be U.S. Standard.

6-6.12 Hoop Tightening. Care shall be taken in 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.

6-6.13 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.

6-7 Accessories.

6-7.1 Roof — General. Where the tank is located out of doors it shall have a flat wooden cover over the top and a conical roof above the wooden cover, except that the flat cover can be omitted and the conical cover made self-supporting provided that approval of the detailed design is first obtained from the authority having jurisdiction. Roofs shall be constructed as shown by Figures B-3 and B-4, or in accordance with other designs approved by the authority having jurisdiction. Roof boards shall be not less than 1 in. (25.4 mm) nominal thickness or ⅝ in. (9.5-mm) Exterior Grade Plywood laid without spacing between. If plywood is used, end joints shall be made over roof joists or ply clips shall be used to support edges. Shiplap or matched joints shall be used on boards in the flat cover, unless plywood is used. The joint between the tank staves and roof shall be tight. Nails or staples shall be heavily galvanized or of nonferrous metals.

6-7.2 Flat Cover. The flat cover, if provided, shall rest on parallel joists and shall be spaced not over 36 in. (914 mm)

on centers. The nominal size of joists shall be at least 2 in. × 6 in. (51 mm × 152 mm) for lengths up to 18 ft (5.5 m); 3 in. × 6 in. (76 mm × 152 mm) for lengths up to 22 ft (6.7 m); and 3 in. × 8 in. (76 mm × 203 mm) for lengths up to 30 ft (9.2 m). The full section of all joists at their ends shall be solidly supported by resting in slots cut entirely through the staves or by other means approved by the authority having jurisdiction.

6-7.3 Conical Roof. (See Figure B-4.)

6-7.3.1 The conical roof shall be supported by 2-in. × 4-in. (51-mm × 102-mm) rafters spaced not over 36 in. (914 mm) apart around the top of the tank.

6-7.3.2 Although the rafter and header type of construction is considered preferable, other types of roof construction shall be acceptable, provided approval of design is first obtained from the authority having jurisdiction.

6-7.3.3 The roof shall be covered with galvanized iron, at least 60-lb (27-kg) asphalt, asbestos, or equivalent fire-resistive roofing, securely fastened in place. Prepared asphalt roofing shall be laid with at least 2½-in. (64-mm) laps, properly cemented, and using ¾-in. (19.1-mm) galvanized roofing nails with at least ½-in. (12.7-mm) heads and large washers spaced not over 3 in. (76 mm) on centers, or 0.050-in. (1.27-mm) nonferrous staples ½ in. (12.7 mm) in length for 65-lb (30-kg) covering and ¾ in. (19.1 mm) for 90-lb (41-kg) covering.

6-7.4 Roof Anchorage. All parts of the roof and cover shall be securely fastened together and anchored to the tank staves to prevent extreme winds from blowing them loose.

6-7.5 Roof Hatches.

6-7.5.1 A hatch not less than 20 in. × 22 in. (508 mm × 559 mm) shall be built in the conical roof and shall be accessible from the tank ladder. The hatch shall be placed high enough up the conical roof to make entrance to the flat roof reasonably easy when the cover for the flat roof hatch is in place.

6-7.5.2 The four sides of the hatch shall be of not less than 1½-in. (38.1-mm) dressed stock and shall be raised not less than 3 in. (76 mm) above the roof boards. The top of the hatch cover shall be made of not less than 1-in. (25.4-mm) dressed and matched boards or ⅝ in. (9.5-mm) Exterior Grade Plywood, and shall be covered with the same material as specified for the roof. The edges of the hatch cover shall be of not less than 1½-in. (38.1-mm) dressed stock and shall lap down over the raised sides of the hatch. The hatch cover shall be arranged to open freely by sliding upward on two ½-in. (12.7-mm) guide rods securely bolted to the roof, one on each side of the cover. A substantial handle shall be bolted to the lower side of the cover.

6-7.5.3 Other forms of hatch covers shall be acceptable provided approval is first obtained from the authority having jurisdiction.

6-7.5.4 A hatch not less than 20 in. × 22 in. (508 mm × 559 mm) shall be built in the flat cover, if provided, and shall be located directly beneath the hatch in the conical roof. The hatch cover shall be made of 1-in. (25.4-mm) dressed and matched boards or ⅝ in. (9.5-mm) Exterior Grade Plywood, and shall be of sufficient size to prevent its falling through the hatch.

6-7.6 Ladders — General. Inside and outside ladders arranged for convenient passages from one to the other and through the roof hatch shall be provided. Ladders shall not interfere with the opening of the hatch cover. All ladders exceeding 20 ft (6.1 m) shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

6-7.7 Outside Ladders.

6-7.7.1 A steel ladder shall be provided on the outside of the tank extending from the balcony to the roof. The sides of the ladder shall extend 18 in. (457 mm) above the top of the tank and thence downward in an arch to the roof or cover where the ends shall be securely fastened. The ladder shall be placed at least 3 ft (0.91 m) to one side of the tower ladder if a balcony is provided. (See 6-7.9.)

6-7.7.2 The outside ladder shall have not less than 2-in. $\times$ 1/2-in. (51-mm $\times$ 12.7-mm) or 2 1/2-in. $\times$ 3/8-in. (64-mm $\times$ 9.5-mm) flat side bars, spaced at least 16 in. (406 mm) apart, and at least 3/4-in. (19.1-mm) round or square rungs, spaced 12 in. (305 mm) on centers. The rungs shall be firmly welded to the side bars. The ladder shall be securely fastened at least 7 in. (178 mm) between the side of the tank and the centerline of the rungs by brackets. The upper brackets shall be placed not more than 12 in. (305 mm) below the top of the tank staves, and the lower end of the ladder shall be securely fastened to the balcony (see 6-7.9) or, in the absence of a balcony, to the tower ladder. The brackets shall be designed to support a load of 350 lb (159 kg) on the ladder and shall be securely fastened to the tank with through bolts not less than 3/8 in. (9.5 mm) in diameter.

6-7.8 Inside Ladder.

6-7.8.1 A wooden ladder made of the same type 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 about 10 degrees from the vertical.

6-7.8.2 The inside ladder, up to 16 ft (4.9 m) in height, shall have 2-in. $\times$ 4-in. (51-mm $\times$ 102-mm) side pieces. Ladders over 16 ft (4.9 m) shall have 2-in. $\times$ 6-in. (51-mm $\times$ 152-mm) side pieces. All side pieces shall be spaced at least 16 in. (406 mm) apart. Rungs shall be 1 1/4 in. $\times$ 3 in. (32 mm $\times$ 76 mm) spaced 12 in. (305 mm) on centers, securely spiked with noncorrosive nails into slots not less than 3/4 in. (19.1 mm) and shall be not more than 1 in. (25.4 mm) in depth. The ladder shall be securely fastened at the upper and lower ends with noncorrosive nails.

6-7.9 Balcony — General. A wooden or steel balcony shall be placed around the base of the tank where the tank bottom is elevated more than 25 ft (7.6 m) above the main building roof. For tanks of a diameter in excess of 15 ft 6 in. (4.7 m), the width of the balcony shall be 24 in. (607 mm) and, for smaller tanks, not less than 18 in. (457 mm).

6-7.10 Balcony Floor. If the balcony is of wood, the planks shall be at least 2-in. (51-mm) nominal dressed lumber of good, sound quality spaced 1/2 in. (12.7 mm) apart. The planks shall be laid crosswise on stringers or lengthwise on cross beams, spaced not over 4 ft (1.2 m) apart. If the balcony is of steel, it shall be built of at least 1/4-in. (6.4-mm) plate and shall be provided with drain holes.

6-7.11 Balcony Clearance. A clearance of not less than 3 in. (76 mm) nor more than 5 in. (127 mm) at any point shall be

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

6-7.12 Balcony Supports. The balcony supports shall be built of structural steel shapes.

Exception: Reinforced concrete supports shall be permitted to be used when the tank is located on a concrete tower.

6-7.13 Balcony Railing. A railing 42 in. (1067 mm) high shall be placed around the balcony and shall be rigid. The top rail and posts shall be of not less than 1 1/2-in. pipe or of angles not lighter than 2 in. $\times$ 2 in. $\times$ 3/8 in. (51 mm $\times$ 51 mm $\times$ 9.5 mm). An intermediate rail shall be provided. Maximum spacing of rail posts shall not be more than 8 ft (2.4 m). The railing shall be designed to withstand a 200-lb (91-kg) load in any direction at any point on the top rail. A toe board shall be provided if needed.

6-7.14 Balcony Opening. Where a hole is cut in the balcony for the tower ladder it shall be at least 18 in. $\times$ 24 in. (457 mm $\times$ 607 mm).

6-7.15 Painting Inaccessible Parts. Portions of steelwork inaccessible after erection shall be painted before assembling.

6-7.16 Painting. All exterior surfaces shall be cleaned by commercial blasting in accordance with SSPC-SP6 or Pickling in accordance with SSPC-SP8, 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, *Standard for Painting Steel Water Storage Tanks*.

6-7.17 Field Painting-Steelwork. After erection, a patch coat of the same kind of paint as the coat shall be applied to all steel surfaces where the coat has become removed and also to the thoroughly cleaned hoop threads. Two overall field coats of aluminum or alkyd enamel in a color specified by the purchaser shall be used in accordance with the requirements for Outside Paint System No. 1 of AWWA D102, *Standard for Painting Steel Water Storage Tanks* (see 3-7.10.6). Other finish coats shall be permitted for use provided they are compatible with the primer and provided permission is obtained from the authority having jurisdiction.

6-7.18 Painting Application. All painting shall be accomplished in accordance with 3-7.12.

6-7.19 Preservatives — Woodwork. Exposed wood such as balconies, stringers, and supporting beams shall be provided with at least two coats of a good grade preservative sealer.

6-7.20 Lightning Protection. (See Section 1-14.)

Chapter 7 Embankment-Supported Coated Fabric Suction Tanks

7-1 General. This section shall apply to the materials, embankment preparation, and installation of embankment-supported coated fabric suction tanks.

7-2 Standard Capacities. The standard capacities shall be in increments of 100,000 gal to 1,000,000 gal (378.5 m³ to 3785 m³).

Table 7-1 Physical Properties of the Finished Embankment Tank Assembly

		Federal Standard 191 Method	ASTM Method	
Weight		5041	D 751	40.5 ± 2 oz/yd ² (0.06 kg/0.84m ²)
Thickness		5030	D 751	0.042 in. ± 0.003 in. (1.07 mm ± 0.08 mm)
Breaking Strength	Warp	5100	D 751	300 lb (136.2 kg) Avg
	Fill	5100	Grab	300 lb (136.2 kg) Avg
Tear Strength	Warp	5134	D 2261	20 lb (9.1 kg) Avg
	Fill	5134	Tongue	20 lb (9.1 kg) Avg
Adhesion of Coating to Fabric: Jaw Separation Speed 12 in./min.		5970	D 751	15 lb/in. width, min
Puncture Resistance— per Paragraph 4.6.17 of MIL-T-6396C				
Parallel to warp				90 lb min
Parallel to fill				90 lb min
45 degrees to cords				90 lb min
Abrasion Resistance, Wheel—H-22		5306	D 1183 Taber	No fabric showing after 4000 cycles
Weight—100 gms/wheel				Rating of 1—max.
Blocking Resistance		5872		No seam slippage
Seam strength 2 in. wide specimen		8311*		
Low Temperature				No cracking at -20° F (-29°C)
Flexibility Paragraph 4.4.4.2 of MIL-C-8068A (ASG)				

*Federal Test Method Standard 601

For SI units: 1 oz = 28.350 gr; 1 lb = 0.454 kg; 1 in. = 25.4 mm;
°C = $\frac{5}{9}$ (°F - 32).**7-3 Materials.**

7-3.1 Construction. The material shall be a nylon fabric and coated with an elastomer that is compounded to provide abrasion and weather resistance. (See Table 7-1.)

7-3.2 Design. The tank shall be designed in accordance with 7-3.2.1 through 7-3.2.4.

7-3.2.1 The tank shall be designed to provide an assembly that will have seams with a strength equal to or greater than the strength of the basic tank construction.

7-3.2.2 The top surface of the tank shall be coated with a weather-resistant elastomeric paint as recommended by the tank manufacturer.

7-3.2.3 The tank shall be designed to accommodate the field attachment of inlet/outlet fittings during installation.

7-3.2.4 The tank shall be tested for leakage prior to shipment.

7-4 Embankment Preparation and Tank Installation Procedure.

7-4.1 Foundation. The embankment and earth base that support the tank shall be installed in accordance with Figure B-5.

7-4.1.1 The embankment shall be designed for stability and drainage. Where two tanks are installed with a single embankment between tanks, such an embankment shall be designed to resist the load of a full single tank when one tank is drained.

7-4.1.2 A shallow excavation shall be permitted to be made below nominal grade level where local soil and groundwater conditions permit. The removed soil, if suitable, shall be permitted to be used to extend the embankment above grade for the required height (cut and fill method).

7-4.1.3 The internal and external slopes of the embankment shall be 1½ to 1. The slope shall be maintained in original design conditions to ensure the integrity of the embankment. Also, the soil shall provide a stable embankment. All of the above shall be subject to verification by a qualified professional soils engineer.

7-4.1.4 The inside corners of the embankment at intersections of dike walls shall be rounded, using a radius of 1 ft (0.31 m) ± at the bottom and a radius of 2 ft 6 in. (0.76 m) ± at the top of the dike with uniform gradation from bottom to top, as approved by an authorized design or soils engineer.

7-4.1.5 The floor of the embankment shall be graded to locate the inlet/outlet fitting at a minimum of 3 in. (76 mm) below the toe of the embankment inside juncture with the floor. Grading between the fitting location and all points along the juncture of the sloping side walls and the floor shall be uniform in order to provide positive drainage.

7-4.1.6 Earth dike construction tolerances shall be: 6 in. (152 mm) ± for surface variance on the interior slope of the dike walls; plus two percent on specified vertical dimension for the dike height; plus or minus one percent on horizontal dimensions specified for the dike length and width if approved by the soils engineer.

7-4.1.7 A 6-in. (152-mm) thick layer of fine sand or top soil shall be used for the surface layer of the floor and shall be underlaid by a 3-in. (76-mm) thickness of selected pea gravel to provide a firm, smooth bed and good drainage.

7-4.1.8 The finished surfaces of the inside dike walls and floor shall be free from sharp rocks and debris.

7-4.1.9 A 4-in. (102-mm) diameter porous drain pipe shall be provided around the perimeter of the floor to ensure positive drainage of melted snow and rainwater from inside the dike. The outlet of the pipe also shall serve as a "telltale leak detector" for the tank.

7-4.1.10 A cement-lined gutter, shown on Figure B-5, shall be provided through the top and down the outside of the end wall nearest the inlet/outlet fitting to provide positive drainage of melted snow and rainwater from the tank top.

7-4.1.11 The exterior sides and top of the dike walls shall be protected against surface erosion.

7-4.2 Installation. Installation of the tank in the prepared embankment shall be accomplished with the assistance of the tank manufacturer's field technician.

7-4.2.1 The tank shall be shipped to the site packaged in a material designed for ease of handling by a crane and winch and that facilitates efficient placement in the enclosure.

7-4.2.2 The fittings shall be installed on site.

7-4.2.3 At the time of installation, the tank shall be filled and final adjustments on the tank shall be made to ensure that it rests uniformly against the embankment on all four sides. Adjustments in anchoring stakes shall be made at this time. The stakes shall be installed in accordance with Figure B-5. The tank shall be secured all around the top

periphery of the embankment walls utilizing ropes that pass through straps built on the outer surface of the tank and that are tied around the stakes. The tank also shall be tested for leakage after installation. This entire operation shall be carried out under the direction of the tank manufacturer's field technician.

7-5 Tank Sump and Support for Bottom Fittings.

7-5.1 Inlet/Outlet. The concrete pad that contains the common inlet/discharge fitting and drain fitting of the tank shall be located near a corner of the embankment floor with the centerline of the inlet/discharge fitting located a minimum of 7 ft (2.1 m) from the bottom edges of the sloping embankment walls. (See Figure B-5.)

7-5.2 Finish. The surface of the concrete pad shall be smooth and the edges shall be rounded. The soil-to-concrete interface around the pad shall have a slight shoulder of sand to support the tank so that the coated-fabric construction of the tank is not abraded on the edge of the concrete.

7-6 Pipe Connections and Fittings.

7-6.1 General Information. The tank fittings, accessories, and piping connections shall be as shown in Figure B-6. The fittings attached to the tank shall be flanged type. All metal parts shall be corrosion resistant.

7-6.2 Fittings Attached to Tank.

7-6.2.1 The tank shall include either one or two access manhole fittings with cover plates in the top surface. A vent pipe with a pressure-relief cap shall be attached to each manhole fitting.

7-6.2.2 The fittings located in the bottom of the tank shall include a combination inlet/outlet fitting and a drain fitting. Both of these fittings shall be located and secured to the concrete sump in the bottom of the tank.

7-6.2.3 A vortex-plate assembly, as shown in Figure B-6, shall be bolted to the combination inlet/outlet fitting. This assembly, in addition to controlling vortex flow, shall serve as a guard to make it possible to pump the calculated water capacity out of the tank at a high rate of flow.

7-6.2.4 An overflow shall be provided and shall be sized for the filling rate or 2 in. (51 mm) larger than the fill line. (See Figure B-8.)

7-6.3 Water-level Gauge. A water-level gauge shall be provided for the tank that consists of a sight glass that is constructed of clear acrylic tubing of 2³/₈-in. (60-mm) outside diameter. Where subject to freezing, the water gauge assembly shall be installed in the heated pump house.

Chapter 8 Concrete Gravity and Suction Tanks

8-1 General. The design, materials, and construction of concrete tanks shall conform to ACI 318, *Building Code Requirements for Reinforced Concrete*, and ACI 350, *Environmental Engineering Concrete Structures*, with water considered as a live load.

8-2 Prestressed Tanks. Prestressed concrete water tanks shall conform to ANSI/AWWA D110, *Standard for Wire-Wound Circular Prestressed-Concrete Water Tanks*.

8-3 Standard Capacities. This chapter shall provide requirements for reinforced concrete tanks of 10,000 gal to 500,000 gal (37.50 m³ to 1892.50 m³) and prestressed concrete tanks of 10,000 gal to 1,000,000 gal (37.50 m³ to 3785.00 m³) net capacity. Tanks of larger capacities shall be permitted.

8-4 Dead Loads. The dead load shall be the estimated weight of all permanent construction and fittings. The unit weight of concrete shall be considered 144 lbs/ft³ (2307 kg/m³) for the concrete.

8-5 Wall Treatments. Concrete tank walls shall be made impermeable with an impervious membrane or coating applied to the interior surface of the tank to prevent visible leakage or seepage through the tank wall.

Exception: Tank designs that will not result in such leakage.

8-6 Leakage Testing. On completion of the tank and prior to any specified backfill placement at the footing or wall, the following test shall be applied to ensure water tightness:

(a) *Preparation.* The tank shall be filled with water to the maximum level and left to stand for at least 24 hours.

(b) *Measurement.* The drop in liquid level shall be measured over the next 72-hour period to determine the liquid volume loss. Evaporative losses shall be measured or calculated and shall be deducted from the measured loss to determine if there is net leakage.

There shall be no measurable leakage after the tank is placed in service.

Chapter 9 Tank and Tower Foundations in the Ground

9-1 Concrete Specifications. Concrete foundations and footings shall be built of concrete with a specified compressive strength of not less than 3000 psi (20.69 MPa). Design, materials, and construction shall conform to ACI 318, *Building Code Requirements for Reinforced Concrete*, with water considered as a live load.

9-2 Suction Tank Foundations.

9-2.1 Steel suction tanks shall be set on a compacted, crushed stone or granular base or on concrete foundations. At least 3 in. (76.2 mm) of clean, dry sand, laid on the compacted grade, shall be provided at the finished tank grade and shall slope up toward the center of the tank at the rate of 1 in. in 10 ft (25.4 mm in 3 m).

The junction of the tank bottom and the top of the concrete ring wall shall be tightly sealed to prevent water from entering the base.

Exception: For tanks supported on concrete slab foundations, a sand cushion at least 1 in. (25.4 mm) thick or a 1/2 in. (12.7 mm) cane fiber joint filler, complying with ASTM D 1751, *Standard Specification for Performed Expansion Joint Filler for Concrete Paving and Structural Construction*, shall be provided between the flat bottom and the foundation.

9-2.2 A reinforced concrete ring wall extending below the frost line, at least 2.5 ft (0.76 m) below finished grade, and 10 in. (254 mm) thick shall be placed directly beneath the

tank shell for tanks supported on crushed stone or granular bases. This ring shall project at least 6 in. (152 mm) above the surrounding grade and shall be reinforced against temperature and shrinkage and to resist the lateral pressure of the confined fill with its surcharge. The minimum reinforcement shall conform to Chapter 14, Section 14.3 of ACI 318. The tops of ring wall foundations shall be level within $\frac{1}{4}$ in. (6.4 mm) [$\pm \frac{1}{8}$ in. (3.2 mm)] in one plate length [34 ft (10.4 m) more or less], and no two points on the wall shall differ by more than $\frac{1}{2}$ in. (12.7 mm) [$\pm \frac{1}{4}$ in. (6.4 mm)].

Exception: In lieu of a concrete foundation, steel suction tanks of 4000 gal (15.1 m³) or less shall be permitted to be supported on granular berms, with or without steel retainer rings, in accordance with AWWA D103, Standard for Factory Coated Bolted Steel Tanks for Water Storage, or AWWA D100, Standard for Welded Steel Tanks for Water Storage, as applicable.

9-2.3 For soil that will not provide direct support for the tank without excessive settlement, shallow foundation construction shall not be adequate, and a proper foundation shall be designed by a foundation engineer. (See Section 9-6.)

9-3 Foundation Piers for Elevated Tanks.

9-3.1 The tops of foundation piers shall be level and at least 6 in. (152 mm) above grade and shall be located accurately at the correct elevations. The bottom of foundations shall be located below the frost line or at least 4 ft (1.2 m) below grade, whichever is greater.

9-3.2 Pier foundations shall be of any suitable shape and shall be either plain or reinforced concrete. Where supporting a tower, the center of gravity of the pier shall lie in the continued center of the gravity line of the tower column, or shall be designed for the eccentricity. The top surface shall extend at least 3 in. (76 mm) beyond the bearing plates on all sides and shall be chamfered at the edge.

9-4 Anchorage.

9-4.1 The weight of the piers shall be sufficient to resist the maximum net uplift occurring with the tank empty and wind loads on the structure, as specified in previous sections. The wind shall be considered blowing from any direction. The weight of earth vertically above the base of the pier shall be permitted to be included.

9-4.2 Anchor bolts shall be arranged to securely engage a weight at least equal to the net uplift with the tank empty and the wind blowing from any direction. Their lower ends shall be hooked or fitted with an anchor plate.

9-4.3 Anchor bolts shall be accurately located with sufficient free length of thread to fully engage their nuts. Expansion bolts shall not be acceptable. Anchor bolts and nuts exposed to weather, water, or corrosive environments shall be protected by one of the following methods:

- (a) galvanizing,
- (b) corrosion-resistant alloys, and
- (c) field-applied coating after installation.

The minimum size of anchor bolts shall be $1\frac{1}{4}$ in. (32 mm).

Exception: Anchor bolts and nuts less than $1\frac{1}{4}$ in. (32 mm) but not less than $\frac{3}{4}$ in. (19.1 mm) in diameter shall be permitted to be used provided that they are protected in accordance with (a) or (b) above.

9-5 Grouting. Bearing or base plates shall have complete bearing on the foundation or shall be laid on 1-in. (25.4-mm) minimum thickness cement grout to secure a complete bearing. The stressed portion of anchor bolts shall not be exposed except where necessary. If the stressed portions of anchor bolts must be exposed, they shall be protected from corrosion by encasing them in cement mortar.

Exception: If exposed anchor bolts are accessible for complete cleaning and painting, it shall not be necessary to encase them in cement mortar.

9-6 Soil-bearing Pressures.

9-6.1 The design soil-bearing pressure and the corresponding depth of foundation shall be determined by subsurface investigation and by review of foundation experience in the vicinity. Such an investigation shall include test borings made by or under the supervision of an experienced soils engineer or soils testing laboratory and to the depth necessary to determine the adequacy of support [usually 20 ft to 30 ft (6.1 m to 9.1 m) minimum].

9-6.2 Where the presence of limestone or other soluble rock types are suspected, subsurface investigation shall include cavity investigation and competency of bedrock. The potential for subsidence, collapse, soil liquefaction, and settlement shall be evaluated.

9-6.3 The design soil-bearing pressure shall not exceed a pressure that would cause settlements that impair the structural integrity of the tank.

9-6.4 Foundations shall not be constructed over buried pipes or immediately adjacent to existing or former deep excavations unless the foundation bases go below the excavation.

9-6.5 The design soil-bearing pressure shall provide for a factor of safety of three based on the calculated ultimate bearing capacity of the soil for all direct vertical loads, including wind moment load on the columns. The factor of safety shall not be less than two when considering the toe pressure for the direct vertical loads, plus the overturning moment caused by wind shear at the tops of individual piers.

Chapter 10 Steel Towers

10-1 General.

10-1.1* This section shall define the design, fabrication, and erection of steel towers to support water tanks.

10-1.2 Height. The height of the tower shall be the vertical distance from the top of the foundations to the bottom capacity line of the tank.

10-1.3 Strength. The material as specified shall be without defects affecting the strength or service of the structure. The workmanship shall be of a quality that defects or injuries are not produced in the manufacture or erection. Unit stresses as specified shall not be exceeded. The structures and their details shall possess the requisite strength and rigidity.

10-1.4 Details. The details shall conform to the following rules and, where not covered therein, to AWS D1.1, *Structural Welding Code*.

10-2 Material.

10-2.1 Plates, Shapes, and Tubular Columns.

10-2.1.1 Plates. Plate materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to the following ASTM specifications: A 36; A 283, Grade A, Grade B, Grade C, and Grade D, except that where plates of thickness greater than $\frac{3}{4}$ in. (19.1 mm) are used, A 283, Grade D steels shall not be specified; as alternatives A 285, Grade A, Grade B, and Grade C; A 516, Grade 55 and Grade 60; A 442, Grade 55 and Grade 60; or A 131, Grade A, Grade B, and Grade C shall be permitted to be used.

10-2.1.2 Shapes. Structural materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to ASTM A 36 or to A 131, Grade A, Grade B, or Grade C. Copper-bearing steel with content of about 0.20 percent copper shall be used. In other particulars, the steel shall conform to the specifications enumerated above. (See 3-2.1.)

10-2.1.3 Tubular Columns. Steel pipe shall be permitted to be used for tubular columns or other structural members provided it complies with specifications ASTM A 139, Grade B; ASTM A 53, Type E or Type S, Grade B; API Specification 5L, Grade B; and provided the minimum wall thickness of any such material shall comply with the design requirements and the minimum thickness requirement of this standard. For the purposes of this standard, the allowable under-run shall be subtracted from the nominal wall thickness when calculating the minimum pipe wall thickness. Tubular sections shall not be flattened to form end connections.

10-2.2 Bolts, Anchor Bolts, and Rods. Bolts and anchor bolts shall conform to ASTM A 307, Grade A or Grade B. ASTM A 36 shall be considered an acceptable alternate material for anchor bolts. Rods shall be open hearth, electric furnace, or basic oxygen process steel, conforming to ASTM A 36. (See 3-2.2.)

10-2.3 Pins. Pins shall comply with any of the following ASTM specifications: A 307, Grade A or Grade B; A 108, Grade 1018 or Grade 1025; or A 36. Size and diameter tolerances on turned pins shall be equal to that of cold-finished shafting. The surface finish shall depend on the application, but shall not be rougher than 125 micro-in. (3.18 μm).

10-2.4 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 section shall be acceptable when approved by the authority having jurisdiction.

10-3 Loads.

10-3.1 Dead Load. The dead load shall be the estimated weight of all the permanent construction and fittings. The unit weight of steel shall be considered as 490 lb/ft³ (7849 kg/m³) and of concrete as 144 lb/ft³ (2307 kg/m³).

10-3.2 Live Load. Under normal conditions, the live load shall be the weight of all the liquid when overflowing the top of the tank. The unit weight of water shall be considered as 62.4 lb/ft³ (1000 kg/m³). Proper provision must be made for temporary stresses during erection. When roofs have a slope of less than 30 degrees they

shall be designed to support a uniform weight of 25 lb/ft² (122 kg/m²) on the horizontal projection.

10-3.3 Live Load — Large Risers.

10-3.3.1 The water directly above any riser shall not be considered as carried by the tower columns except when the riser is suspended from the tank bottom or from the tower columns.

10-3.3.2 If a hemispherical or ellipsoidal bottom is rigidly attached to the top of a large riser by a flat horizontal diaphragm plate and the riser is supported by a separate solid foundation or is suspended from the tower, the riser plates shall be considered as supporting the waterload in a hollow cylinder having an outside radius equal to the radius of the riser at the tank bottom plus one half the distance from the edge of the riser to the connection of the flat horizontal diaphragm plate to the hemispherical or ellipsoidal bottom plates. The inside radius of this hollow cylinder shall be considered equal to the radius of the riser at the tank bottom. This load shall be deducted from the weight of the tank water when designing the tower unless the riser is suspended from the tower.

10-3.3.3 If the hemispherical or ellipsoidal shape is continuous to the shell of the large riser without a flat horizontal diaphragm plate and the riser is supported by a separate solid foundation or is suspended from the tower, the riser plates shall be designed to carry the water load of a hollow cylinder extending from the bottom of the tank to the top of the tank. The outside radius of this hollow cylinder shall be taken as 2 ft (0.61 m) greater than, and the inside radius equal to, the radius of the riser shell at the tank bottom. This load shall not be deducted from the tank water load when designing the tank and tower.

Exception: The load shall be permitted to be deducted for the tower design of tanks with ellipsoidal bottoms of a flat shape at the connection to risers supported by a separate solid foundation.

10-3.3.4 If the bottom is a torus shape, the riser plate shall be designed to carry the weight of all water in the tank between a cylinder that intersects the bottom at its lowest elevation and a cylinder that is the diameter of the riser. This load shall be deducted from the weight of the tank water when designing the tower.

10-3.4 Wind Load. The wind pressure shall be assumed to be 30 lb/ft² (147 kg/m²) on a vertical plane surface. In calculating the wind load on a cylindrical surface, 18 lb/ft² (88 kg/m²) shall be applied to the total area of the vertical projection, and the point of application of the load shall be at the center of gravity of the projected area. The load on the tower shall be assumed to be concentrated at the panel points. When designing for wind velocities over 100 mph (161 km/hr) all of the above mentioned unit pressures shall be adjusted in proportion to the square of the velocity assuming that the above pressures are for 100 mph (161 km/hr).

10-3.5 Balcony and Ladder Loads. A vertical load of 1000 lb (454 kg) shall be assumed to be applied to any 10 ft² (0.93 m²) of area on the balcony floor and on each platform; 500 lb (227 kg) applied to any 10 ft² (0.93 m²) area on the tank roof; and 350 lb (159 kg) on each vertical section of ladder. All of the structural parts and connections shall be designed to withstand such loads. The above loadings shall not need to be combined with snow loading.

10-3.6 Earthquake Load. Tank towers shall meet the requirements for resisting earthquake damage by complying with the earthquake design load provisions of AWWA D100 (AWS D5.2), *Standard for Welded Steel Tanks for Water Storage*, and 10-4.7.2 of this standard.

10-4 Unit Stresses.

10-4.1 General. The maximum stresses in lb/in.² (kg/mm²) produced by the above loads shall not exceed the values specified in Tables 10-4.1, 10-4.3, 10-4.4, and 10-4.5.

Table 10-4.1 Allowable Unit Stress

Axial Tension: On net section, rods, and ASTM A 36 structural steel shapes 15,000 psi (1034 bar)	
Axial Compression: Gross section of columns and struts of structural shapes:	
$\frac{P}{A} = \left\{ 1 + \frac{\frac{18,000}{L^2}}{18,000r^2} \right\}$	or 15,000 psi (1034 bar), whichever is the smaller.
For tubular columns and struts: $\frac{P}{A} = XY$, in which $X = 1 + \frac{18,000}{L^2}$	
or 15,000 psi (1034 bar), whichever is the smaller, and	

$$(1) Y = \frac{2}{3} \left(100 \frac{t}{R} \right) \left[2 - \frac{2}{3} \left(100 \frac{t}{R} \right) \right]$$

(2) Y = Unity (1.00) for values of $\frac{t}{R}$ equal to or greater than 0.015.

In the foregoing formulae, the symbols have the following meaning:

P = total axial load in lb (kg).
A = cross-sectional area in in.² (mm²).
L = effective length in in. (mm).
r = least radius of gyration in in. (mm).
R = radius of the tubular member to the exterior surface in in. (mm).
t = thickness of the tubular member in inches; minimum allowable thickness — 1/4 in. (mm).

All circumferential joints in tubular sections shall be butt joints welded for complete penetration.

Compression on short lengths — 18,000 psi (124.11 MPa). (See 10-5.4.)

For SI units: 1 lb = 0.45 kg; 1 in. = 25.4 mm; 1 in.² = 645.16 mm²; 1000 psi = 6.895 MPa

10-4.2 Slenderness Ratio. The maximum permissible slenderness ratio L/r for compression members carrying the weight or pressure of the tank contents shall be 120.

The maximum permissible slenderness ratio L/r for compression members carrying the loads from wind and earthquake only shall be 175.

The maximum permissible slenderness ratio L/r for columns carrying roof loads only shall be 175.

10-4.3 Bending. (See Table 10-4.3.)

10-4.4 Shearing. (See Table 10-4.4.)

10-4.5 Bearing. (See Table 10-4.5.)

10-4.6 Combined Stresses. Members subject to both axial and bending stresses shall be so proportioned that the sum of the stresses at the critical point does not exceed the allowed axial stress.

10-4.7 Wind and Earthquake Allowances.

Table 10-4.3 Maximum Bending Stress

	psi	MPa
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 of:		
$\frac{ld}{bt}$ 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	155.14
Cast steel.....	11,250	77.57

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

Table 10-4.4 Maximum Shear Stress

	Psi	MPa
Pins and turned bolts in reamed or drilled holes	11,250	77.57
Unfinished bolts	7500	51.71
Webs of beams and plate girders, gross section	9750	67.23
Cast steel	7325	50.51
Tank plates and structural connection materials	11,250	77.57

Table 10-4.5 Maximum Bearing Stresses

	Double Shear		Single Shear	
	psi	MPa	psi	MPa
Turned bolts in reamed or drilled holes	30,000	206.85	24,000	165.48
Unfinished bolts	18,750	129.28	15,000	103.43
Pins		24,000		165.48
Contact area of milled surfaces		22,500		155.14
Contact area of fitted stiffeners		20,250		139.62
Expansion rollers and rockers (lb/linear in.) where d is the diameter of roller or rocker in in.			600d	0.163(d)

10-4.7.1 Wind. For stresses due to a combination of dead load, live load, and wind load as specified in this standard and for wind load alone, the above working stresses shall be permitted to be increased a maximum of 33 1/3 percent. In no case shall the resulting sections be less than that required for dead and live loads alone.

10-4.7.2 Earthquake. For stresses due to a combination of dead load, live load, and earthquake load as specified in this standard and for earthquake load alone, the above working stresses shall be permitted to be increased up to $33\frac{1}{3}$ percent. In no case shall the resulting section be less than that required for dead and live loads alone.

10-4.7.3 Wind and earthquake shall not need to be considered as acting simultaneously.

10-4.8 Fillet and Groove Welds. Welded joints shall be proportioned so that the loads specified in Section 10-3 shall not cause stresses therein in excess of design stresses obtained by applying the efficiencies in AWWA D100 (AWS D5.2), *Standard for Welded Steel Tanks for Water Storage*, to the allowable working stresses in the base material.

10-5 Details of Design.

10-5.1 Sections. Sections preferably shall be symmetrical. Members preferably shall be built of standard structural shapes or of tubular sections. Structural shapes shall be designed with open sections to permit painting all surfaces exposed to air or moisture and subject to corrosion. Tubular sections of columns and struts shall be airtight.

10-5.2 Minimum Thickness — General. The minimum thickness of metal shall be $\frac{1}{4}$ in. (6.4 mm) except in the webs of channels and I-beams and in minor parts that carry no load. The minimum size of sway rods shall be $\frac{3}{4}$ in. (19.1 mm).

10-5.3 Columns.

10-5.3.1 Splices. Column splices shall be designed to withstand the maximum possible uplift or at least 25 percent of the maximum compression, whichever is greater. The abutting joints of welded tubular columns shall be either butt welded with a backer strip or spliced by plates welded to both sections being joined. Where a horizontal plate $\frac{1}{4}$ in. (6.4 mm) minimum thickness is used to seal the top and bottom of a column section, the backing strip or splice plate shall be omitted.

10-5.3.2 Strength Diaphragm in Tubular Columns. A substantial diaphragm or equivalent resistance to local tube distortion shall be provided at all panel points, points of concentrated loading, and at the top diagonal wind rod connections. Where a horizontal plate [minimum thickness $\frac{1}{4}$ in. (6.4 mm)] is used to seal the top and/or bottom of a column section and is located within 18 in. (457 mm) of the panel point, a diaphragm plate shall not be necessary.

10-5.4 Combined Shapes. The shapes shall be separated at least $\frac{3}{8}$ in. (9.5 mm) if they are not in contact. For tension members with component parts that are separated by spacers, the spacers shall not be over 3 ft 6 in. (1.07 m) apart and shall be attached by welding or bolting.

10-5.5 Starred Angles. Compression members built of two angles in a star section shall have pairs of tie plates or angles spaced not over 20 in. (0.51 m) on center for the 3-in. (76-mm) angles; 24 in. (0.61 m) for the 4-in. (102-mm) angles; 36 in. (0.91 m) for the 5-in. (127-mm) angles; 42 in. (1.07 m) for the 6-in. (152-mm) angles; and 48 in. (1.22 m) for the 8-in. (203-mm) angles. The tie plates or angles shall be connected to each of the angles of the compression members by not less than two bolts, and at

least three bolts shall be used in 6-in. (152-mm) or 8-in. (203-mm) angles. Equivalent welded tie plates shall be permitted to be used.

10-5.6 Connections—General. The strength of connections shall be sufficient to transmit the full stress in the member. A group of bolts at the end of any member that transmits stress into that member, shall have its center of gravity in the line of the center of gravity of the member, or provisions shall be made for the effect of the resulting eccentricity. Connections between the columns, struts, and tension members shall be made by gusset plates that can also serve as splice plates. Diagonal bracing shall, where possible, be connected to the same gusset plates that connect the columns and struts. Bolts shall not be subjected to tensile stress.

10-5.7 Pins. Adjustable tension members shall be connected to gusset plates by finished or cold-rolled steel pins. Pins shall be headed on one end and threaded on the other; threaded on both ends; or plain on each end with washers welded onto them. Threaded ends shall be fitted with nuts, and the threads shall be burred outside the nuts to prevent easy removal of the nuts.

10-5.8 Net Area of Pin-plate. The net area of the gusset-plate section ahead of a clevis pin shall not be less than 62.5 percent of the net area of the tension member.

10-5.9 Clevises, Forked Ends, Turnbuckles.

10-5.9.1 Bar or plate clevises, forged clevis nuts, or forked ends shall be used to connect adjustable tension members to the clevis pins. The strength of clevises shall not be less than that of the tension member. The minimum sectional area through forked ends shall not be less than the area of the tension member at its smallest section.

10-5.9.2 Clevis plates shall be fusion-welded to wind rods. There shall be two plates at each end of the rod. The plates shall be symmetrical. There shall not be any open spaces between the rod and the clevis plates. The plates shall be bent in easy lines to reduce to a minimum the stretch under the load, or they shall be flat with filler plates on the pin. In any case, the clevis pin shall be designed to carry the maximum stresses, including bending, without over-stressing.

10-5.9.3 Turnbuckles shall be of the open type and shall have a strength not less than that of the tension member.

10-5.10 Tank Connection. The center of gravity lines of the column circular girder, and the lowest plate of the tank cylinder shall meet at a point, or the columns shall be designed for the eccentricity. The combined axial and bending stress in the detail connecting the top of the column to the tank plate shall not be more than $33\frac{1}{3}$ percent in excess of the allowable axial working-stress, which, in the case of compression, is that allowed for short lengths.

10-5.11 Tie Plates. The main constituent parts of columns shall be solidly tied together at the points of connection of tension or compression members.

10-5.12 Length of Tension Members. The horizontal projection of the unsupported length in in. (mm) of a non-adjustable tension member in a horizontal or inclined position shall not exceed 200 times the radius of gyration about the horizontal axis.

10-5.13 Column Bases and Caps.

10-5.13.1 Columns shall have bases built of steel plates and structural shapes. The lower end of each column shall be faced and must bear fully on the base plate, or shall have sufficient welding to transmit loads to the base plate. The base plate and anchor bolt connections to the column shall be designed to load the foundation uniformly and also to transmit the net uplift from the column when subjected to the greatest possible wind stress to the foundations with the tank empty. Footings shall either be designed without pockets or be filled with concrete and flashed with asphalt to prevent the collection of dirt and moisture inside.

10-5.13.2 Where the tower supports a flat-bottom tank, the columns shall have steel caps designed to transmit the load from the grillage beams concentrically to the columns. The upper ends of the columns shall be faced and bear fully on the cap plates, or shall have sufficient welding to transmit all loads to the top plate. If the batter of columns exceeds 1.8 in. (46 mm) horizontal to 12 in. (305 mm) vertical, rigid ties shall be provided between the column bases.

10-5.14 Circular Girder with Inclined Columns. Tops of inclined columns shall be connected by a continuous, horizontal circular girder if the tank bottom is suspended. The outer flange preferably shall be symmetrical about the web plate, but if eccentric, the allowable working stresses for the flanges shall be reduced 25 percent. The bending moment shall be considered as carried entirely by the flanges; the shear, by the web; and the compression, by the flanges and web in proportion to their areas at the section considered. Splices shall be designed to transmit the load in the spliced member. The horizontal component of the maximum column load shall be transmitted to the girder by welding. The circular girder shall be permitted to be used as a balcony. Drain holes shall be provided in the web plate.

10-5.15 Circular Girder with Vertical Columns. If the columns are vertical and the tank bottom is suspended, the circular girder shall be as stated in 10-5.14 or shall be a structural shape connected to the tank by welding.

10-5.16 Interior Bracing. Bracing inside the tank shall be avoided if possible but, if used, $\frac{1}{16}$ -in. (1.6-mm) additional thickness shall be added to the calculated sections to provide for corrosion. The sections shall be open to facilitate cleaning and painting.

10-5.17 Top Struts. The thrust from battered columns supporting a flat bottom tank shall be resisted by struts connected to the extreme top of the columns or to the cap plates on all sides of the tower.

10-5.18 Grillage. Where the tower supports a flat-bottom tank, all of the supporting beams shall be steel and shall be welded or bolted to the post cap girders. The latter shall be either welded or bolted to the column caps and shall be braced to prevent overturning. The load on the outside grillage beams shall be considered as increasing from zero at the ends to a maximum at the center.

10-5.19 Base Braces. Where the tower is supported by a building, insecure earth, or foundations extending more than approximately 1 ft (0.3 m) above grade, rigid members shall be placed between the adjacent column bases or foundations. Rigid members shall be provided between adjacent column bases when the columns are welded to the base plates and the batter exceeds 1.8 horizontal to 12 vertical.

10-5.20 Web Stiffeners. Web stiffeners shall be provided at points of concentrated loading on beams and girders when necessary to prevent buckling of webs. Web stiffeners shall be designed in accordance with the specifications of the American Institute of Steel Construction.

10-5.21 Large Risers; Water Spheres.

10-5.21.1 Large steel-plate pipes 3 ft (0.91 m) or more in diameter shall be designed to withstand stress caused by the weight or pressure of the tank and riser contents and by the load imposed on the top of the riser pipe by the tank bottom or by members supporting the tank bottom as specified in 10-3.3.2. If the design of the riser plates is controlled by hoop tension, 0.3 of the compressive stress in the vertical direction shall be added to the full calculated tensile stress in the horizontal direction in determining the thickness. If the design of the riser plates is controlled by vertical compression, 0.3 of the tensile stress in the horizontal direction shall be added to the full calculated compressive stress in the vertical direction in applying the formula in Table 10-4.1.

10-5.21.2 The thickness of the bottom ring of the steel plate shall be sufficient so that the specified unit stresses shall not be exceeded when combined with bending or other stress around the manhole or other openings.

10-5.21.3 For the design of water spheres and conical frustums at the base of the sphere, the symbol R representing the radius in Table 10-4.1 shall be taken as either the radius of the sphere or the radius of the cone perpendicular to the conical surface.

10-5.21.4 The surface of the conical frustum supporting the sphere shall not be inclined to the horizontal at an angle less than 30 degrees. If compression reinforcing is required at the junction of the conical frustum and the tubular support, the effective width in in. (mm) of each plate at the joint that can be considered as contributing to this required reinforcing shall be limited to the square root of the product of each plate thickness in in. (mm) and its respective inside radius in in. (mm).

10-5.22 Anchor Bolts. In earthquake locations there shall be at least two anchor bolts per column.

10-6 Workmanship.

10-6.1 Shearing. All shearing shall be done neatly. Material over $\frac{3}{4}$ in. (19.1 mm) thick shall have $\frac{1}{8}$ in. (3.2 mm) planed from the sheared edges.

Exception: Base plates or other plates not carrying actual stress.

10-6.2 Straightening and Fitting. The several pieces forming built sections shall be straight and shall fit closely together.

10-6.3 Use of Bolts and Welding. Members shall be welded throughout. Field connections of nonadjustable tension members carrying wind stress only and compression members and grillages in towers supporting tanks of 30,000 gal (113.55 m³) or less capacity shall use unfinished bolts. The threads of unfinished bolts shall be burred outside of the nuts. High-tensile bolts or the equivalent shall be used in field connections of towers supporting tanks of 100,000 gal (378.50 m³) or less capacity. Where machined bolts are needed, the bolt holes shall be reamed parallel

and the bolts shall be machined to a driving fit with the threads burred outside the nuts, unless special listed locking devices are provided.

10-6.4 Threads and Nuts. Screw threads on rods shall be cut or rolled to the U.S. Standard, or shall have self-locking threads and make tight fits in nuts and turnbuckles. All threads and nuts in turnbuckles shall be engaged. Machined bolts shall have threads entirely outside the holes, and washers not less than $\frac{1}{8}$ in. (3.2 mm) thick shall be used under the nuts. Nuts on all bolts shall be drawn tight and threads burred outside the nuts.

10-6.5 Grouting of Base Plates. During field erection the columns shall be built on thin metal wedges that, after the structure is completed, shall be driven to equal resistance so that all columns will be loaded equally. The spaces beneath the base plates and the anchor bolt holes shall be completely filled with portland cement mortar that consists of a minimum of one part portland cement to three parts clean sand.

10-6.6 Assembly.

10-6.6.1 Component parts of built-up members shall be held in firm contact by adequate clamps or other means. Spaces where inaccessible corrosion can form shall not be left between component parts of members.

10-6.6.2 Erection bolts or other positive devices imparting sufficient strength and stiffness to resist all temporary weights and lateral loads, including wind, shall be used for temporarily fastening the members together and bracing the framework.

10-6.7 Alignment. Members and all component parts shall be straight and free from appreciable buckles or warping.

10-6.8 Tubular Column Distortion. The column axis shall not deviate from a straight line more than $\frac{1}{1000}$ of the laterally unsupported length. The difference between the maximum and minimum outside diameters shall not exceed 2 percent of the nominal outside diameter at any cross-section. Local dents shall be no deeper than the plate thickness.

10-7 Accessories.

10-7.1 Connections. Connections shall be provided on the tower for the necessary pipe and frostproof casing braces.

10-7.2 Ladders — General. A steel ladder shall be placed on one of the tower columns extending from a point within easy reach of the ground to the balcony around the tank or to the revolving tank ladder. The ladder shall not incline outward from the vertical at any point. Where the tower supports a wood tank or where the balcony is not used as a circular girder, the ladder shall pass through an opening in the balcony not less than 18 in. $\times$ 24 in. (457 mm $\times$ 609 mm) in the clear. The ladder shall be securely fastened at its upper end. Welding of ladders and their connections shall be permitted. Ladders for pedestal-supported tanks preferably shall be placed inside the pedestal.

10-7.3 Ladders — Details.

10-7.3.1 The ladder shall have not less than 2-in. $\times$ $\frac{1}{2}$ -in. (51-mm $\times$ 12.7-mm) or 2 $\frac{1}{2}$ -in. $\times$ $\frac{3}{8}$ -in. (64-mm $\times$ 9.5-mm)

flat side bars spaced at least 16 in. (406 mm) apart and at least $\frac{3}{4}$ -in. (19.1-mm) round or square rungs, spaced 12 in. (305 mm) on centers. The rungs shall be firmly welded to the side bars. The sections of the ladder shall be connected by lap or butt joints. If joints are bolted, at least two $\frac{1}{2}$ -in. (12.7-mm) bolts shall be used on each side of each splice.

10-7.3.2 The ladder shall be connected to the tower column or the pedestal support at least 7 in. (178 mm) between the column and centerline of the rungs by flat bar brackets spaced not over 12 ft (3.7 m) apart. The brackets shall be rigidly connected to the column and designed to support a load of 350 lb (159 kg) on the ladder. All ladders shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

10-7.3.3 Other arrangements of tower ladders shall be permitted provided approval is first obtained from the authority having jurisdiction. Such arrangements are not recommended, however, unless made necessary by a special design of tower, and with distances greater than 12 ft (3.7 m) between supports, the side bars of the ladder shall be made of angles not lighter than 3 in. $\times$ 3 in. $\times$ $\frac{3}{8}$ in. (76 mm $\times$ 76 mm $\times$ 9.5 mm) or their equivalent.

10-7.4 Walkway.

10-7.4.1 A walkway at least 18 in. (457 mm) wide that extends from a point accessible from the tower ladder to an expansion joint located under the tank and terminates in a platform giving at least 20 in. (508 mm) clearance around the enlarged portion of the frostproofing casing, shall be provided when the tower is 30 ft (9.1 m) or more in height. Walkway flooring shall be 2-in. (51-mm) dressed plank spaced $\frac{1}{2}$ in. (12.7 mm) apart, or $\frac{1}{4}$ -in. (6.4-mm) steel plate with drain holes. The walkway and platform shall be rigidly supported and braced laterally to prevent swinging.

10-7.4.2 All supports shall be of steel, and connections shall be welded. A railing 42 in. (1067 mm) high shall be placed on each side of the walkway and around the outer edge of the platform and shall be rigid. The top rail and posts shall be of not less than 1 $\frac{1}{2}$ -in. pipe or of angles not lighter than 2 in. $\times$ 2 in. $\times$ $\frac{3}{8}$ in. (51 mm $\times$ 51 mm $\times$ 9.5 mm). An intermediate rail shall be provided. Ends of threads shall be burred on all bolted connections. Maximum spacing of rail posts shall not be more than 8 ft (2.4 m). The railing shall be designed to withstand a 200 lb (91 kg) load in any direction at any point on the top rail. A toe board shall be provided if needed.

10-7.5 Balcony.

10-7.5.1 Towers over 20 ft (6.1 m) high and that have a horizontal circular girder at the top of the inclined columns to resist the inward thrust from the columns shall be provided with a balcony at least 24 in. (610 mm) wide around the base of the cylindrical portion of the tank. A rigid railing at least 42 in. (1067 mm) high shall be provided around the outside of the balcony. The top rail and posts shall be not lighter than 1 $\frac{1}{2}$ -in. pipe or 2 in. $\times$ 2 in. $\times$ $\frac{3}{8}$ in. (51 mm $\times$ 51 mm $\times$ 9.5 mm) angles. An intermediate rail shall be provided. Maximum spacing of rail posts shall not be more than 8 ft (2.4 m). The railing shall be designed to withstand a 200 lb (91 kg) load in any direction at any point on the top rail. A toe board shall be provided if needed.

10-7.5.2 A balcony shall not be required for pedestal- or tripod-supported tanks. For inclined column tower-supported tanks without a cylindrical shell, a balcony shall not be omitted without the approval of the authority having jurisdiction.

10-7.6 Painting Inaccessible Parts. Inaccessible parts subject to corrosion shall be protected by paint before assembly.

NOTE: The interior of hermetically sealed surfaces, including such tubular columns, shall not need to be painted.

10-7.7 Painting. All steel, except where encased in concrete or where edges are to be welded, shall be cleaned, primed, and coated in accordance with 3-7.10.2. Appropriate primers for other exterior paint systems shall be permitted to be used.

10-7.8 Field Painting. After construction, all weld seams, unprimed margins, field bolts, and any areas where the paint has been damaged shall be blast-cleaned and patch-primed with the same primer. Two overall finish coats of aluminum or alkyd enamel in a color as specified by the purchaser shall be used in accordance with the requirements for Outside Paint System No. 1 of AWWA D102, *Standard for Painting Steel Water Storage Tanks*. The total system dry film thickness shall be 3.5 mils (87 μm) for aluminum finishes and 4.5 mils (112 μm) for alkyd enamels. As provided for by Outside Paint System No. 4 of AWWA D102, the purchaser shall be permitted to specify an extra complete coat of primer for a total minimum system dry film thickness of 6.0 mils (150 μm) for alkyd enamels for the more severe atmospheric exposures. Other finish coats shall be permitted to be used provided they are compatible with the primer and provided permission is first obtained from the authority having jurisdiction. In any event, the finish coats shall be the same type selected for exterior tank surfaces (see 3-7.11).

10-7.9 Painting Application. All painting shall be accomplished in accordance with 3-7.12.

Chapter 11 Pipe Connections and Fittings

(For embankment-supported coated fabric suction tanks, see Section 7-6.)

11-1 General Information.

11-1.1 Watertight Intersections at Roofs and Floors.

11-1.1.1 The intersections of all tank pipes with roofs and concrete or waterproof floors of buildings shall be watertight. Where tank pipes pass through concrete roofs, a watertight intersection shall be obtained by fittings caulked with oakum or by pouring the concrete solidly around the pipes, which shall have first been wrapped with two or three thicknesses of building paper. If concrete is used, the upper side of the intersection shall be well flashed with a suitable firm, waterproof material that will be noncracking and will retain its adhesion and flexibility. Wood roofs also shall be built tightly around the pipes and shall be made watertight by fittings caulked with oakum or by adequate flashing.

11-1.1.2 Where tank pipes pass through a concrete or waterproof floor, a watertight intersection, as described above, shall be obtained so that water from above cannot follow down the pipe to lower floors or the basement.

11-1.2 Rigid connections to steel tanks shall be made by means of a welded joint with approval by the authority having jurisdiction. A rigid connection to a wood tank shall be made by means of a running nipple or by threaded flanges, one inside and one outside the tank, bolted together through the wood with movable nuts outside.

11-1.3 Placing Tank in Service. All tank piping shall be done immediately after completion of the tank and tower so that the tank can be filled and placed in service promptly. Wood tanks can be greatly damaged by shrinkage if left empty after being erected.

11-1.4 The Contract. To ensure installation of adequate equipment, the contract shall specify that the finished work shall conform with this standard in all respects.

11-1.5 Approval of Layouts. Complete information regarding the tank piping on the tank side of the connection to the yard or sprinkler system shall be submitted to the authority having jurisdiction for approval. The information submitted shall include the size and arrangement of all pipes; the size, location, and type of all valves, tank-heater, and other accessories; the steam pressures available at the heater; the arrangement of and full information regarding the steam supply and return system together with pipe sizes; and the details of construction of the frost-proof casing.

11-1.6 Inspection of Completed Equipments.

11-1.6.1* Immediately after the work is finished, a joint inspection of the tank piping shall be conducted by a representative of the contractor and a representative of the owner.

11-1.6.2 Written reports of these inspections shall be made in triplicate, and a copy that has been signed by the contractor and the owner shall be sent to the authority having jurisdiction.

11-1.7 Precautions During Repairs. The authority having jurisdiction shall be notified well in advance when the tank will be drained. The following precautions shall be observed:

(a) Work shall be planned carefully to enable completion in the shortest possible time.

(b) If available, a second reasonably reliable water supply with constant suitable pressure and volume, usually public water, shall be connected to the system.

(c) If such a supply is not available, the fire pump shall be started and kept running to maintain suitable pressure in the system.

(d) Additional portable fire extinguishers shall be placed in buildings where protection is impaired, and extra, well-instructed watch personnel shall be continuously on duty.

(e) The members of the private fire brigade, as well as the public fire department, shall be familiar with conditions.

11-1.8* Heater Thermometer.

11-1.8.1 For a gravity circulating heating system (Figures B-9, B-10, B-11, B-12, B-13, B-17, B-18, and B-21), an accurate thermometer shall be located as specified in 13-1.7.2.

11-1.8.2 For a tank containing a radiator steam heater, an accurate socket thermometer shall be located as specified in 13-3.6.

11-1.9* Connections for Use Other than Fire Protection. The authority having jurisdiction shall be consulted before the tank is designed if water for other than fire protection purposes is to be drawn from the tank.

11-1.10 Filling. The tank shall be kept well filled and the water level shall never be lower than 3 in. or 4 in. (76 mm or 102 mm) below the designated fire service level. The filling bypass shall be kept closed when not in use.

11-1.11* Water-Level Gauge. A water-level gauge of suitable design shall be provided. It shall be carefully installed, adjusted, and properly maintained.

11-1.11.1 If an altitude gauge is used, it shall be at least 6 in. (152 mm) in diameter and shall be of noncorrodible construction.

11-1.11.2 The gauge shall be located to prevent it from freezing. If necessary it shall be in a heated building or enclosure. A blow-off cock shall be between the gauge and the connection to the tank.

11-1.11.3 A listed, closed-circuit, high- and low-water level electric alarm shall be permitted to be used in place of the gauge if acceptable to the authority having jurisdiction. Provisions shall be made for the attachment of a calibrated test gauge.

11-1.12* Frostproof Casing. The frostproof casing shall be kept in good repair and shall be weathertight throughout.

11-1.13 Tanks with Large Risers.

11-1.13.1* Large steel plate riser pipes 3 ft (0.91 m) or more in diameter without frostproof casing shall be acceptable if properly heated. (See Chapter 13.)

11-1.13.2 The check valve and gates in the discharge pipe, filling arrangement, overflow, and drain are generally provided. Sometimes a blow-off valve is furnished near the base of the larger riser. A manhole at least 12 in. $\times$ 16 in. (305 mm $\times$ 406 mm) shall be provided with its lower edge level with the discharge piping protection specified.

11-1.14 Discharge Piping Protection. For tanks with a large steel plate riser [3 ft (0.91 m) diameter or larger], the inlet to the vertical discharge pipe located within the large riser shall be protected against entry of foreign material. This can be done with an American National Standards Institute 125-lb/in.² (8.6-bar) flanged tee with the "run" of the reducing tee placed horizontally and with horizontal outlets one pipe size smaller than the discharge pipe, or with a fabricated plate extending at least 4 in. (102 mm) beyond the outside diameter of the pipe. The plate shall be supported by at least three supporting bars 1½ in. $\times$ ¼ in. (38.1 mm $\times$ 6.4 mm), ⅝-in. (15.9-mm) round rods, or equivalent, that elevate all portions of the plate a distance at least equal to the pipe diameter above the discharge pipe inlet. Attachments of the supports to the discharge pipe shall be made directly by welding or bolting or by a ¼-in. (6.4-mm) thick tightly fitting sectional clamp or collar having ⅝-in. (15.9-mm) bolts in the outstanding legs of the clamps or collar. A clearance of at least 6 in. (152 mm) shall be provided between all portions of the flanges of a tee or fabricated plate and the large riser plate.

11-1.15 Steel Pipe.

11-1.15.1 Steel pipe shall conform to ASTM A 53, Type E, Type F, Type S, Grade A or Grade B manufactured by the open-hearth, electric furnace, or basic oxygen process, or to ASTM A 106, Grade A or Grade B.

11-1.15.2 For steel pipe in contact with storage water, the following shall apply:

- (a) Steel pipe smaller than 2 in. shall not be used.
- (b) Steel pipe 2 in. to 5 in. shall be extra-strong weight.
- (c) All steel pipe 6 in. and larger shall be standard weight.

11-2 Discharge Pipe.

11-2.1 At Roofs and Floors. The intersection of the discharge pipe, as well as all other tank pipes, with the roof or waterproof or concrete floors shall be watertight. (See 11-1.1.)

11-2.2 Size.

11-2.2.1 Conditions at each individual plant shall influence the size of the discharge pipe needed. The size, however, shall not be less than 6 in. for tanks up to and including 25,000-gal (94.63-m³) capacity, and generally not less than 8 in. for 30,000 gal to 100,000 gal (113.55 m³ to 378.50 m³) inclusive, or 10 in. for greater capacities.

11-2.2.2 Smaller pipe than specified above (not less than 6 in.) shall be permitted in some cases if conditions are favorable and large flows of water are not needed. On the other hand, larger pipe might be required because of the location and arrangement of piping, height of buildings, or other conditions. In all cases, approval of the pipe sizes shall be obtained from the authority having jurisdiction.

11-2.3 Pipe Material. The discharge pipe shall be of flanged cast iron or steel pipe, welded steel, or of listed corrosion-resistant materials with flanged or welded connections.

Exception: For steel-plate risers, standpipes, or suction tanks, the short length of vertical pipe from the base elbow through the bottom plate shall be permitted to be of cast iron with a spigot at the lower end.

11-2.4 Braces. Either the pipe, the large steel-plate riser pipe, or both shall be braced laterally by rods not less than ⅝ in. (15.9 mm) in diameter and shall be connected to the tower columns near each panel point. End connection of braces shall be by eyes or shackles; open hooks shall not be permitted.

11-2.5 Support. The discharge pipe shall be supported at its base by a double-flanged base elbow resting on a concrete or masonry foundation, except that for tanks with steel-plate risers or for suction tanks or standpipes, the base elbow shall have bell ends. The joint at the connection of yard piping to the base elbow shall be strapped or the base elbow shall be adequately backed up by concrete. If the discharge pipe is offset inside of a building, it shall be supported at the offset by suitable hangers from the roof or floors, in which case the base elbow might not be required. Large steel riser pipes shall be supported on a reinforced concrete pier designed to support the load specified in Section 10-3. Concrete grout shall be provided beneath the large riser to give uniform bearing when empty.

11-2.6 Offsets. The discharge pipe outside of buildings shall extend vertically to the base elbow or building roof without offsets if possible. If an offset is unavoidable, it shall be supported at the offsetting elbows and at intermediate points not over 12 ft (3.7 m) apart and also shall be rigidly braced laterally. The supports shall consist of steel beams across the tower struts or of steel rods from the tower columns so arranged that there will be no slipping or loosening.

11-2.7 Expansion Joint. Tanks with flanged or welded pipe risers (12 in. in size and under) shall have a listed expansion joint on the fire-service discharge pipe where the tank is on a tower that elevates the bottom 30 ft (9.1 m) or more above the base elbow or any offset in the discharge pipe. Expansion joints shall be built to conform to Section 11-3.

11-2.8 Rigid Connection.

11-2.8.1 When the distance between the tank bottom and the base elbow or supporting hanger is less than 30 ft (9.1 m), the discharge pipe shall be connected by an expansion joint built to conform to Section 11-3 or shall be rigidly connected in accordance with 11-1.2. The top of the pipe (or fitting attached to the top) shall extend above the inside of the tank bottom or base of a steel-plate riser to form a settling basin.

11-2.8.2 The top of a steel plate riser shall be connected rigidly to the suspended bottom of the tank. The discharge pipe from a steel plate riser of a tank over a building shall be connected rigidly to the base of the larger riser. A rigid flanged connection or welded joint shall be used between the discharge pipe and the bottom of a suction tank, stand-pipe, or the base of a steel plate riser of a tank on an independent tower, but special approval shall be obtained from the authority having jurisdiction. When the base of a steel plate riser is in its final position on a concrete support, it shall be grouted to obtain complete bearing.

11-2.9 Swing Joints. If the vertical length of a discharge pipe below an offset, either inside or outside of a building, is 30 ft (9.1 m) or more, a four-elbow swing joint, of which the offset forms a part, shall be provided in the pipe.

11-2.10 Settling Basin. The depth of the settling basin in the tank bottom shall be 4 in. (102 mm) for a flat-bottom tank and 18 in. (457 mm) for a suspended-bottom tank. The settling basin at the base of a large steel plate riser shall be at least 3 ft (0.91 m) deep.

11-2.11 Check Valve. A listed check valve shall be placed horizontally in the discharge pipe and shall be located in a pit under the tank when the tank is on an independent tower. (See Figure B-9.) Where the tank is located over a building, the check valve shall ordinarily be placed in a pit, preferably outside the building. (See Figure B-10.) Where yard room is not available, the check valve shall be located on the ground floor or in the basement of a building provided that it is adequately protected against breakage.

11-2.12 Controlling Valves.

11-2.12.1 A listed gate valve, generally with an indicator post, shall be placed in the discharge pipe on the yard side of the check valve between the check valve and any connection of the tank discharge to other piping. (See Figure B-9.) If yard room for an indicator post is not available, a listed outside screw and yoke gate valve similarly arranged, but inside of the valve pit or room, shall be used.

11-2.12.2 A listed outside screw and yoke gate valve shall be placed in the discharge pipe on the tank side of the check valve. (See Figure B-9.) If the tank is on an independent tower, this valve shall be placed in the pit with the check valve preferably on the yard side of the base elbow. If the tank is located over a building, the valve shall be placed under the roof near the point where the discharge pipe enters the building. (See Figure B-10.) For suction tanks, the valve shall be as close to the tank as possible.

11-2.13 Anti-Vortex Plate Assembly. Where a tank is used as the suction source for a fire pump, the discharge outlet shall be equipped with an assembly to control vortex flow. This assembly shall consist of a horizontal steel plate at least twice the diameter of the outlet on an elbow fitting, if required, mounted at the outlet a distance above the bottom of the tank equal to one-half the diameter of the discharge pipe. The minimum distance above the bottom of the tank shall be 6 in. (152 mm). [See Figure B-15(a).]

11-3 Expansion Joint.

11-3.1 Connection to Tank. A listed expansion joint shall be used where required by 11-2.7 and 11-2.8.1. The expansion joint shall be placed immediately above the foot elbow or shall be connected to the tank bottom using welding for a steel tank and bolts or a special screw fitting for a wood tank. The movable nuts on bolts shall be on the outside of the tank.

11-3.2 General Design. The design shall be such that the joint will operate reliably over periods of years without attention and shall be of adequate strength to resist the stresses and corrosion to which it will be subjected. One or both of the two parts that slide, one on the other, shall be of brass or other noncorrodible metal of ample strength and wearing qualities.

11-3.3 Clearances. At least $\frac{1}{16}$ -in. (1.6-mm) clearance shall be provided around all movable parts to prevent binding and at least $\frac{1}{2}$ in. (12.7 mm) shall be provided between the cast-iron body and an iron or steel slip-tube.

11-3.4 Body. The body shall be steel or cast iron and, if connected to the tank bottom, shall provide for a settling basin extension of proper length (see 11-2.10). Provisions shall be made for a packing space of adequate size (see 11-3.7).

11-3.5 Gland. The adjustable gland shall be brass or iron and must be connected to the body casting, preferably with four standard bolts at least $\frac{5}{8}$ in. (15.9 mm) in size and of sufficient length to permit full adjustment.

11-3.6 Slip-tube. The sliding tube at the top of the discharge pipe shall be brass or iron. If the gland is iron, the slip-tube shall have a triple-plated brass outer surface. If the gland is brass, the slip-tube shall be cast iron or steel and the top of the packing space shall be formed with brass and a clearance of at least $\frac{1}{2}$ in. (12.7 mm) provided at all points between the cast iron body and the slip-tube. The upper part of the slip-tube shall be machined over a length such that the top of the gland can be dropped to 6 in. (152 mm) below the bottom of the body casting so as to enable repacking. The top of the slip-tube shall be located about 5 in. (127 mm) below the top of 4-in. (102-mm) settling-basin extensions and 12 in. (305 mm) below the top of 18-in. (457-mm) settling-basin extensions.

11-3.7 Packing. The packing shall consist of asbestos wicking saturated with rape oil and graphite or an equally suitable material. Packing at least 2 in. (51 mm) deep and $\frac{1}{2}$ in. (12.7 mm) thick shall be provided in the packing space.

11-3.8 Connections for Use Other than Fire Protection. Connections for a use other than fire protection preferably shall not be made, but where unavoidable they shall be connected rigidly to the tank bottom and a standard expansion joint, if needed, shall be provided in each such pipe below, and entirely independent of, the tank.

11-4 Filling.

11-4.1 Bypass around Check Valve. When the tank is to be filled from the fire protection system under city or fire-pump pressure, the filling pipe preferably shall be a bypass around the check valve. (See *Figures B-9 and B-10.*) The bypass shall be connected into tapped bosses on the check valve or into the discharge pipe between the check valve and all other valves. The bypass shall be sized to fill the tank in eight hours, but shall not be smaller than 2 in. An outside screw and yoke gate valve shall be placed in the bypass and kept closed except when the tank is being filled.

11-4.2 Filling Pumps. When the tank is to be filled by a special filling pump, the pump and connections shall be of such size that the tank can be filled in eight hours. The filling pipe shall be at least 2 in. in size and, except as noted in 11-4.3, shall be connected directly into the tank discharge pipe, in which case a listed outside screw and yoke gate valve and a check valve shall be placed in the filling pipe near the tank discharge pipe, the check valve being on the pump side of the gate valve. The filling pump suction pipe shall not be connected to a fire service main supplied from the tank. The filling valve shall be open only when the tank is being filled.

11-4.3 When a separate fill pipe is used, automatic filling shall be permitted to be provided.

11-4.4 Filling from Drinking Water Supply. Where the water in the fire protection system is not suitable for drinking purposes and the tank is filled from a potable water supply, the filling pipe shall be installed in accordance with the regulations of the local health authority.

11-4.5 Filling Pipe at Roofs and Floors. The intersection of a separate filling pipe with a roof or waterproof or concrete floor shall be watertight. (See 11-1.1.)

11-4.6 Suction Tanks. Pipes for automatic filling of suction tanks shall discharge into the opposite half of the tanks from the pump suction pipe. If an over-the-top fill line is used, the outlet shall be directed downward.

11-5 Overflow.

11-5.1 Size. The overflow pipe shall be of adequate capacity for the operating conditions and shall be not less than 3 in. in size throughout.

11-5.2 Inlet. The inlet of the overflow pipe shall be located at the top capacity or high water line. The inlet also shall be located at least 1 in. (25.4 mm) below the bottom of the flat cover joists in a wood tank, but shall never be closer than 2 in. (51 mm) to the top of the tank. Unless the maximum fill capacity is known and the overflow capacity is calculated to be at least equal to the fill capacity, the

overflow pipe shall be at least one pipe size larger than the fill line and shall be equipped with an inlet such as a concentric reducer, or equivalent, that is at least 2 in. larger in diameter. The inlet shall be arranged so that the flow of water is in no way retarded by any obstruction. An overflow pipe cut with the opening to fit the roof shall be used on a steel tank provided a suitable horizontal suction plate and vortex breaker are used to ensure full capacity flow for the overflow.

11-5.3* Stub Pipe. Where the dripping of water or a small accumulation of ice is not objectionable, the overflow, by the choice of the owner, shall pass through the side of the tank near the top. (See *Figures B-11 and B-12.*) The pipe shall be extended with slight downward pitch to discharge beyond the tank or balcony and away from the ladders, and shall be adequately supported.

Overflows for pedestal tanks preferably shall be extended to ground level within the access tube and pedestal. (See *Figure B-13.*)

11-5.4 Inside Pipe. Where a stub pipe is undesirable, the overflow pipe shall extend down through the tank bottom and inside the frostproof casing or steel plate riser and shall discharge through the casing near the ground or roof level. The section of the pipe inside the tank shall be of brass, flanged cast iron, or steel (see 11-1.15). Inside overflow pipes shall be braced to tank and riser plates at points not over 25 ft (7.6 m) apart by substantial clamps. The discharge shall be visible, and the pipe pitched to drain. If the discharge is exposed, the exposed length shall not exceed 4 ft (1.2 m) and shall avoid the entrance to the valve pit or house.

11-6 Clean-out and Drain.

11-6.1 Handhole. A standard handhole, with a minimum dimension of 3 in. (76 mm), or a manhole shall be provided in the saucer plate outside of the frostproof casing and at the bottom of an elevated steel tank with a suspended bottom (see *Figure B-12*), unless the tank has a large riser pipe 3 ft (0.91 m) or more in diameter.

11-6.2 Shell Manholes. Two manholes shall be provided in the first ring of the suction tank shell at locations to be designated by the purchaser. The design of the manholes shall be in accordance with AWWA D100, *Standard for Welded Steel Tanks for Water Storage*, for welded steel tanks and AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*, for bolted steel tanks.

11-6.3 For Elevated Flat-bottom Tanks. Where elevated, at least a 2-in. pipe clean-out also shall be provided outside of the frostproof casing in the bottom of a wood tank or a flat-bottom steel tank. For wood tanks, the clean-out connection shall consist of a special screw fitting with gasket or a pair of 2-in. pipe flanges. For steel tanks, the connection shall consist of an extra-heavy coupling welded to the bottom plate. The coupling shall be welded to both sides of the tank plates. A piece of 2-in. brass pipe about 5 in. (127 mm) long capped at the top with a brass cap shall be screwed into the inner fitting or flange. The clean-out shall be watertight. (See *Figure B-11.*)

11-6.4 Riser Drain.

11-6.4.1 A drain pipe at least 2 in. in size that is fitted with a reliable controlling valve and a $\frac{1}{2}$ -in. drip valve shall

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12-1.2.1 Materials shall conform to ASTM Designation C 578, *Preformed, Block-Type Cellular Polystyrene Thermal Insulation*, Grade 2, Type II. Since nonburning polystyrene does not exist, care must be taken in specifying this material for frostproofing if the threat of direct exposure to flame exists.

12-1.2.2 Materials shall conform to ASTM Designation C 591, *Rigid Preformed Cellular Urethane Thermal Insulation*, Grade 2, Type II. Since nonburning polyurethane does not exist, care must be taken in specifying this material for frostproofing if the threat of direct exposure to flame exists.

12-1.3 Dimensions. A valve pit or house shall be of sufficient size to provide a clearance of 12 in. (305 mm) and preferably 18 in. (457 mm) around all contained equipment. A valve pit shall extend at least 6 in. (152 mm) above the grade and far enough below grade to place the base-elbow below the frost line and shall be at such an elevation that connection to the system can be conveniently made. An adequate size pit shall be carefully planned in advance for the equipment, but ordinarily a pit 7 ft (2.1 m) deep and 6 ft × 9 ft (1.8 m × 2.7 m) horizontally inside will be of sufficient size. A valve house containing only the OS&Y gate in the discharge pipe and the heater can usually be made smaller.

12-1.4 Design of Valve Pit.

12-1.4.1 All parts of the pit and soil beneath shall be adequate to resist all loads, including the frostcasing or large steel riser and contained water. This shall require reinforced 1:2:4 concrete for the roof. The walls and floor also shall be reinforced 1:2:4 mixture if subjected to appreciable bending stresses from groundwater pressure or other loads. The walls and floor shall be plain 1:3:5 concrete, usually not less than 8 in. (203 mm) thick, when bending stresses are insignificant.

12-1.4.2 The load considered in designing the pier and its bearing that supports a large steel-plate riser, where the hemispherical or ellipsoidal shape is continuous to the shell of the large riser without a flat horizontal diaphragm plate, shall be the weight of the water column from the pier to the tank bottom plus the weight of a cylinder of water 4 ft (1.2 m) greater in diameter than the large riser, and extending from the bottom to the top of the tank. If a hemispherical or ellipsoidal bottom is rigidly attached to the top of a larger riser by a flat horizontal diaphragm plate, the weight considered to be acting on the pier shall be the weight of the water column from the pier to the tank bottom plus the weight of a cylinder of water whose radius equals the radius of the riser at the tank bottom plus one half the distance from the edge of the riser to the connection of the flat horizontal diaphragm plate to the hemispherical or ellipsoidal bottom plates, and extending from the bottom to the top of the tank. The pier shall adjoin a pit containing the usual valves and accessories. An adequate slip joint shall be provided between the pier and the valve pit if the soil is incapable of sustaining a load of 2 tons/ft² (19 548 kg/m²) without negligible settlement.

12-1.5 Pit Manhole. A standard round manhole with a cover at least 24 in. (610 mm) in diameter; a square metal manhole with a substantially hinged cover at least 20 in. (508 mm) on a side; or a raised hatch of equivalent size with a cover built of 2-ply matched boards with tar-paper between, shall be provided in the roof of the valve pit. Where there is

no heater in the pit, the manhole shall have a properly fitted inside cover of 2-in. (51-mm) plank, or its equivalent, located at least 4 in. (102 mm) below the outer cover.

12-1.6 Pit Ladder. A rigidly secured steel ladder shall extend from the manhole to the floor.

12-1.7 Waterproofing Pit. If the pit is below drainage level, the outside surface shall be thoroughly waterproofed. Waterproofing shall be done either by painting with asphalt and then covering with at least two layers of felt and asphalt alternately, the felt shall be lapped 18 in. (457 mm), or by other suitable methods.

12-1.8* Pit Drain. A sump and drain shall be provided wherever a sewer is available or soil conditions make the arrangement possible.

12-1.9 Heater House.

12-1.9.1 A heater house above grade shall be substantial, and the roof shall be strong enough to support the frostproof casing, if provided, and other loads without excessive deflection. A tight-fitting double door of sufficient size for admittance of persons or equipment shall be provided.

12-1.9.2 If the house contains a heater that burns oil or a gas that is heavier than air, and is located over a valve pit below grade, the entrance to the pit shall be outside of the heater house. The portion of the floor of the heater house that is over the pit shall be continuous concrete and shall be tightly caulked around all pipes.

12-1.9.3 If the house contains a fuel-burning heater, louvers above the maximum snow level or a vent shall be provided to furnish sufficient fresh air for combustion of fuel, in addition to the vent to exhaust the products of combustion from the house.

12-1.10 Heating Valve House or Pit and Heater House. The valve or heater house above grade, as well as the valve pit, shall be heated sufficiently to maintain a temperature of at least 40°F (4.4°C) during the most severe weather.

12-2 Frostproof Casing.

12-2.1 General. A listed frostproof casing shall be placed around all exposed tank piping in localities where the lowest mean atmospheric temperature for one day, as shown by the Isothermal Map, Figure 13-1.4, is 20°F (-6.7°C) or lower. Tank piping subjected to temperatures below freezing within unheated buildings, or dry risers of elevated tanks, also shall be adequately protected. Combustible frostproof casings subjected to serious fire exposure shall be protected by at least 1 in. (25.4 mm) of cement plaster on metal lath. The casing or discharge pipe shall be braced as specified in 11-2.4, and bracing shall be provided between the frostproof casing and the discharge pipe. Non-combustible construction, as indicated in Figure B-16, or its equivalent, shall be preferred throughout.

12-2.2 Wood.

12-2.2.1 Where special permission is obtained from the authority having jurisdiction, frostproof casings shall be permitted to be of wood. (See A-13-1.2.) All lumber used for frostproof casings shall be sound and free from large or loose knots. Sheathing shall be matched stock, dressed from a nominal thickness of at least 1 in. (25.4 mm) to a finished thickness not less than 5/8 in. (15.9 mm). One thickness of heavy nonabsorbent or saturated building

paper shall be wrapped around all except the outer courses of sheathing. Air spaces shall be neither less than 1 in. (25.4 mm) nor more than 2 in. (51 mm). Horizontal nailing strips shall be provided not over 4 ft (1.2 m) apart.

12-2.2.2 Effective fire stops shall be provided in all air spaces about 6 ft (1.8 m) and 10 ft (3.0 m) above the base of the casing, except that for prefabricated casing the lower fire stop shall be at the base of the casing. If the casing contains only water pipes, noncombustible insulating material at least 4 in. (102 mm) thick and supported on 2-in. (51-mm) planks, or the equivalent, shall be used for these fire stops. The insulating material shall be packed tightly in any spaces between planks and pipes. If the casing contains a steam pipe, a listed noncombustible material shall be used instead of the 2-in. (51-mm) planks. The pipes shall be protected against corrosion at these fire stops by liberal application of red lead paint with litharge added (*See 3-7.10*), after careful cleaning of the pipes with wire brushes and scrapers. At least 1½-in. × ⅛-in. (38.1-mm × 1.6 mm) galvanized iron flats or ⅜-in. (9.5-mm) round hoops shall be placed around circular casings over each nailing strip. Bracing between the frostproof casing and the discharge pipe shall be spaced at intervals of not over 4 ft (1.2 m), except that prefabricated casing shall be braced to the discharge pipe at the ends of the sections at intervals not over 16 ft (4.9 m) long.

12-2.3 Top. Where the casing is wood or metal, an enlarged section shall be provided directly under the tank bottom and shall fit over the main portion of the casing with a slip joint lapping at least 6 in. (152 mm) to provide for expansion or settlement of the tower. This section shall have the same insulating qualities as the main casing and shall be tightly and securely fitted to the tank bottom. For a tank with a hemispherical or other suspended bottom, it shall be built in the shop.

12-2.4 Bottom. The casing shall be substantially supported at the bottom by the roof of the valve pit or building, using beams if necessary. The joint around the bottom shall be watertight to prevent leakage from outside. Where

the tank is over a building, the joint between the roof and pipes inside the casing also shall be watertight to keep water from draining into the building in case of a broken pipe. (*See 11-1.1.*) The lower end of the casing shall be protected from absorption of moisture.

12-2.5 Paint. Unless the lumber used in a wood casing has been suitably treated with a preservative, all exposed parts shall be given at least two coats of a good grade of paint. If a metal casing is used, all surfaces shall be given two coats of paint as specified in 3-7.10 and 3-7.11.

Chapter 13 Tank Heating

13-1* General.

13-1.1 Tanks that are subjected to freezing shall be heated.

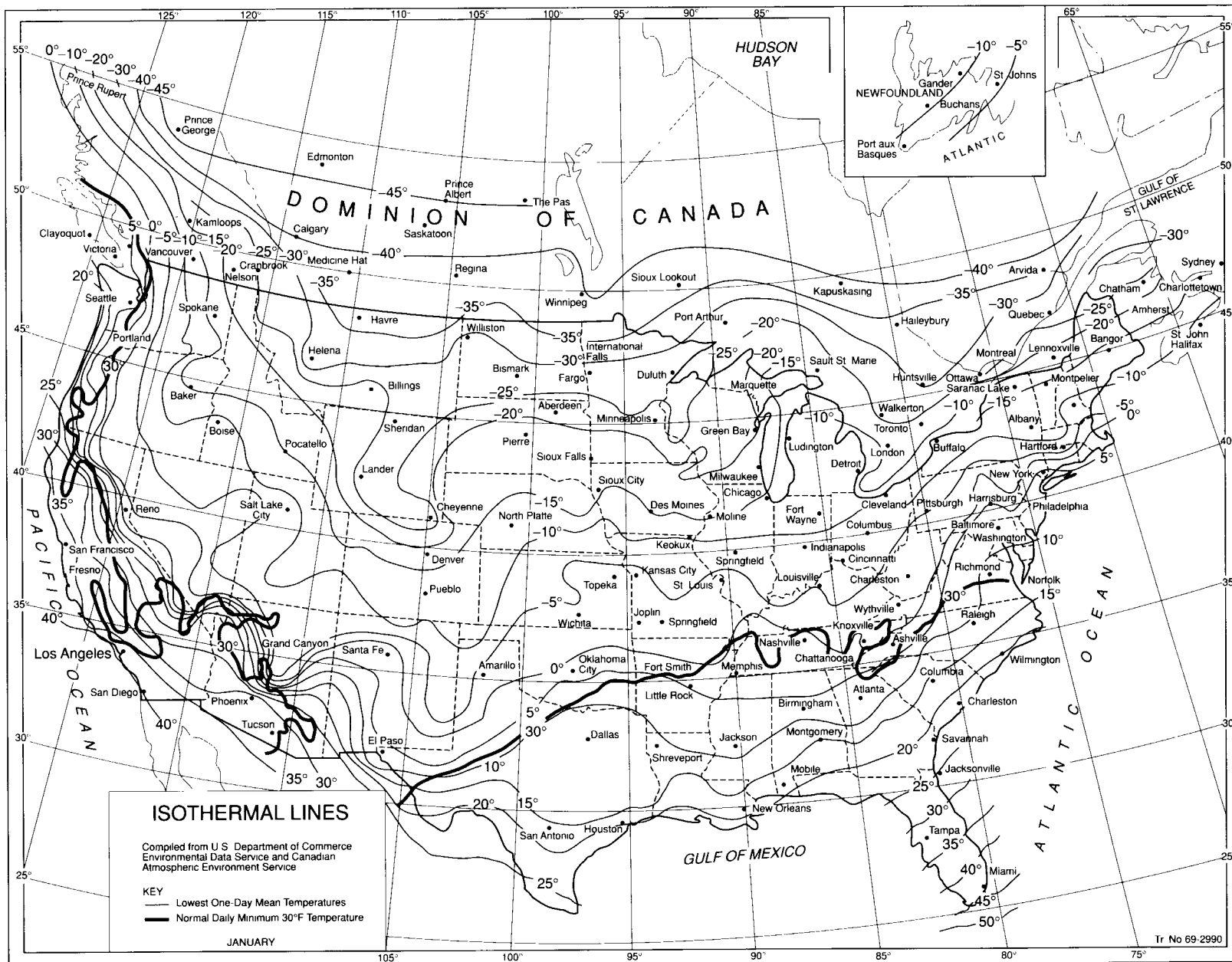
13-1.2* The heating system shall be of such capacity that the temperature of the coldest water in the tank or riser or both will be maintained at or above 42°F (5.6°C) during the coldest weather.

13-1.2.1* The coldest weather temperature used to determine the need for heating shall be based on the lowest mean temperature for one day as shown on the Isothermal Map, Figure 13-1.4.

13-1.2.2* A low-water-temperature alarm, set at 40°F (4.4°C), shall be provided.

13-1.3* The method of heating used shall conform to 13-2.1, 13-2.2, or 13-2.3, according to the type of tank and its geographical location.

13-1.4* The method of heating used shall employ one of the heaters described in 13-3.1 through 13-3.7, and shall have a Btu capacity per hour (kw), according to Figure 13-1.4 and Tables 13-1.4(a) through (h), as appropriate for determination of heater capacity.



Compiled from United States Weather Bureau records.
SI units: $^{\circ}\text{C} = \frac{5}{9}(^{\circ}\text{F} - 32)$; 1 mi = 1.609 km

Figure 13-1.4 Isothermal lines—lowest one-day mean temperature ($^{\circ}\text{F}$).

Table 13-1.4(a) Thousands of British Thermal Units Lost per Hour from Uninsulated Elevated Steel Tanks**Based on minimum water temperature of 42°F (5.6°C) and a wind velocity of 12 mph (19.3 km/hr).**

[See Table 13-1.4(b) for wood tanks and Table 13-1.4(c) for steel standpipes.]

To determine capacity of heater needed, find the minimum mean atmospheric temperature for one day from the Isothermal Map, Figure 13-1.4, and note the corresponding heat loss below.

TANK CAPACITIES—THOUSANDS U.S. GALLONS												
Atmo- spheric Temper- ature °F	Heat (Btu/hr) Loss Per ft ² Tank Radiating Surface	25	30	40	50	75	100	150	200	250	Add Btu Per Lineal ft Uninsulated Steel Riser	
		ft ² of tank surface*										
		<u>1210</u>	<u>1325</u>	<u>1550</u>	<u>1800</u>	<u>2370</u>	<u>2845</u>	<u>3705</u>	<u>4470</u>	<u>5240</u>		
		Btu lost per hour, thousands										3 ft dia.
35	32.3	40	43	51	59	77	92	120	145	168	50	69
30	46.1	56	62	72	83	110	132	171	207	242	144	192
25	61.5	75	82	96	111	146	175	228	275	323	255	340
20	77.2	94	103	120	139	183	220	287	346	405	380	506
15	93.6	114	125	146	169	222	267	347	419	491	519	692
10	110.9	135	147	172	200	263	316	411	496	582	670	893
5	128.9	156	171	200	233	306	367	478	577	676	820	1092
0	148.5	180	197	231	268	352	423	551	664	779	982	1309
−5	168.7	205	224	262	304	400	480	626	755	884	1152	1536
−10	190.7	231	253	296	344	452	543	707	853	1000	1329	1771
−15	213.2	258	283	331	384	506	607	790	954	1118	1515	2020
−20	236.8	287	314	368	427	562	674	878	1059	1241	1718	2291
−25	262.3	318	348	407	473	622	747	972	1173	1375	1926	2568
−30	288.1	349	382	447	519	683	820	1068	1288	1510	2145	2860
−35	316.0	383	419	490	569	749	900	1171	1413	1656	2381	3174
−40	344.0	417	456	534	620	816	979	1275	1538	1803	2620	3494
−50	405.6	491	538	629	731	962	1154	1503	1814	2126	3139	4186
−60	470.8	570	624	730	848	1116	1340	1745	2105	2467	3702	4936

*These numbers are ft² of tank radiating surfaces used for each capacity to compute the tabulated heat loss values and are typical for tanks with D/4 ellipsoidal roofs and bottoms.

Note: Heat loss for a given capacity with a different tank radiating surface than shown above shall be obtained by multiplying the radiating surface by the tabulated heat loss per ft² for the atmospheric temperature involved. The minimum radiation surface area shall be the wetted tank steel surface area plus the top water surface area. For tanks with large steel plate risers, the heat loss from the riser shall be added to that from the tank. The riser loss per linear foot shall be as tabulated above.

For SI units: 1 ft = 0.3048 m; 1 ft² = 0.0929 m²; 1 Btu/hr = 0.293 W; 1 Btu/ft² = 11.356 kJ/m²; °C = $\frac{5}{9}$ (°F - 32); 1000 gal = 3.785 m³.

Table 13-1.4(b) Thousands of British Thermal Units Lost per Hour from Elevated Wood Tanks**Based on minimum water temperature of 42°F (5.6°C) and a wind velocity of 12 mph (19.3 km/hr).**

[See Table 13-1.4(a) for elevated steel tanks and Table 13-1.4(c) for steel standpipes.]

To determine capacity of heater needed, find the minimum mean atmospheric temperature for one day from the Isothermal Map, Figure 13-1.4, and note the corresponding heat loss below.

TANK CAPACITIES—THOUSANDS U.S. GALLONS									
Atmospheric Temperature °F	10	15	20	25	30	40	50	75	100
35	8	10	11	13	14	19	21	28	33
30	11	14	16	19	21	27	31	40	49
25	15	20	21	25	28	36	42	54	65
20	19	25	27	32	35	46	54	69	83
15	24	31	34	39	44	57	66	85	102
10	28	36	40	46	51	68	78	100	121
5	33	43	47	54	60	78	92	117	142
0	38	49	53	62	69	90	106	135	164
-5	43	56	61	71	79	103	120	154	187
-10	49	63	69	80	89	116	136	174	211
-15	54	71	77	89	100	130	153	195	236
-20	61	79	86	99	111	145	169	217	262
-25	68	87	95	110	123	160	188	240	291
-30	74	96	104	121	135	176	206	264	319
-35	81	105	115	133	148	193	226	289	350
-40	88	114	125	144	162	210	246	317	382
-50	104	135	147	170	190	246	290	372	450
-60	122	157	171	197	222	266	307	407	490

For SI units: 1 Btu/hr = 0.293 W; °C = $\frac{5}{9} (°F - 32)$; 1000 gal = 3.785 m³.

Table 13-1.4(c) Thousands of British Thermal Units Lost per Hour from Uninsulated Steel Suction Tanks and Standpipes**Based on minimum water temperature of 42°F (5.6°C) and a wind velocity of 12 mph (19.3 km/hr).**

[See Table 13-1.4(a) for wood tanks and Table 13-1.4(b) for elevated steel or wood tanks.]

To determine capacity of heater needed, find the minimum mean atmospheric temperature for one day from the Isothermal Map, Figure 13-1.4, and note the corresponding heat loss below.

Atmo- spheric Temper- ature °F	Heat (Btu/hr) Loss Per ft ² Tank Radiating Surface	TANK CAPACITIES—THOUSANDS U.S. GALLONS									
		100	125	150	200	250	300	400	500	750	1000
		ft ² of tank surface*									
		2610	3030	3505	4175	4795	5360	6375	7355	9650	11740
		Btu lost per hour, thousands									
35	32.3	85	98	114	135	155	175	206	238	312	380
30	46.1	121	140	162	193	222	248	294	340	445	542
25	61.5	161	187	216	257	295	330	393	453	594	722
20	77.2	202	234	271	323	371	414	493	568	745	907
15	93.6	245	284	329	391	449	502	597	689	904	1099
10	110.9	290	337	389	463	532	595	707	816	1071	1302
5	128.9	337	391	452	539	619	691	822	949	1244	1514
0	148.5	388	450	521	620	713	796	947	1093	1434	1744
−5	168.7	441	512	592	705	809	905	1076	1241	1628	1981
−10	190.7	498	578	669	797	915	1023	1216	1403	1841	2239
−15	213.2	557	646	748	891	1023	1143	1360	1569	2058	2503
−20	236.8	619	718	830	989	1136	1270	1510	1742	2286	2781
−25	262.3	685	795	920	1096	1258	1406	1673	1930	2532	3080
−30	288.1	752	873	1010	1203	1382	1545	1837	2119	2781	3383
−35	316.0	825	958	1108	1320	1516	1694	2015	2325	3050	3710
−40	344.0	898	1043	1206	1437	1650	1844	2193	2531	3320	4039
−50	405.6	1059	1229	1422	1694	1945	2175	2586	2984	3915	4762
−60	470.8	1229	1427	1651	1966	2258	2524	3002	3463	4544	5528

*These numbers are ft² of radiating surface used for each capacity to compute the tabulated heat loss values and are typical for cone roof reservoirs on grade.Note: Heat loss for a given capacity with a different radiating surface than shown above shall be obtained by multiplying the radiating surface by the tabulated heat loss per ft² for the atmospheric temperature involved. The minimum radiation surface area shall be the wetted surface exposed to atmosphere plus the top water surface area. No heat loss shall be figured for tank bottoms resting on grade.For SI units: 1 ft = 0.3048 m; 1 ft² = 0.0929 m²; 1 Btu/hr = 0.293 W; 1 Btu/ft² = 11.356 kJ/m²; °C = 5/9 (°F - 32); 1000 gal = 3.785 m³.

Table 13-1.4(d) Thousands of British Thermal Units Lost per Hour from Embankment-Supported Coated Fabric Suction Tank**Based on minimum water temperature of 42°F (5.6°C) and a wind velocity of 12 mph (19.3 km/hr).***To determine capacity of heater needed, find the minimum mean atmospheric temperature for one day from the Isothermal Map, Figure 13-1.4, and note the corresponding heat loss below.*

		TANK CAPACITIES—THOUSANDS U.S. GALLONS							
Atmospheric Temperature °F	Heat (Btu/hr) Loss Per ft² Tank Radiating Surface	100	200	300	400	500	600	800	1000
		ft² of exposed tank surface							
		2746	4409	6037	7604	9139	10630	13572	16435
		Btu lost per hour, thousands							
35	22.2	61	98	134	168	202	235	300	363
30	28.5	78	126	173	217	261	304	389	470
25	35.1	96	155	212	266	320	372	476	576
20	41.5	114	183	251	315	379	441	564	682
15	48.0	132	212	290	364	438	510	652	789
10	54.5	149	241	329	413	497	579	740	896
5	61.0	167	269	369	463	557	648	828	1003
0	67.5	185	298	408	512	616	717	916	1109
−5	73.9	203	326	447	561	675	786	1004	1216
−10	80.4	220	355	486	610	734	855	1092	1322
−15	86.8	238	384	525	659	793	924	1180	1429
−20	93.3	256	412	564	708	852	992	1268	1536
−25	99.9	273	441	604	758	912	1061	1356	1642
−30	106.2	291	469	643	807	971	1130	1444	1749
−40	119.3	327	526	721	905	1089	1268	1620	1962
−50	131.9	362	584	799	1003	1207	1406	1796	2175
−60	145.1	397	641	878	1102	1326	1544	1972	2389

Note: Heat loss for a given capacity with a different radiating surface than shown above shall be obtained by multiplying the radiating surface by the tabulated heat loss per ft² for the atmospheric temperature involved. The minimum radiation surface area shall be the wetted surface exposed to atmosphere. No heat loss shall be figured for tank bottoms resting on grade.

For SI units: 1 ft = 0.3048 m; 1 ft² = 0.0929 m²; 1 Btu/hr = 0.293 W; 1 Btu/ft² = 11.356 kJ/m²; °C = $\frac{5}{9}$ (°F - 32); 1000 gal = 3.785 m³.

Table 13-1.4(e) Heat Loss from Insulated* Steel Gravity Tanks (English Units).*(Thousands of British thermal units lost per hour when the temperature of the coldest water is 42°F. Mean water temperature is 54°F).*

Atmospheric Temperature, °F	Heat Loss, Btu/hr/ft ² Tank Surface	Tank Capacity, U.S. gal x 1000							Add Btu/hr/lin ft Uninsulated Steel Riser	
		50	75	100	150	200	250	300	3 ft dia	4 ft dia
		(1800)**	(2370)	(2845)	(3705)	(4470)	(5240)	(5905)		
15	3.90	7.02	9.24	11.10	14.45	17.43	20.4	23.0	36.8	49.0
10	4.40	7.92	10.43	12.52	16.30	19.67	23.1	26.0	41.5	55.3
5	4.90	8.82	11.61	13.94	18.15	21.9	25.7	28.9	40.2	61.6
0	5.40	9.72	12.79	15.36	20.0	24.1	28.3	31.9	50.9	67.9
-5	5.90	10.62	13.98	16.79	21.9	23.4	30.9	34.8	55.6	74.1
-10	6.40	11.52	15.17	18.21	23.1	28.6	33.5	37.8	60.3	80.4
-15	6.90	12.42	16.35	19.36	25.6	30.8	36.2	40.1	65.0	86.7
-20	7.40	13.32	17.54	21.1	27.4	33.1	38.8	43.1	69.7	93.0
-25	7.90	14.22	18.72	22.5	29.3	35.3	41.4	46.6	74.5	99.3
-30	8.40	15.12	19.91	23.9	31.1	37.5	44.0	49.6	79.2	105.6
-35	8.90	16.02	21.1	25.3	33.0	39.8	46.6	52.6	83.9	111.8
-40	9.40	16.92	22.3	26.7	34.8	42.0	49.3	55.5	88.6	118.1
-50	10.40	18.72	24.6	28.6	38.5	46.5	54.5	61.4	98.0	130.7

*Based on an "R" factor of 10 hr-ft²-°F/Btu.

**Numbers in parentheses are ft² of tank surface used for each capacity to compute the tabulated heat loss values and are typical for tanks with D/4 ellipsoidal roofs and bottoms.

Table 13-1.4(f) Heat Loss from Insulated* Steel Gravity Tanks (Metric Units).
(Kilowatts lost when the temperature of the coldest water is 5.6°C. Mean water temperature is 12.2°C).

Atmospheric Temperature, °C	Heat Loss, W/m ² of Tank Surface	Tank Capacity, m ³							Add W/lin m Uninsulated Steel Riser	
		189 (167)**	284 (220)	379 (264)	568 (344)	757 (415)	946 (437)	1136 (549)	0.9 m dia	1.2 m dia
-10	12.61	2.11	2.77	3.33	4.34	5.23	6.14	6.92	36.1	47.6
-12	13.75	2.30	3.03	3.63	4.73	5.71	6.70	7.55	39.3	51.8
-15	15.45	2.58	3.40	4.08	5.32	6.41	7.53	8.48	44.2	58.3
-18	17.16	2.87	3.77	4.53	5.90	7.12	8.36	9.42	49.1	64.7
-21	18.86	3.15	4.15	4.98	6.49	7.83	9.19	10.36	53.9	71.1
-23	20.00	3.34	4.40	5.28	6.88	8.30	9.74	10.98	57.2	75.4
-26	21.70	3.62	4.77	5.73	7.47	9.01	10.57	11.92	62.1	81.8
-29	23.41	3.91	5.15	6.18	8.05	9.71	11.40	12.85	66.9	88.3
-32	25.11	4.19	5.52	6.63	8.64	10.42	12.23	13.79	71.8	94.7
-34	26.25	4.38	5.78	6.93	9.03	10.89	12.78	14.41	75.0	99.0
-37	27.95	4.67	6.15	7.38	9.62	11.60	13.61	15.35	79.9	105.4
-40	29.66	4.95	6.52	7.83	10.20	12.31	14.44	16.26	84.8	111.8
-45	32.50	5.43	7.15	8.58	11.18	13.49	15.83	17.84	92.9	122.5

*Based on an "R" factor of 1.76 m²·°C/W.

**Numbers in parentheses are m² of tank surface used for each capacity to compute the tabulated heat loss values and are typical for tanks with D/4 ellipsoidal roofs and bottoms.

Table 13-1.4(g) Heat Loss from Suction Tanks, Walls and Roof Insulated* (English Units).
(Thousands of British thermal units lost per hour when the temperature of the coldest water is 42°F. Mean water temperature is 54°F.)

Atmospheric Temperature, °F	Heat Loss, Btu/hr/ft ² Tank Surface	Tank Capacity, U.S. gal x 1000								
		100 (2610)**	150 (3505)	200 (4175)	250 (4795)	300 (5360)	400 (6375)	500 (7355)	750 (9650)	1000 (11740)
15	3.90	10.2	13.7	16.3	18.7	20.9	24.9	23.7	37.6	45.8
10	4.40	11.5	15.4	18.4	21.1	23.6	28.1	32.4	42.5	51.7
5	4.90	12.8	17.2	20.5	23.5	26.3	31.2	36.0	47.3	57.5
0	5.40	14.1	18.9	22.5	25.9	28.9	34.4	39.7	52.1	63.4
-5	5.90	15.4	20.7	24.6	28.3	31.6	37.6	43.4	56.9	69.3
-10	6.40	16.7	22.4	26.7	30.7	34.3	40.8	47.1	61.8	75.1
-15	6.90	18.0	24.2	28.8	33.1	37.0	44.0	50.7	66.6	81.0
-20	7.40	19.3	25.9	30.9	35.5	39.7	47.2	54.4	71.4	86.9
-25	7.90	20.6	27.7	33.0	37.9	42.3	50.4	58.1	76.2	92.7
-30	8.40	21.9	29.4	35.1	40.3	45.0	53.6	61.8	81.1	93.6
-35	8.90	23.2	31.2	37.2	42.7	47.7	56.7	65.5	85.9	104.5
-40	9.40	24.5	32.9	39.2	45.1	50.4	59.9	69.1	90.7	110.4
-50	10.40	27.1	36.5	43.4	49.9	55.7	66.3	76.5	100.4	122.1

*Based on an "R" factor of 10 hr·ft²·°F/Btu.

**Heat admitted to tank water from the ground not included. Numbers in parentheses are ft² of surface used for each capacity to compute the tabulated heat loss values.

13-1.4.1 The heater shall be plainly marked with a plate or cast lettering that gives the Btu/hr (kw) input, type of heater, and the manufacturer's name.

13-1.4.2 The allowable working pressure of the heater shall not be less than the maximum filling pressure sustained when the tank is being filled.

13-1.5 Location. The heater shall be located in a valve pit, a special heater-house, or a building at or near the base of the tank structure. Where the tank is over a building, the heater shall be located in the top story. Where placed inside of combustible frostproof casings heaters shall not be in contact with any combustible material.

13-1.6 Heat Insulation. All heaters shall be insulated to prevent excessive heat losses. Where the tank heater is the only source of heat in a valve pit or other heater room, enough of the heater or steam pipe shall be left bare to keep the temperature of the air above freezing.

13-1.7* Heater Water-Circulating Pipes. The size of heater water-circulating pipes for wood and steel tanks shall be not less than 2 in. in size and shall be not less than shown in Table 13-1.7. The installation of the hot and cold water-circulating pipes shall be in accordance with 13-1.7.1 and 13-1.7.2. If the circulating pipes pass through the roof or waterproofed or concrete floors, the intersections shall be made watertight. (See 11-1.1.)

Table 13-1.4(h) Heat Loss from Suction Tanks, Walls and Roof Insulated* (Metric Units).
 (Kilowatts lost when the temperature of the coldest water is 5.6°C. Mean water temperature is 12.2°C.)

Atmospheric Temperature, °C	Heat Loss W/m ² of Tank Surface	Tank Capacity, m ³								
		379 (243)**	568 (326)	757 (388)	946 (445)	1136 (498)	1514 (592)	1893 (683)	2839 (897)	3785 (1091)
-10	12.61	3.06	4.11	4.89	5.61	6.28	7.47	8.61	11.31	13.76
-12	13.75	3.34	4.48	5.34	6.12	6.85	8.14	9.39	12.33	15.00
-15	15.45	3.75	5.04	5.99	6.88	7.69	9.15	10.55	13.86	16.86
-18	17.16	4.17	5.59	6.66	7.64	8.55	10.16	11.72	15.39	18.72
-21	18.86	4.58	6.15	7.32	8.39	9.39	11.17	12.88	16.92	20.6
-23	20.00	4.86	6.52	7.76	8.90	9.96	11.84	13.66	17.94	21.8
-26	21.70	5.27	7.07	8.42	9.66	10.81	12.85	14.82	19.46	23.7
-29	23.41	5.69	7.63	9.08	10.42	11.66	13.86	15.99	21.0	25.5
-32	25.11	6.10	8.19	9.74	11.17	12.50	14.87	17.15	22.5	27.4
-34	26.25	6.38	8.56	10.18	11.68	13.07	15.54	17.93	23.5	28.6
-37	27.95	6.79	9.11	10.84	12.44	13.92	16.55	19.09	25.1	30.5
-40	29.66	7.21	9.67	11.51	13.20	14.77	17.56	20.3	26.6	32.4
-45	32.50	7.90	10.60	12.61	14.46	16.18	19.24	22.2	29.2	35.5

*Based on an "R" factor of 1.76 m²·°C/W.

**Heat admitted to tank water from the ground not included. Numbers in parentheses are m² of surface used for each capacity to compute the tabulated heat loss values.

The "R" value of insulation is determined by its thickness and insulating qualities. An "R" factor of 10 or more may be obtained by applying 1½ in. (38 mm) of polyurethane foam, 2½ in. (64 mm) of glass fiber board, or 4 in. (100 mm) of cellular glass board.

For other R values, use Heat Loss = Tabulated $\times \frac{(10)}{R}$ or Heat Loss Metric = Tabulated $\times \frac{(176)}{R}$.

Table 13-1.7 Minimum Size in In. of Circulating Pipes Required for Elevated Steel Tanks. Tank Capacity (U.S. Gallons).

Minimum One-Day Mean Temp. °F	15,000	20,000	25,000	30,000	40,000	50,000	60,000	75,000	100,000	150,000
+10	2	2	2	2	2	2	2	2	2	2½
+5	2	2	2	2	2	2	2	2	2	2½
0	2	2	2	2	2	2	2	2	2½	2½
-5	2	2	2	2	2	2	2	2	2½	2½
-10	2	2	2	2	2	2	2	2½	2½	2½
-15	2	2	2	2	2	2	2½	2½	2½	3
-20	2	2	2	2	2	2½	2½	2½	2½	3
-25	2	2	2	2	2½	2½	2½	2½	3	3
-30	2	2	2	2	2½	2½	2½	2½	3	3
-35	2	2	2	2½	2½	2½	2½	3	3	3
-40	2	2	2	2½	2½	2½	2½	3	3	3

For SI units: °C = $\frac{5}{9} (°F - 32)$; 1000 gal = 3.785 m³

13-1.7.1 Hot-Water Pipe. Copper tubing, steel conforming to Section 3-2, or brass (85 percent copper) pipe shall be used throughout. If the tank is elevated, the hot-water pipe shall be placed near the discharge pipe inside of the frostproof casing. The pipe shall pitch upward at all points and shall have a four-elbow swing joint or adequately supported brass expansion joint located either just above the heater or just below the tank bottom. The hot water shall discharge inside the tank through a tee fitting of the nominal pipe size, at about one third of the height of the tank. The pipe shall be adequately braced inside the tank and also at points not over 25 ft (7.6 m) apart throughout its length, providing enough play to allow for expansion. A listed indicating valve of the nominal pipe size shall be placed in the pipe near the heater.

13-1.7.2 Cold-Water Pipe. The cold-water return pipe shall be connected to the discharge pipe or tank side at a point that will ensure circulation throughout the entire portion of the discharge pipe that is subject to freezing. An accurate thermometer graduated at least as low as 30°F (-1.1°C) shall be placed in the cold-water pipe at a point where it will register the temperature of the coldest water in the system. A listed indicating valve of the same size as the pipe shall be placed in the cold-water pipe at the point of connection to the discharge pipe or tank side. A 2-in. drainpipe discharging at a visible point shall be connected into the cold-water return pipe between the heater and the cold-water controlling valve to enable the flushing of water from the tank through the hot-water pipe, heater, and drain for clean-out purposes. The drainpipe shall be arranged as specified in Figures B-9 and B-10.

13-1.8 Relief Valve. A listed relief valve shall be provided in the water chamber or pipe between the hot- and cold-water valves of any water heater. The relief valve shall be carefully adjusted to open at a pressure of 120 lb/in.² (8.3 bars), except that the opening pressure shall be neither greater than the allowable working pressure of the heater nor less than the maximum static or filling pressure to which it might be subjected. If the heater is close to stock that might be damaged by water, the relief shall be piped to a safe point.

13-1.9 Operation.

13-1.9.1* The thermometer shall be observed daily, and the supply of heat shall be regulated to maintain the temperature at 42°F (5.6°C). Lower temperatures are dangerously near the freezing point and shall not be permitted. Excessively high temperatures, moreover, are detrimental to the equipment, particularly wood tanks and the paint in steel tanks.

13-1.9.2 Steam pressure shall be regulated by throttling the steam valve or by means of a listed automatic regulatory device. A very small flow of steam shall constantly pass by the automatic regulating device so that circulation will not cease entirely when the regulator bulb is in a circulating pipe not exposed to atmospheric temperature.

13-1.9.3 When circulating systems are temporarily shut off, circulation shall be started and run for at least two hours to ensure that the water in the pipe is not assuming room temperature while the water in the tank is in danger of freezing. Valves in circulating pipes shall be wide open when the heater is in operation.

13-1.9.3.1 Avoid explosion or rupture hazard to the heater by shutting off or removing the source of heat when both hot-water and cold-water valves are shut for any reason. A relief valve will not compensate for this precaution.

13-1.9.4 All air shall be blown from steam heaters, radiators, and traps by means of the air valve or vent on the radiator or trap when first admitting steam.

13-2* Heating Requirements.

13-2.1* When tanks are located where the lowest mean temperature for one day is less than 5°F (–15°C) as shown by the Isothermal Map, Figure 13-1.4, a gravity-circulating method of heating elevated tanks or water storage tanks installed on or below grade shall be employed for special situations, as covered in 13-2.1.1 or 13-2.1.2.

13-2.1.1 A steam-heated vertical radiator system shall be used for elevated tanks with unprotected risers 3 ft (0.91 m) or more in diameter having tower heights under 100 ft (30.5 m) (see 10-1.2), standpipes, and on-grade suction tanks. For tower heights over 100 ft (30.5 m), a steam-heated vertical radiator system also shall be used, except that an open-ended pipe sleeve similar to that shown in Figure B-19 shall be used.

13-2.1.2 For suction tanks and standpipes having flat bottoms supported near ground level, immersed steam coils shall be used if the tank is kept filled so that the steam coils are continuously submerged.

13-2.2 Where the lowest mean temperature for one day is 5°F (–15°C) or above as shown by the Isothermal Map, Figure 13-1.4, and only intermittent heating is required for elevated tanks having unprotected risers less than 3 ft (0.91 m) in diameter, the method of heating shall be either water circulation, immersed steam coils, or blowing steam from an adequate supply directed into the water. Suction tanks, standpipes, and elevated tanks having risers 3 ft (0.91 m) or more in diameter shall need no provision for heat.

13-2.3 Where the lowest mean temperature for one day is above 15°F (–9.4°C) as shown on the Isothermal Map, Figure 13-1.4, the method of heating tanks with frostproof risers less than 3 ft (0.91 m) in diameter shall be a steam loop or radiator, or thermostatically controlled electric strip heaters placed inside the frostproof casing.

13-3 Heating Systems.

13-3.1* Steam Water Heaters. A steam water heater shall consist of a cast iron or steel shell where water circulates around steam tubes or coils of brass or copper. Galvanized steel or iron steam tubes shall be permitted but are not

advised because of their more rapid depreciation and poorer heat-transfer qualities. The shell and tubes shall be designed to withstand a test pressure of at least two and one-half times the permissible working pressure and not less than 300 lb/in.² (20.7 bars), and shall be so tested before shipment. Heaters shall have a bolted flange on at least one end to facilitate disassembly for inside cleaning.

Heaters designed so that water passes through the tubes or coils surrounded by steam are practical for ease of cleaning. However, such heaters shall be well insulated unless it is desired to use the heat loss for heating the valve pit or other housing.

13-3.1.1 Steam Supply. Steam water heaters shall be connected to a reliable steam supply with a pressure preferably not less than 10 lb/in.² (0.7 bars) and not over 50 lb/in.² (3.4 bars). The steam pipes shall have an area at least equivalent to that of 1-in. nominal-size pipe for each heater supplied and shall run direct from the boiler heater if possible. A globe valve shall be placed in the line near the heater, and a steam gauge shall be provided preferably between the valve and the heater. Where the heater is connected to a vacuum system, the layout shall have the approval of the maker of the heating specialties and, in all cases, a final approval shall be obtained from the authority having jurisdiction.

13-3.1.2 Steam Return. The steam return shall be arranged to quickly relieve the heater of condensate. The area of the return pipe shall be at least equivalent to the area of ¾-in. nominal-size pipe for each heater served. A reliable steam trap of adequate size and equipped with an air vent, and preferably a water gauge, shall be provided near the heater wherever the return is not by gravity or to a vacuum system. Excessive lifts from the trap shall be avoided. A ¾-in. nominal-size pipe or larger bypass with a globe valve normally kept shut shall be provided around the trap. A globe valve also shall be placed on each side of the trap between the bypass connections.

13-3.1.2.1 A gravity return shall be used only where the heater is located well above the boiler water-level and where the steam pressure at the heater plus the static head of water in the return pipe between the heater and the boiler water-level is greater than the steam pressure at the boiler.

13-3.1.2.2 Wherever it becomes necessary to return the condensate to a vacuum heating system, the layout shall have the approval of the makers of the heating specialties, as well as a final approval by the authority having jurisdiction.

13-3.1.3 Multiple Heaters. If two or more heaters are used, they shall be placed at one level, connected in parallel with symmetrical piping, and with a relief valve and controlling valves in the water lines of each. A globe valve shall be placed in each steam supply line.

13-3.2 Gas-Fired Water Heaters. A gas-fired water heater of sufficient strength to resist the water pressure shall be permitted to be used. The heater shall be of a type listed by a recognized testing laboratory and shall have a permanent marking showing the input ratings in Btu/hr (kw). The heater and accessories shall be installed in accordance with the manufacturer's recommendations and provided with listed combustion safeguards.

13-3.2.1 The gas-fired water heater shall be equipped to prevent abnormal discharge of gas, in the event of ignition

failure or accidental flame extinguishment, by automatic means specifically approved for the heater.

13-3.2.2 A high-limit switch shall be provided in the hot-water pipe close to the heater to shut off the gas supply automatically when the water temperature exceeds 190°F (87.8°C).

13-3.2.3 Thermostatic control of the burner with a temperature response element shall be located in the coldest water affected by atmospheric temperature, and a minimum water temperature of at least 42°F (5.6°C) shall be maintained.

13-3.3 Oil-Fired Water Heaters. An oil-fired water heater of sufficient strength to resist the water pressure shall be permitted to be used. The heater shall be of a type listed by a recognized testing laboratory and shall have a permanent marking showing the input rating in Btu/hr (kw).

13-3.3.1 The heater and accessories shall be installed in accordance with the manufacturer's recommendations and provided with listed combustion safeguards.

13-3.3.2 The heater shall be equipped to prevent abnormal discharge of oil at the burner, in the event of ignition failure or accidental flame extinguishment, by automatic means specifically approved for the heater.

13-3.3.3 A high-limit switch shall be provided in the hot-water pipe to the heater to shut off the oil supply automatically when the water temperature exceeds 190°F (87.8°C).

13-3.3.4 Thermostatic control of the burner with a temperature response element shall be located in the coldest water affected by atmospheric temperature, and a minimum water temperature of at least 42°F (5.6°C) shall be maintained.

13-3.3.5 The oil tank shall be buried outside the heater house.

13-3.4 Coal-Burning Water Heaters. A coal-burning water heater of sufficient strength to resist the water pressure shall be used. Water circulates through a chamber, a series of chambers, or through brass pipe coils around and over the fire. The heater and accessories shall be installed in accordance with the manufacturer's recommendations and provided with listed combustion safeguards.

13-3.5 Electric Water Heaters. An electric water heater of sufficient strength to resist the water pressure shall be permitted to be used. A water-circulating pump shall be used in conjunction with electric heating elements. A single water heater or boiler of adequate capacity shall be permitted to be used. However, to avoid sudden peak demands on the electric service, multiple heaters shall be installed in parallel (*see 13-3.1.3*) with the various thermostatic controls set at different temperatures. With all of the heater elements in operation, the system shall have adequate capacity to maintain a minimum water temperature of at least 42°F (5.6°C). Thermostatic control with a temperature response element shall be located in the coldest water affected by atmospheric temperature.

13-3.5.1 In the hot-water pipe close to the heater, there shall be a manual reset high-limit control thermostat that disconnects all ungrounded electrical conductors to the heater in the event that the water temperature exceeds the temperature of the high-limit thermostat [approximately 190°F (87.8°C)].

13-3.5.2 Electric heaters and accessories shall be of a type listed by a recognized testing laboratory; shall have a permanent marking showing the kilowatt capacity; and shall be installed in accordance with the manufacturer's recommendations. The installation of all electrical wiring shall comply with NFPA 70, *National Electrical Code*®.

13-3.6 Vertical Steam Radiators. A vertical steam radiator, shown in Figure B-19, but without the open-ended pipe sleeve around the radiator heater is reasonably well adapted to heating elevated tanks with larger risers for tower heights under 100 ft (30.5 m) (*see 10-1.2*), suction tanks, and standpipes. For tower heights over 100 ft (30.5 m), a steam-heated vertical radiator system also shall be permitted to be used, except that an open-ended pipe sleeve similar to that shown in Figure B-19 shall be used. Except for suction tanks not over 25 ft (7.6 m) high, an accurate angle socket thermometer with at least a 6-in. (152-mm) stem and calibrated as low as 30°F (-1.1°C) shall be permanently inserted through the plate or standpipe and as far from the heating unit as possible. The radiator shall consist of a steam pipe of sufficient size, but never less than 1½ in., to convey the steam required under worst conditions, contained within a watertight condensing chamber of copper tubing, cast iron, steel or brass pipe, or suction tank, and shall have sufficient area to maintain the temperature of the coldest water at not less than 42°F (5.6°C) (*see A-13-3.1*). For radiator heaters without surrounding pipe sleeve (explained below), surface water temperatures shall be ascertained by means of a listed temperature-detecting device. This device shall have the temperature response element secured in a position about 3 ft (0.91 m) below the permanent fire service water-level. If long-distance thermometers are used, the external tubing shall be supported substantially at about 12-ft (3.7 m) intervals, and the indicating dial shall be located conveniently near grade in a substantial weatherproof cabinet. For a high structure without a permanent fire service water-level, a circulating type of heating system or radiator heater with sleeve shall be used with a socket thermometer located in the coldest water.

13-3.6.1 The radiator shall be supplied from a reliable source with, preferably, at least 10 lb/in.² (0.7 bars) steam pressure. (*See A-13-3.1 for low-pressure steam.*) If steam pressure in excess of 100 lb/in.² (6.9 bars) is available on the heater, a reducing valve shall be placed in the steam-supply pipe near the boiler header and a relief valve set at 100 lb/in.² (6.9 bars) shall be installed between the reducing valve and the heater. The steam-supply pipe shall be at least 1½ in. in size, but of sufficient size to furnish the required quantity of steam, and shall have a steam gauge with siphon at a convenient location. Except in the case of a radiator heater supplied by a separately fired boiler located above grade near the tank (*see Figure B-20*), the steam supply and a return connection at least ¾ in. in size from the base of the condensing chamber shall be provided with a trap arrangement, as shown in Figure B-22. Other arrangements for disposing of condensate shall be acceptable provided approval is first obtained from the authority having jurisdiction.

13-3.6.2 If a separately fired boiler located above grade near the tank supplies steam to the radiator, the inner pipe shall contain several ¼-in. (6.4-mm) holes below the water level of the boiler. The steam-supply pipe shall pitch upwards from the top of the nearby boiler to a connection to the inner pipe in the radiator, as shown in Figure B-20.

13-3.6.3 For all radiator heaters, the inner pipe shall extend to within approximately 1 ft (0.3 m) of the top of the condensing chamber. The radiator sleeve and reduced extension of the sleeve up into the main tank shall be adequately supported and braced at points not over 25 ft (7.6 m) apart.

13-3.7 Heating with Hot Water. Hot water as a heating element in the coils or shell of a heater designed for steam shall not be used unless special permission to do so is obtained from the authority having jurisdiction. In all such cases, the complete detailed design of the heater, together with information regarding the temperature of the hot water, shall be submitted to the authority having jurisdiction and approval received before the equipment is installed.

13-3.8 Steam Coils inside Tanks.

13-3.8.1 The coil shall consist of at least 1¼-in. brass or copper pipe or 2-in. steel pipe. The pipe shall be pitched to drain and shall be supplied with steam, preferably at not less than 10 lb/in.² (0.7 bars) pressure, through a pipe of sufficient size to furnish the required quantity of steam from a reliable source. A globe valve and a steam gauge with siphon shall be placed in the steam supply line. The coil shall be substantially supported and, together with the supply and return pipes, shall have adequate provision for expansion. The return shall be connected to a steam trap. If the tank is elevated, the steam pipes shall be placed inside the frostproof casing around the discharge pipe. (See 13-1.5.) The coil shall contain a sufficient area of heating surface (see A-13-3.1) to maintain the temperature of the coldest water at not less than 42°F (5.6°C). The coil shall be placed within a distance of approximately 3 ft (0.91 m) from the shell and shall be sized for a maximum steam velocity of 8000 ft/min (2438 m/min) so that the pressure drop does not exceed one half of the initial inlet pressure.

13-3.8.2 The surface water temperatures for elevated tanks, standpipes, and suction tanks shall be ascertained by means of a listed temperature-detecting device. This device shall have the temperature response element secured in a position approximately 3 ft (0.91 m) below the permanent fire service water-level. If long-distance thermometers are used, the external tubing shall be supported substantially at approximately 12-ft (3.7-m) intervals and the indicating dial shall be located conveniently near grade in a substantial weatherproof cabinet. For a high structure without a permanent fire service water-level, a circulating type of heating system or radiator heater with a sleeve shall be used with a socket thermometer located in the coldest water. For any exception to these provisions, approval from the authority having jurisdiction shall first be obtained.

13-3.9 Direct Discharge of Steam. When blowing steam from an adequate supply directly into the tank, a pipe not less than 1 in. in diameter shall be used. The steam pipe shall extend inside the frostproof casing, through the bottom to a point above the maximum water level and then horizontally a short distance. An air vent and a check valve shall be provided to keep the water from siphoning back and thence downward to a point 3 ft or 4 ft (0.9 m or 1.2 m) below the normal fire service water-level. The section of the pipe inside the tank shall be of securely braced brass or copper. A ½-in. drip valve shall be provided at the base of the steam pipe.

13-3.10 Solar Heating. Tanks shall be permitted to be equipped with solar heating to reduce the consumption of

other forms of heating energy. A solar-heated tank shall have a backup heating system, as described in this chapter.

13-4 Tank Insulation. Where permitted by the authority having jurisdiction, tanks shall be permitted to be insulated to conserve energy. Insulation materials shall be listed and installed with protection against fire, exposure, corrosion, and weather. Heating requirements shall be based on design information in *The Handbook of Fundamentals*, as published by the American Society of Heating, Refrigerating, and Air Conditioning Engineers. Outside winter design temperatures shall be taken from Figure 13-1.4. Heat-loss calculations shall be based on an average water temperature of 55°F (12.8°C).

13-5 Heating for Embankment-Supported Coated Fabric Suction Tanks.

13-5.1 When tanks are located where the lowest mean temperature for one day is less than 5°F (–15°C) as shown on the Isothermal Map, Figure 13-1.4, a water-recirculating system with a heat exchanger/heater shall be provided and installed according to the heater manufacturer's recommendations. The heat exchanger/heater shall be plainly marked with a plate giving the Btu/hr (kw) input.

13-5.2 A fitting for the water-recirculation line shall be located in the bottom of the tank diagonally opposite from the concrete sump containing the inlet/outlet for the tank. (See Figure B-7 for a typical installation.)

13-5.3 The heater shall have a Btu/hr (kw) capacity according to Figure 13-1.4 and Table 13-1.4(d) for determination of heater capacity.

13-5.4 When the ambient air temperature drops below 42°F (5.6°C), a thermostat shall activate a pump drawing water from the tank through the inlet/discharge and pumping the water back into the tank through the recirculation fitting.

13-5.5 When the temperature of the water flowing through the inlet/discharge line in the pump house drops below 44°F (6.7°C), a second thermostat shall activate a heat exchanger/heater.

13-5.6 The heat exchanger/heater shall be located in a valve pit. (See Figure B-7 for a typical installation.)

13-5.7 The valve pit temperature shall be maintained above freezing at all times.

13-5.8 The recirculation pipe shall be not less than 2 in. in size. The size of the pipe required is a function of the tank size and the winter weather conditions prevailing at the site, as indicated in Figure 13-1.4 showing isothermal lines for the lowest one-day temperature.

Chapter 14 Care and Maintenance of Water Tanks

14-1 General.

14-1.1 Tanks shall be periodically inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

14-1.2 No waste material, such as boards, roofing, and paint cans, shall be left in the tank or in the space at the top of the tank since it can get into the water and obstruct the piping.

14-1.3 The hatch covers in the roofs and the door at the top of the frostproof casing shall always be kept securely fastened with substantial catches as a protection against freezing and windstorm damage.

14-1.4 Ice that can cause injury to personnel or damage to property shall not be allowed to collect in or on any part of the tank or structure.

14-1.5 Bases of tower columns shall be kept free from dirt and rubbish that would otherwise permit the accumulation of moisture with consequent corrosion. The tops of foundation piers shall always be at least 6 in. (152 mm) above the ground level.

14-1.6 Coal, ashes, or combustible material or construction of any kind shall not be piled near the columns. This can cause failure of the steelwork due to fire, heating, or corrosion. The tank site shall be kept cleared of weeds and brush.

14-1.7 Examination of all points, including the inside of steel tanks without corrosion protection (*see A-3-7.12*) and the hoops and grillage of a wood tank, shall be made at least once every two years. Steelwork without corrosion protection shall be kept painted to prevent the formation of rust. Frequent repainting shall be necessary where the paint is exposed to conditions causing rapid disintegration.

14-1.8 Before repainting, the surface shall be thoroughly dried and all loose paint, rust, scale, and other surface contamination shall be removed. After proper surface preparation, the original paint system shall be restored. It might be necessary or economical to repaint the entire inside surface. On the exterior, normal maintenance shall involve local patching and periodic application of one complete finish coat when the preceding has weathered thin, or for improved appearance after patching.

14-1.9 The painters shall not allow any scrapings or other foreign material to fall down the riser or outlet. If the opening is covered for protection, only a few sheets of paper tied over the end of the settling-basin-stub shall be used. The paper shall be removed upon completion of the job.

14-1.10 If corrosion protection is maintained in a steel tank (*see A-3-7.12*), the tank shall be cleaned often enough to prevent sediment and scale from entering the discharge pipe.

14-1.11 Repairs to the interior of the tank shall not be made with materials that can become dislodged and obstruct the outlet pipe. The authority having jurisdiction shall always be notified in advance of when and for how long the tank is to be out of service.

14-2 Pressure Tanks.

14-2.1 The interior of pressure tanks shall be inspected carefully at three-year intervals to determine if corrosion is taking place and if repainting or repairing is needed.

14-2.2 Where repainting is needed, the basic procedures set forth by Section 14-1 shall be followed. Each relief valve shall be tested at least once each month.

14-3 Embankment-Supported Coated Fabric Suction Tanks.

14-3.1 No waste materials, such as boards, paint cans, trim, or loose material, shall be left in the tank or on the surface of the tank.

14-3.2 The access fitting(s) in the top of the tank shall be kept securely fastened as a protection against freezing and windstorm damage.

14-3.3 Large accumulations of ice shall not be allowed to collect on the top of the tank. This can be overcome by maintaining the temperature of the water above freezing and keeping the tank filled to capacity.

14-3.4 The tank shall be located in a protected area or be enclosed by a manproof fence.

14-3.5 Combustible material of any kind shall not be permitted near the tank, and the site shall be kept clear of weeds, brush, and dead foliage.

14-3.6 The exposed surface of the tank shall be inspected for painting every two years, and the interior of the tank shall be cleaned and inspected as required to eliminate a buildup of sediment.

14-3.7 Before painting, the surface of the tank shall be thoroughly cleaned with detergents and washed and allowed to thoroughly dry.

14-3.8 A paint and procedures of application recommended by the manufacturer shall be used to refurbish the top surface of the tank.

14-3.9 The surfaces of the embankment and the berm subject to erosion shall be surfaced or grassed to prevent soil erosion. Care shall be taken to ensure adequate grass cover.

14-4 Pipe Connections and Fittings.

14-4.1 A tank and its piping constitute an important part of the fire protective equipment and shall be carefully maintained to ensure reliability. Annual inspection of the tank piping, controlling valves, check valve, heating system, mercury gauge, expansion joint, and all other accessories shall be made to make sure that everything is in good repair. At times of cleaning or painting the tank interior or making repairs, it shall be ascertained that the tank is free of foreign material and all piping is clear of obstruction before placing the tank back in service. The heating system shall be given daily supervision during freezing weather. The expansion joint shall be replaced and adjusted if it binds or develops leaks.

Chapter 15 Referenced Publications

15-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

15-1.1 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*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

15-1.2 Other Publications.

15-1.2.1 ACI Publications. American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, MI 48219.

ACI 318, *Building Code Requirements for Reinforced Concrete*, 1992.

ACI 350, *Environmental Engineering Concrete Structures*, 1989.

15-1.2.2 API Publication. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

API 5LC, *Specification for CRA Line Pipe*, 1991.

15-1.2.3 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, GA 30329.

The Handbook of Fundamentals, 1993.

15-1.2.4 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME Boiler and Pressure Vessel Code, 1995.

ASME Rules for the Construction of Unfired Pressure Vessels, 1989.

15-1.2.5 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

A 6/A 6M, *Specifications for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use*, Rev A-94.

A 27/A 27M, *Specifications for Mild-to Medium-Strength Carbon-Steel Castings for General Application*, 1993.

A 36/A 36M, *Specifications for Structural Steel*, 1994.

A 53, *Specifications for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*, 1994.

A 105/A 105M, *Forgings for General Purpose Piping and Piping Components*, 1995.

A 106, *Specifications for Seamless Carbon Steel Pipe for High Temperature Service*, Rev A-94.

A 108, *Specification for Steel Bars, Carbon, Cold Finished, Standard Quality*, 1993.

A 131/A 131M, *Specification for Structural Steel for Ships*, 1994.

A 139, *Specification for Electric-Fusion (arc)-Welded Steel Pipe (sizes 4 in. and over)*, Rev A-93.

A 181/A 181M, *Specifications for Forgings, Carbon Steel for General Purpose Piping*, 1995.

A 283/A 283M, *Specification for Low- and Intermediate-Tensile Strength Carbon Steel Plates of Structural Quality*, Rev A-93.

A 285/A 285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*, 1990.

A 307, *Specifications for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*, 1994.

A 442/A 442M, *Specifications for Pressure Vessel Plates, Carbon Steel Improved Transition Properties*, 1990.

A 502, *Specifications for Steel Structural Rivets*, 1993.

A 516/A 516M, *Specifications for Pressure Vessel Plates, Carbon Steel for Moderate- and Lower-Temperature Service*, 1990.

A 572, *Standard Specification for High Strength Low-Alloy Columbium — Vanadium Steels of Structural Quality*, Rev C-94.

A 607, *Standard Specification for Steel, Sheet and Strip, High Strength, Low Alloy, Columbium or Vanadium or Both, Hot-Rolled and Cold-Rolled*, Rev A-92.

A 615/A 615M, *Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement*, 1995.

A 668, *Specification for Steel Forgings, Carbon and Alloy for General Industrial Use*, 1995.

A 675, *Specifications for Steel Bars and Bar Size Shapes, Carbon, Hot-Rolled, Special Quality, Subject to Mechanical Property Requirements*, Rev A-90.

A 715, *Standard Specification for Steel Sheet and Strip, High Strength, Low Alloy, Hot-Rolled and Steel Sheet, Cold Rolled, High Strength, Low Alloy with Improved Formability*, Rev A-92.

C 578, *Specifications for Preformed Block-Type Cellular Polystyrene Thermal Insulation*, 1992.

C 591, *Specifications for Rigid Preformed Cellular Urethane Thermal Insulation*, 1994.

D 751, *Testing Coated Fabrics*, 1989.

D 1171, *Test Method for Rubber Deterioration — Surface Ozone Cracking Outdoors or Chamber (Triangular Specimens)*, 1994.

D 1183, *Standard Test Methods for Resistance of Adhesives to Cyclic Laboratory Aging Conditions*, 1992.

D 1751, *Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction*, 1983.

D 4021, *Standard Specification of Glass Fiber Reinforced Polyester Underground Petroleum Storage Tanks*, 1992.

E 380, *Standard for Metric Practice*, 1993.

15-1.2.6 AWWA Publications. American Water Works Association, Inc., 6666 W. Quincy Avenue, Denver, CO 80235.

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

D100, *AWWA Standard for Welded Steel Tanks for Water Storage*, 1984.

D102, *AWWA Standard for Painting Steel Water Storage Tanks*, 1978.

D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*, 1987.

D110, *Standard for Wire-Wound Circular Prestressed-Concrete Water Tanks*, 1986.

15-1.2.7 AWS Publications. American Welding Society, Inc., 550 NW LeJeune Road, P.O. Box 351040, Miami, FL 33135.

AWS A5.1, *Specifications for Covered Carbon Steel Arc-Welding Electrodes*, 1991.

AWS D1.1, *Structural Welding Code*, 1994.

AWS D5.2, *Standard for Welded Steel Tanks for Water Storage*, 1984.

15-1.2.8 AWWA Publication. American Wood Preservers Association, 7735 Old Georgetown Ave., NW, Suite 500, Washington, DC 20036.

Standard Specifications of the American Wood Preservers Association by the Empty-Cell Process.

15-1.2.9 NWTI Publication. National Wood Tank Institute, 848 Eastman Street, Chicago, IL 60622.

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

15-1.2.10 SSPC Publication. Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213.

Systems and Specifications Steel Structure Painting Manual, Volume 2, Third Edition, Chapter 5, "Paint Application Specifications, No. 1 — Shop, Field, and Maintenance Painting."

15-1.2.11 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Federal Standard 191 Method.

Federal Test Method Standard 601.

Federal Specifications TT-P-86 Type I or Type II.

15-1.2.12 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

UL 1316, *Glass Fiber Reinforced Plastic Underground Storage Tanks for Petroleum Products*, 1994.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-4 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority

having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-3-6.7.2 Suitable petroleum-base oils include No. 2 fuel oil, drain oil, or other oils of equivalent viscosity.

A-3-7.12 Corrosion Protection. The following methods of corrosion protection may be used to supplement required cleaning and painting, subject to the approval of the authority having jurisdiction.

(a) A listed cathodic system of corrosion protection designed to protect all wetted surfaces, including that of the riser, may be used. Anodes should be of suitable material and construction, approved by the authority having jurisdiction. All anodes should be provided with listed containment devices to prevent any portions thereof from separating and falling. All such containment devices should be fastened securely. To ensure continued reliable operation of such cathodic protection equipment, the owner should make arrangements with the supplier for annual inspections and maintenance of the equipment.

(b) Chemical water additives designed to inhibit corrosion on metal surfaces may be used. The chemicals used shall be nontoxic, nonstaining, and odorless. The additives should be introduced into the water filling the tank in the recommended proportions to maintain corrosion-resistant properties. A chemical-proportioning pump may be used for this purpose. To ensure that the proper chemical balance is being maintained, semiannual chemical analysis of the water should be made.

A-4-1.1 For further information on bolted steel tanks, see AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*.

A-4-6.5 The manufacturer should take precautions to prevent damage to tank components during transport. These precautions include stacking the panels on racks, physically separating the panels, separating with burlap, or otherwise protecting the panels to prevent damage to the coating.

A-4-7.4 Care should be taken when re-tourquing bolts in leaking areas. Over-tourqued bolts can cause linings to crack, splinter, or be otherwise damaged. Manufacturers' recommendations should be followed for the repair or replacement of panels.

A-5-1.4 The condition known as airlock can occur when a pressure tank and a gravity tank are connected into the sprinkler system through a common riser and the gravity water pressure at the gravity-tank check valve is less than the air pressure trapped in the pressure tank and common riser by a column of water in the sprinkler system after water has been drained from the pressure tank. For instance, if the pressure tank is kept two-thirds full of water with an air pressure of 75 lb/in.² (5.2 bars) as usual, and a sprinkler opens 35 ft (10.7 m) or more above the point where the common tank riser connects to the sprinkler system, the pressure tank drains, leaving an air pressure of

15 lb/in.² (1.0 bars) balanced by a column of water of equal pressure [35-ft (10.7-m) head] in the sprinkler system, and the gravity-tank check valve is held closed unless the water pressure from the gravity tank is more than 15 lb/in.² (1.0 bars) [35-ft (10.7-m) head].

Airlock can be prevented by increasing the volume of water and decreasing the air pressure in the pressure tank so that little or no air pressure remains after water has been exhausted. For instance, if the pressure tank is kept four-fifths full of water, with an air pressure of 60 lb/in.² (4.1 bars), the air pressure remaining in the tank after water has been drained is zero, and the gravity-tank check valve opens as soon as the pressure at that point from the pressure tank drops below the static head from the gravity tank.

Under normal conditions, airlock may be conveniently prevented in new equipment by connecting the gravity tank and pressure tank discharge pipes together 45 ft (13.7 m) or more below the bottom of the gravity tank and placing the gravity-tank check valve at the level of this connection.

A-6-5.3 Example: A 1-in. (25.4-mm) hoop 13.5 ft (4.1 m) down from the top of a 22-ft (6.7-m) diameter tank. What is the allowable spacing? Enter Figure 6-5.3 at 13.5 ft (4.1 m) depth, follow the dash line vertically to 22 ft (6.7 m) diameter, then horizontally to 1-in. (25.4-mm) hoop, then vertically out of the diagram at 8.9 in. (226 mm) spacing. One half of the sum of the actual distances to the next hoop above and below should not exceed 8.9 in. (226 mm) plus the tolerance.

Tolerances: The design spacing may exceed the computed spacing a maximum of 1/2 in. (12.7 mm). The spacing as installed may exceed computed spacing a maximum of 1 in. (25.4 mm).

A-10-1.1 Fireproofing Tank Towers. (See Section 1-5 for locations where fireproofing is needed.)

Fireproofing, where necessary, is usually not installed by the tank contractor. One acceptable method of fireproofing of steel columns consists of poured concrete, 2 in. (51 mm) outside of all projecting steel. One method of construction is to wind No. 5 B & S gauge (4.62-mm) steel wire spirally at a pitch of 8 in. (203 mm) around the section and then to erect wooden forms about 6 ft (1.8 m) high, filling and tamping before erecting the next 6-ft (1.8-m) section.

The best coarse aggregates arranged in order of preference are limestone or calcareous gravel, trap rock, granite, sandstone, and hard coal cinders, less than 1 in. (25.4 mm) in size. A 1:2:4 mixture of portland cement, clean sand, and one of the above coarse aggregates should be used.

Another method of construction consists of winding 4-ft or 5-ft (1.2-m or 1.5-m) lengths of expanded metal around the section, the mesh taking the place of wooden forms and wire ties. The concrete should be of relatively dry consistency, however, so that it will not escape from the mesh. The mesh should be kept about 1 in. (25.4 mm) away from the steel by means of spacers so that the concrete will completely surround the steel. Ends of the mesh should be lapped and securely wired together. After the concrete has set, a 1-in. (25.4-mm) layer of portland cement mortar is trowelled on the outside of the mesh.

Ordinarily, columns are so nearly vertical that the weight of concrete fireproofing does not cause significant bending stresses. The vertical load is carried by the foundations. If columns are considerably inclined, reinforcing bars should be placed in the concrete so designed as to make the fireproofing self-supporting.

Fireproofing should extend continuously through the floors and roof of a building. The extreme top of the concrete should be thoroughly flashed with asphalt, including all exposed junctions between steel and concrete. Concrete surfaces exposed to freezing temperatures should be coated with special waterproof paint suitable for concrete surfaces to prevent spalling.

Horizontal struts and compression portal braces should also be encased in solid concrete 2 in. (51 mm) outside of all projecting steel. Wooden forms and wire ties are necessary, and reinforcing rods should be located near the bottom of the section so designed as to make the fireproofing self-supporting. Care should be taken in designing the supports for the forms, as compression members are not usually of sufficient strength to safely resist bending. If any of the struts are used for supporting forms, their strength should be carefully investigated by a consulting structural engineer.

Cement plaster on metal lath has not been satisfactory out-of-doors or in moist locations, due to unobserved corrosion of the steel sections.

Diagonal wind rods or tension portal members are not usually fireproofed, being less subject to failure when heated than the compression members. Where very severe exposure exists, a weather proof fire-resistant coating should be applied over heavily painted rods. Special care is needed to make such fireproofing watertight at turnbuckles and clevises. Concrete has been used occasionally but wire ties or coarse rectangular mesh are necessary to prevent serious cracking and deterioration of the fireproofing.

Wooden frostproof casings are not usually fireproofed. A few casings have completely burned away from steel tanks without damaging the tower or tank but necessitating replacement of the riser pipes. Grillage beams under a wood tank might possibly fail in case of a serious fire involving the frostproof casing. Wooden casings, unless given a preservative treatment, usually rot and need replacement at eight- to 14-year intervals. This period would probably not be lengthened by the presence of cement plaster fireproofing.

Noncombustible frostproof casings are desirable for wood tanks. For steel tanks, 3-ft (0.91-m) diameter steel risers are satisfactory, and do not require fireproofing. In the case of high risers, it is necessary to strengthen the valve pit roof.

Alternate protection for tank towers in lieu of concrete may consist of open sprinklers if water supplies are sufficient and watch service and other conditions are satisfactory to the authority having jurisdiction.

A-11-1.6.1 This joint inspection will reasonably ensure that there are no defects in the work of sufficient importance to prevent the system being put immediately into service. It will also make the owner's representatives more familiar with the system.

A-11-1.8 One of the chief advantages of the gravity circulation system of heating tanks is the fact that it enables convenient observation of the temperature of the coldest water at a thermometer located in the cold-water return pipe near the heater. Failure to provide an accurate thermometer at this point or to observe it daily and keep it registering the proper temperature is to forfeit this advantage and can result in freezing the equipment.

A-11-1.9 Circulation of water through the tank causes an accumulation of sediment that can obstruct the piping or

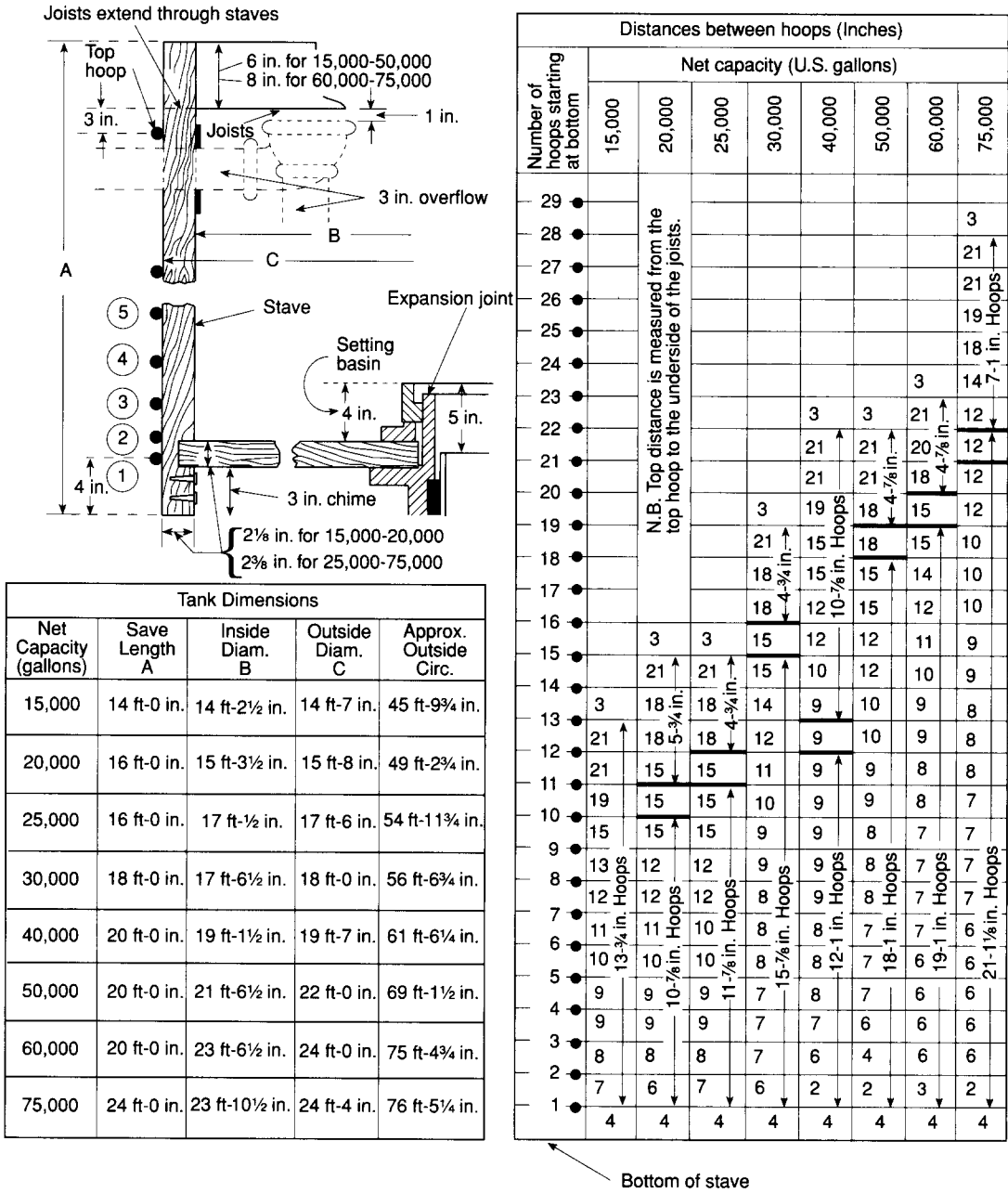


Figure A-6-5.3 Hoop schedules for wood tanks. (Dimensions are for cylindrical tanks.)

sprinklers. A leak or break in a pipe for use other than fire protection may seriously impair the fire protection by partly or completely draining the elevated tank.

A-11-1.11 Water-Level Gauges.

General. A listed mercury gauge as shown in Figure B-14 is considered the most reliable water-level indicator for elevated tanks. For suction tanks of low height other gauge types may be more suitable.

Mercury Gauge Materials. Pipe and fittings containing mercury should be iron or steel. Brass, copper, or galvanized parts, if in contact with mercury, are amalgamated, and leaks will result.

Water Pipe. The water pipe to the mercury gauge should be 1 in. galvanized throughout, and connected into the discharge pipe on the tank side of the check valve. If possible the pipe should be short and run with a continual upward pitch toward the tank piping without air pockets to avoid false readings. The pipe should be buried well below the frost line, or located in a heated conduit.

Valves. The valve at the mercury gauge should be a listed outside screw and yoke gate valve. An additional listed outside screw and yoke gate valve should be installed close to the discharge pipe when the distance to the mercury gauge exceeds 50 ft (15.2 m).

Mercury Catcher. Occasionally, fluctuating water pressures require a mercury catcher at the top of the gauge glass, as shown in Figure B-14, to prevent loss of mercury. The catcher is not a standard part of the equipment and is not furnished by the gauge manufacturer unless especially ordered.

Extension Piece. If the mercury catcher is not needed, it can be replaced by about a 3-ft (0.91-m) extension of 1/8-in. pipe, vented at the top.

Water-Drain Plug. A plugged tee shown at "G" in Figure B-14 should be provided in the mercury pipe between the mercury pot and the gauge glass to permit draining off water that sometimes accumulates on top of the mercury column.

Location. The gauge should be installed in a heated room such as a boiler room, engine room, or office, where it will be readily accessible for reading, testing, and maintenance. It should be so located that it is not liable to become injured or broken.

The column of mercury from the mercury pot to the top will be roughly one-thirteenth the height from the mercury pot to the top of the tank. This fact should be borne in mind when planning a location for the instrument.

Cleaning. Before installing the gauge, remove all grease, dirt, and moisture from the pot and piping that will contain mercury and be sure that the mercury itself is clean. Warm water containing a small amount of washing soda is a good cleaning material.

Installing. The gauge should be accurately installed so that when the tank is filled to the level of the overflow, the mercury level is opposite the FULL mark on the gauge board. The following procedure is advised:

(a) Choose a suitable location as explained in "Locations," above. The height of the top of the scale above the center of the mercury pot will be approximately the height of the top of the tank above the pot, divided by 13.6 (the specific gravity of mercury). About 3 additional ft (0.91 m) of clearance should be allowed over the top of the scale.

(b) Having located the top of the scale as above, set up the instrument as indicated in Figure B-14, and so oriented that test cock "D" will be in a convenient position for testing with the scale board in plain sight and so that a little water from the test cock will not do any harm. Complete the water connections.

(c) Remove plug "E" and, with valve "F" closed, fill the pot with mercury to the mark on the cover corresponding to the height above the pot of the full water level in the tank. Replace plug "E."

(d) Being sure that the tank is full to the top of the overflow, open cock "D" then valve "F," leaving cock "D" open until all air is blown out and water flows freely. Then close cock "D."

(e) Finally, adjust the scale board so the "FULL" mark comes opposite the top of the mercury column, the tank being full to the top of the overflow. Secure the scale board firmly in place. Leave valve "F" open unless the gauge is subjected to heavy fluctuations of pressure.

Testing. To determine that it is accurate, the instrument should be tested occasionally as follows: (References are to Figure B-14.)

(a) Overflow the tank.

(b) Close valve "F." Open test cock "D." The mercury should quickly drop into the mercury pot. If it does not, there is an obstruction that must be removed from the pipe or pot between the test cock and the gauge glass.

(c) If the mercury does lower at once as it should, close cock "D" and open valve "F." If the mercury responds immediately and comes to rest promptly opposite the "FULL" mark on the gauge board, the instrument is all right.

(d) If the mercury column does not respond promptly and read correctly during the above test, there are probably air pockets or possibly obstructions in the water-connecting pipe. Open cock "D." Water should flow out forcibly. Permit water to flow through cock "D" until all air is expelled and rusty water from the tank riser appears. Then close "D." The gauge should now read correctly. If air separates from the water in the 1-in. pipe due to being enclosed in a buried tile conduit with steam pipes, the air can be automatically removed by installing a 3/4-in. air trap at the high point of the piping. The air trap can usually be best installed in at tee connected by a short piece of pipe at "E" with a plug in the top of the Tee so that mercury can be added in the future, if necessary, without removing the trap. If there are inaccessible pockets in the piping, as below grade or under concrete floors, the air can be removed only through petcock "D."

(e) If, in test (d), the water does not flow forcibly through cock "D," there is an obstruction which must be removed from the outlet of the test cock or from the water-pipe between the test cock and the tank riser.

(f) If there is water on top of the mercury column in the gauge glass it will cause inaccurate readings and must be removed. First lower the mercury into the pot as in test (b). Close cock "D" and remove plug "G." Open valve "F" very slowly causing mercury to rise slowly and water above it to drain through "G." Close valve "F" quickly when mercury appears at "G" but have a receptacle ready to catch any mercury that may drain out. Replace plug "G." Replace any escaped mercury in the pot as in "Installing C."

(g) After testing leave valve "F" open, except as noted in "Excessive Water Pressures."

Excessive Water Pressures. If found necessary, to prevent forcing mercury and water into the mercury catcher, the controlling valve marked "F" may be closed when filling the tank, but should be left open after the tank is filled, except when the gauge is subjected to continual fluctuation of pressure, when it may be necessary to keep the gauge shut off except when reading. Otherwise it may be necessary to frequently remove water from the top of the mercury column as in A-11-1.12(f), Testing.

A-11-1.12 The insulating qualities of frostproof casing are greatly impaired if joints spring open or if the casing settles away from the tank or if rotting occurs around the base.

A-11-1.13.1 By heating the large steel plate riser pipes the fire hazard and upkeep of the frostproof casing and provision of an expansion joint or walkway are avoided. On the other hand, painting and heating of the larger riser and building of the stronger and larger valve pit costs more than equipment for the smaller risers.

A-11-5.3 On column-supported tanks with outside overflow, vertical extensions of the pipe below the balcony are not recommended, as they can become plugged with ice.

A-11-8 It is not the intent of this standard to require electronic supervision of tanks, however, where such supervision is required in accordance with NFPA 72, *National Fire Alarm Code*, the following alarms should be required:

- (a) water temperature below 40°F,
- (b) return of water temperature to 40°F,

- (c) water level 3 in. (76.2 mm) (pressure tanks) or 5 in. (127 mm) (all other tanks) below normal,
- (d) water level return to normal,
- (e) pressure in pressure tank 10 psi (0.48 kPa) below normal,
- (f) pressure in pressure tank 10 psi (0.48 kPa) above normal.

A-12-1.2 Insulation.

(a) Layers of listed insulation may be constructed as follows:

1. Remove all rust from the pipes with wire brushes and apply two coats of red lead paint using the mixture as stated in 2-7.11 or a listed paint;
2. Wrap all pipes together with waterproof building paper applied over hardwood cleats equal in thickness to the projections of pipe flanges or couplings;
3. Apply alternate wrappings of 1-in. (25.4-mm) insulation and waterproof building paper using the number of layers equivalent in insulating value to the wooden casings specified in Insulation Classification and Limitation, below, and finishing with building paper;
4. Provide an outer covering of painted 8-oz (0.227-kg) canvas securely bound with No. 16 copper wire (1.29 mm) with windings not over 1 ft (0.305 m) apart or by sewing. This type of casing is likely to settle and expose the pipes at the top of the insulation unless adequately secured to the pipes and the tank bottom. Approval of use of insulating materials should be obtained from the authority having jurisdiction.

(b) Insulating materials between inner and outer layers of wood or metal may be used after obtaining approval of the authority having jurisdiction. Such casings should be watertight and conform with other subsections in this section so far as applicable. Suggestions for insulated metal casings are shown in Figure B-16. Absorbent insulating materials should not be placed in direct contact with iron or steel pipes.

(c) For low towers, brick casings with 1-in. (25.4-mm) air spaces between four 4-in. (102-mm) walls and bonded together with frequent headers supported on concrete foundations have given satisfactory experience in very cold climates.

(d) Closed cellular insulation (foam glass, polystyrene, or polyurethane) or fiberglass insulation in thicknesses as listed in Insulation Classification and Limitation, below, are acceptable. Foam glass and fiberglass should have a heavy vapor-repellant paper (or other suitable material) wrapper on each section. When any of these materials are weather exposed the insulation should be jacketed with weather-resistant material.

(e) Other insulating materials may be used on approval of the authority having jurisdiction.

Insulation Classification and Limitation.

(a) Wooden frostproof casings and insulated metal frostproof casings (see Figure B-16) are for weather-exposed pipes. Each of these casings can protect multiple piping systems. In A-12-1.2, the first paragraph regulates the wrapping of insulation around multiple weather-exposed pipe. Single weather-exposed pipes may be protected by jacketed (weather-resistant), closed cellular, or fiberglass insulations.

(b) Closed cellular or fiberglass material without weather guards is suitable to insulate individual pipes in unheated buildings, dry risers of elevated tanks, or other weather-protected areas.

(c) Table 12-1.2 gives minimum thickness of various materials or types of construction.

Wood Preservatives. The lumber used in wood frost-proof casings is subject to rotting. Treatment of the lumber with a suitable preservative such as sodium fluoride, creosote, or even zinc chloride is advised.

A-12-1.8 If suitable drainage cannot be obtained, an injector is sometimes advisable.

A-13-1 Typical Examples.

Size of Water Heater for an Elevated Tank. Given a 75,000-gal (283.88-m³) steel tank with an insulated riser pipe and 2370 ft² (220 m²) of radiating surface in Duluth, Minnesota, what heater capacity would be needed? If the tank were wood, what heater capacity would be needed?

From Figure 13-1.4, the lowest one-day mean temperature is -28°F (-33.3°C). Interpolating from Table 13-1.4(a), the heat loss for a typical tank is approximately 659,000 Btu/hr (193 kw).

A heater should be capable of delivering 659,000 Btu/hr (193 kw) under field conditions. Table 13-1.7 shows that the size of the water-circulating pipe will be at least 2½ in. in size.

For a wood tank with conditions as above, Table 13-1.4(b) shows a maximum heat loss of about 254,000 Btu/hr (74.4 kw) and the heater installed should be capable of delivering that amount of heat. Table 13-1.7 shows that the size of the water-circulating pipe will be at least 2 in. in size.

Table A-13-1 Approximate Heat Transfer from Coils and Pipe Radiators when Coldest Water Is Just Safely above Freezing

Steam Pressure lb/in. ²	kPa	Heat Transfer (Steam to Water)	
		Btu/hr/ft ²	kw/m ²
10	69	19,500	61.5
15	103	22,000	69.4
20	138	24,500	77.3
30	207	29,500	93.0
40	276	34,500	108.8
50	345	39,000	123.0

NOTE: These values should not be used to determine the area of coil needed in a circulating heater.

Large-Diameter Steel Riser. If the steel tank in the example above has 100 ft (30.5 m) of 3-ft (0.91-m) diameter unprotected steel riser instead of a small insulated riser pipe, it may be heated by a circulating heater arranged as shown in Figures B-18 and B-21 or by a pipe radiator as indicated in Figures B-19 and B-20.

From Table 13-1.4(a), the heat loss is 659,000 Btu/hr (193 kw), as determined above, plus approximately 2057 × 100 = 205,700 Btu/hr (60.3 kw) additional for the riser for a total of approximately 861,700 Btu/hr (252 kw). A water heater should be capable of delivering this much heat.

For a pipe radiator, the heat transfer for 15-lb/in.² (1.0-bars) steam is 22,000 Btu/hr (6.4 kw) from Table A-13-1. The required radiating surface is 864,700 divided by 22,000, or 39.3 ft² (3.65 m).

From Table A-13-2, approximately 33 ft 6 in. (10.2 m) of 4-in. pipe will give the required number of square feet of heating surface. For this length, the pipe sleeve arrangement shown in Figures B-19 and B-20 should be used or it will be necessary to use approximately 67 ft (20.4 m) of 4-in. pipe to reach two thirds of the riser height.

A-13-1.2 Determination of Heater Capacity—General.

To prevent freezing in any part of the tank equipment during the coldest weather that may occur, the heating system should replace the heat lost from the tank and piping when the temperature of the coldest water is safely above the freezing point and the mean atmospheric temperature for one day is at its lowest for the locality being considered.

A-13-1.2.1 Atmospheric Temperature. The map, Figure 13-1.4, gives isothermal lines that show the lowest mean temperature for one day that has ever been officially recorded at any point in the United States or Southern Canada. This map has been compiled from official records and can be used with reasonable accuracy to determine the lowest mean temperature for one day that can be expected to occur.

A-13-1.2.2 The low-water, temperature alarm should be connected to the local proprietary alarm system or to a listed central station supervisory service.

A-13-1.3 Choice of Circulating Heaters. To select a suitable circulating heater, first obtain the lowest mean atmospheric temperature for one day that may occur at the locality in question from the Isothermal Map, Figure 13-1.4, and then determine the total heat loss from the tank equipment in Btu/hr (kw) from Table 13-1.4(a) for an elevated steel tank, Table 13-1.4(b) for an elevated wood tank, Table 13-1.4(c) for a steel suction tank or standpipe, or Table 13-1.4(d) for an embankment-supported coated fabric suction tank. The heater installed should have sufficient capacity to deliver, under actual field conditions, an amount of heat equivalent to that lost from the tank equipment. A steam water heater should be planned with due consideration of the steam pressure available. Other heaters should be planned for the particular kind of fuel to be used.

A-13-1.4 Heat Losses. Tables 13-1.4(a) through (h) show the heat losses from uninsulated elevated steel tanks, elevated wood tanks, steel suction tanks and standpipes, embankment-supported coated fabric suction tanks, insulated steel gravity tanks, and insulated steel suction tanks, respectively, for common sizes exposed to various atmospheric temperatures between 35°F and -60°F (1.7°C and -51.1°C, respectively). The losses are given in British thermal units per hour (kw) lost from the entire tank equipment when the temperature of the coldest water is safely above the freezing point, and represent the Btu/hr that the heating system should supply when the atmospheric temperature is at any degree within the range of the tables.

A-13-1.7 Typical arrangements of the installation of heater water-circulating pipes are shown in Figures B-17, B-18, B-19, B-20, B-21, and B-22.

A-13-1.9.1 A recording thermometer with the sensitive bulb inserted in the coldest water is a valuable accessory, that provides a constant record of water temperatures and makes more careful supervision by the management possible.

A-13-2 Gravity-Circulating Heating Recommendations. Gravity circulation permits convenient observation of coldest water temperatures at a thermometer in the cold-water return pipe and is dependable and economical if correctly

Table A-13-2 Ft² of Heating Surface in Coils or Pipe Radiators of Various Lengths

Length ft	Size of Pipe — In.										
	¾	1	1¼	1½	2	2½	3	3½	4	5	6
1	0.275	0.346	0.434	0.494	0.622	0.753	0.916	1.048	1.175	1.455	1.739
10	2.7	3.5	4.3	4.9	6.2	7.5	9.2	10.5	11.8	14.6	17.4
15	4.1	5.2	6.5	7.4	9.3	11.3	13.7	15.7	17.6	21.8	26.1
20	5.5	6.9	8.7	9.9	12.5	15.0	18.3	21.0	23.5	29.1	34.8
25	6.9	8.6	10.9	12.3	15.6	18.8	22.9	26.2	29.3	36.3	43.5
30	8.3	10.4	13.0	14.8	18.7	22.5	27.5	31.4	35.3	43.6	52.1
35	9.6	12.1	15.2	17.3	21.8	26.3	32.0	36.7	41.1	50.9	60.8
40	11.0	13.8	17.4	19.8	24.9	30.1	36.6	41.9	47.0	58.2	69.5
45	12.4	15.6	19.5	22.2	28.0	33.8	41.2	47.2	52.9	65.5	78.2
50	13.8	17.3	21.7	24.7	31.1	37.6	45.8	52.4	58.7	72.7	87.0
55	15.1	19.1	23.8	27.2	34.2	41.4	50.4	57.6	64.6	80.0	95.7
60	16.5	20.8	26.0	29.6	37.3	45.2	55.0	62.8	70.5	87.3	104.3
65	17.9	22.5	28.2	32.1	40.4	49.0	59.5	68.1	76.4	94.6	
70	19.2	24.2	30.4	34.6	43.5	52.7	64.1	73.3	82.3	101.9	
75	20.6	26.0	32.6	37.1	46.6	56.5	68.7	78.5	88.2		
80	22.0	27.7	34.7	39.5	49.8	60.2	73.2	83.8	93.0		
85	23.4	29.4	36.8	42.0	52.9	63.0	77.8		99.9		
90	24.7	31.2	39.0	44.5	56.0	67.8	82.4		105.8		
95	26.1	32.9	41.2	46.9	59.1	71.5	87.0				
100	27.5	34.6	43.4	49.4	62.2	75.3	91.6				

For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 ft² = 0.0929 m².

planned. Cold water received through a connection from the discharge pipe or from near the bottom of a suction tank or standpipe is heated and rises through a separate hot-water pipe into the tank.

Water has its maximum density at 39.2°F (4°C). When the temperature of the water falls below 39.2°F (4°C), there is a water inversion so that the warmer water settles to the bottom of the tank while the colder water rises. Therefore, if the circulation heater is to be fully effective, sufficient heat should be provided so that the temperature of the coldest water will be maintained safely above 42°F (5.6°C).

Table A-13-3.1 Average Efficiencies of Heaters and Heat Content of Fuels

Type of Heater	Average Efficiency	Fuel	Average Heat Content	
			Btu	MJ
Steam heaters, coils, etc.	95%	Anthracite Coal, per lb	13,300	30.9
Electric Heaters	95%	Bituminous Coal, high grade, per lb	13,200	30.7
Boilers (Fuel Oil)	70%	Bituminous Coal, medium grade, per lb	12,000	27.9
Boilers (Coal)	70%	Bituminous Coal, low grade, per lb	10,300	23.9
Gas Water Heaters	70%	Fuel Oil, per lb	19,000	44.2
		Gas, Natural, per ft ³ (m ³)	1100	41.0
		Gas, Artificial, per ft ³ (m ³)	600	22.4
Coal-Burning Water Heaters	40% to 60%	Electricity, per kw hour	3415	3.6

For SI units: 1 lb = 0.454 kg; 1 ft³ = 0.0283 m³.

A-13-2.1 A circulating-water pump may be used in a bypass line to improve the efficiency of the gravity-circulating system. However, the heater size should be based on gravity circulation to provide the heat loss as determined by Tables 13-1.4(a) through (h). The circulating-water pump should be controlled by an outside thermostat designed to start the pump when the outside temperature drops to 40°F (4.4°C).

A-13-3.1 Steam Coils or Radiators. An adequate area of heating surface in steam coils and pipe radiators can also be determined reasonably accurately by dividing the heat loss found, as explained in A-13-1.4, by the heat transfer in Btu/hr/ft² for the steam pressure available, as given in Table A-13-1. The result is the number of square feet of heating surface in usual pipe sizes of various lengths and

permits a convenient determination of the required length of a coil or pipe radiator. Steam pressures less than 10 lb/in.² (0.7 bar) should never be used for coils or pipe radiators unless special provision, such as an auxiliary trap or drip in the steam-supply pipe, is made to drain out the condensate at the low point of the steam-supply branch line to the heater. The average efficiencies of heaters and heat content of fuels is given in Table A-13-3.1.

Appendix B Typical Installations

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

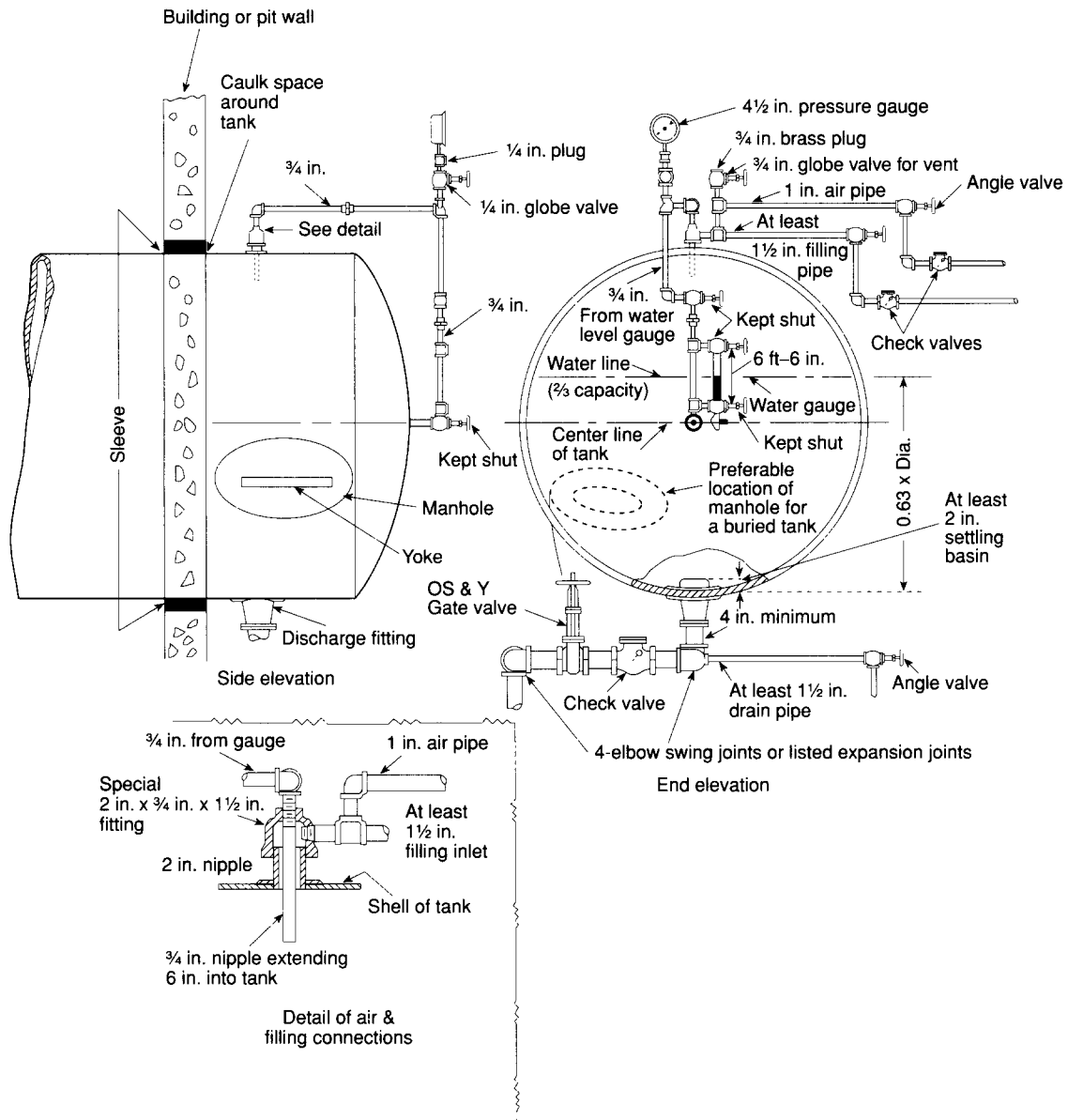
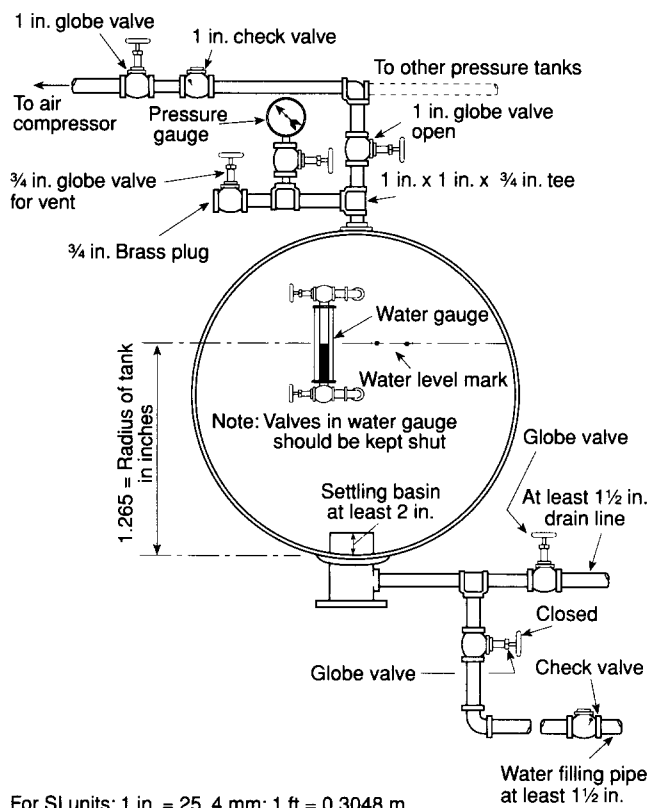
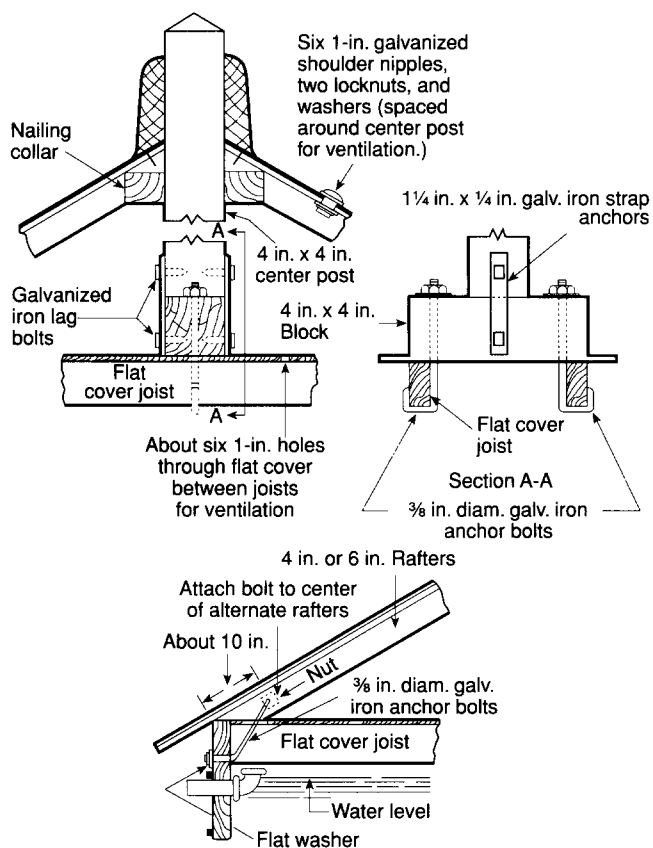


Figure B-1 Pipe connections to pressure tanks.



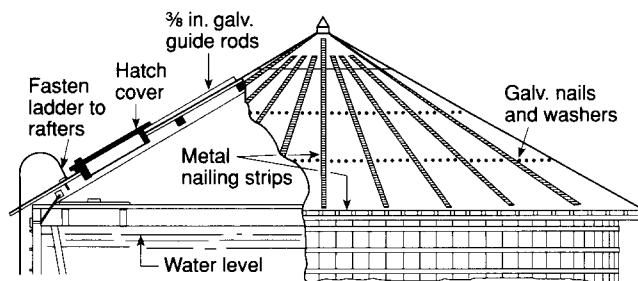
For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure B-2 Alternate connections for pressure tanks.



For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

Figure B-3 Details of tank roof construction.



For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

Figure B-4 Section of conical roof.

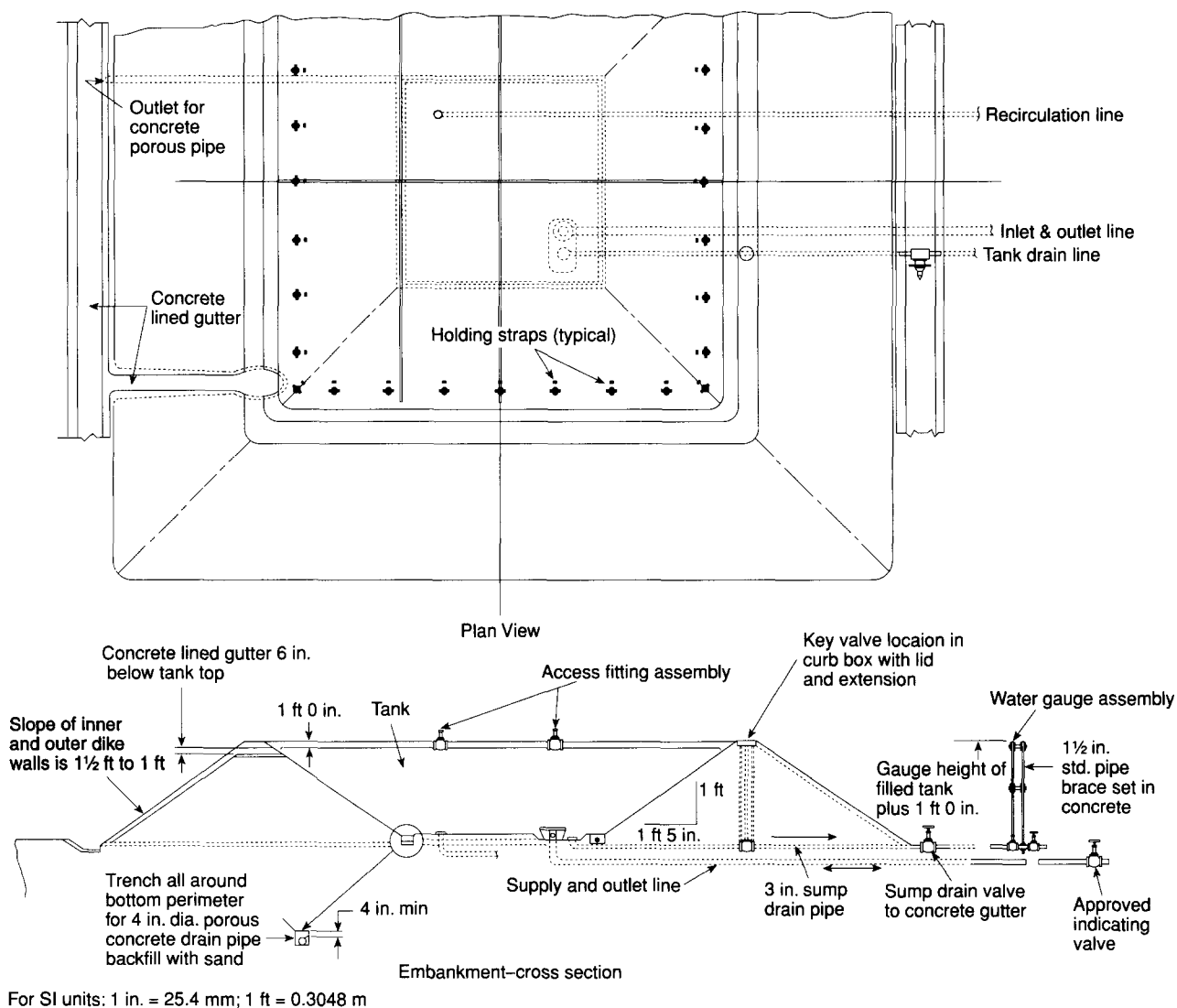
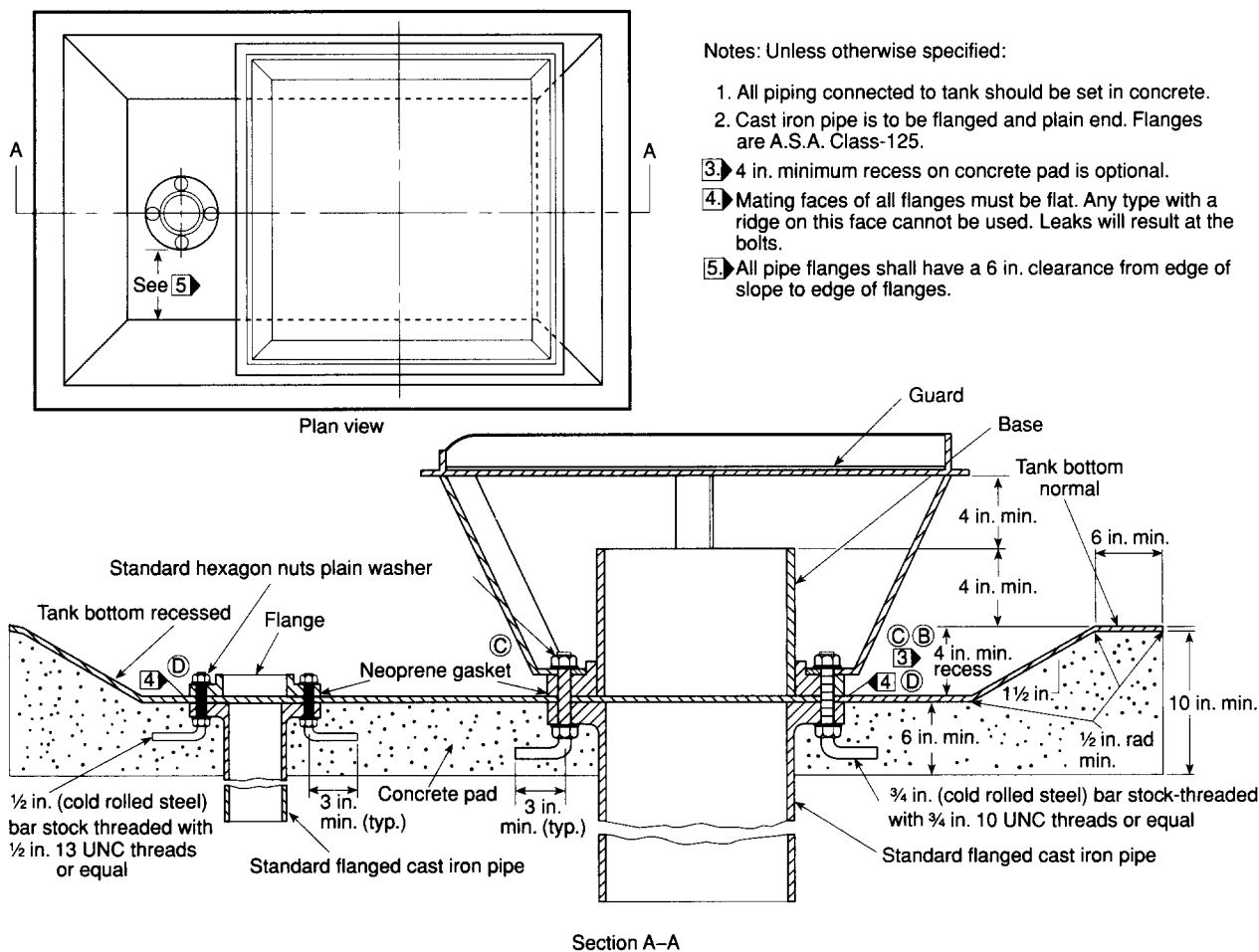


Figure B-5 Typical installation details of an embankment-supported coated fabric suction tank including fittings.



For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

Figure B-6 Inlet-outlet fitting assembly, vortex plate assembly, and sump drain fitting for embankment-supported coated fabric suction tank.

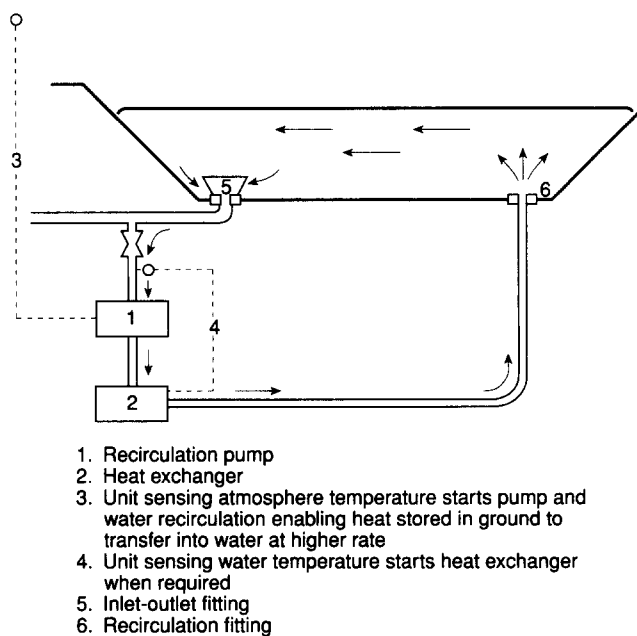


Figure B-7 Embankment-supported coated fabric suction tank recirculation and heating schematic.

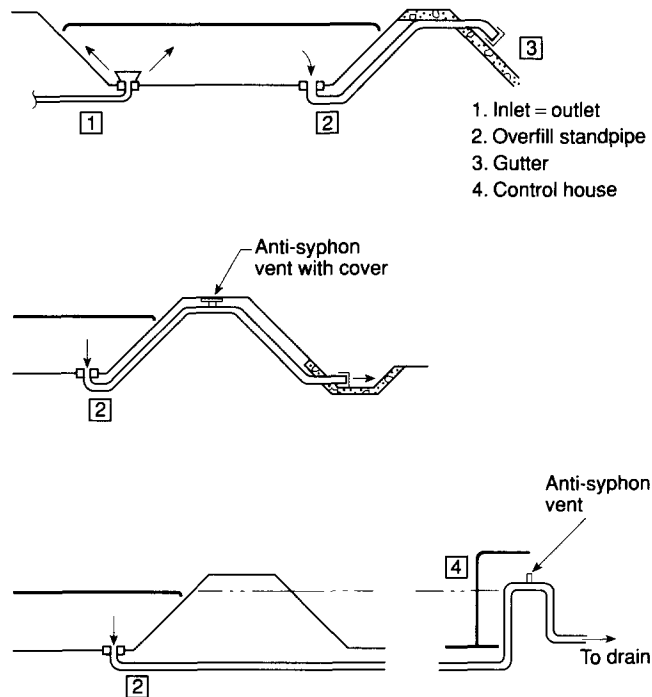
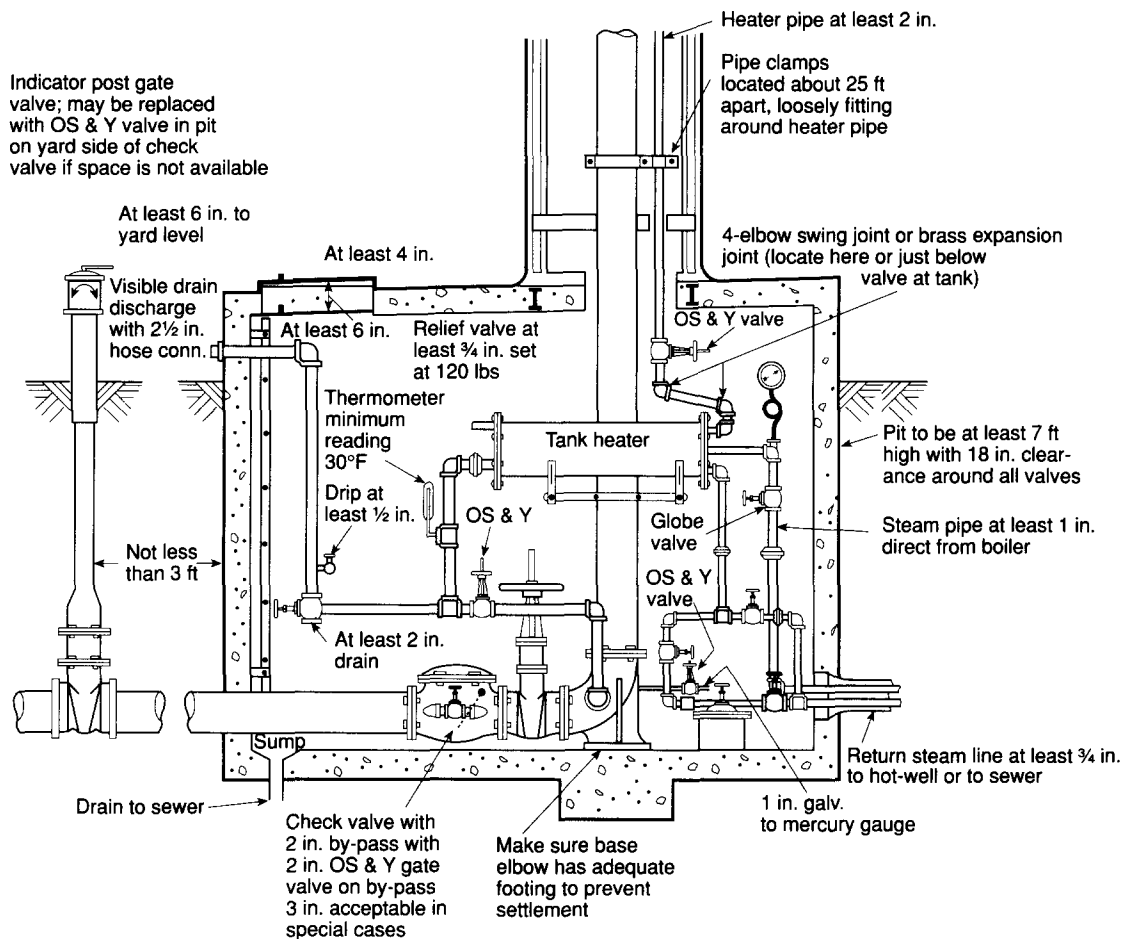
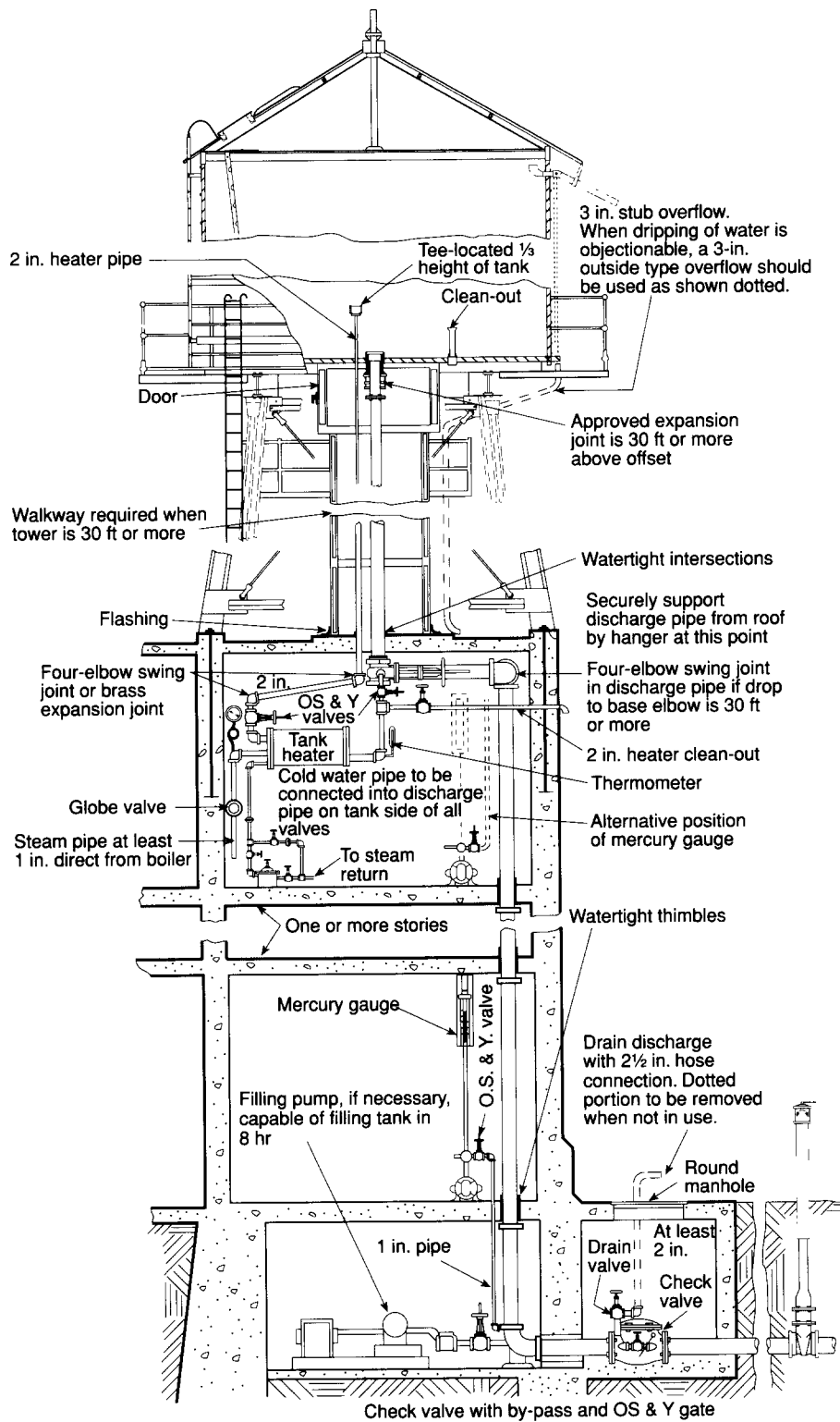


Figure B-8 Embankment-supported coated fabric suction tank overfill standpipe alternates — protect from freezing.



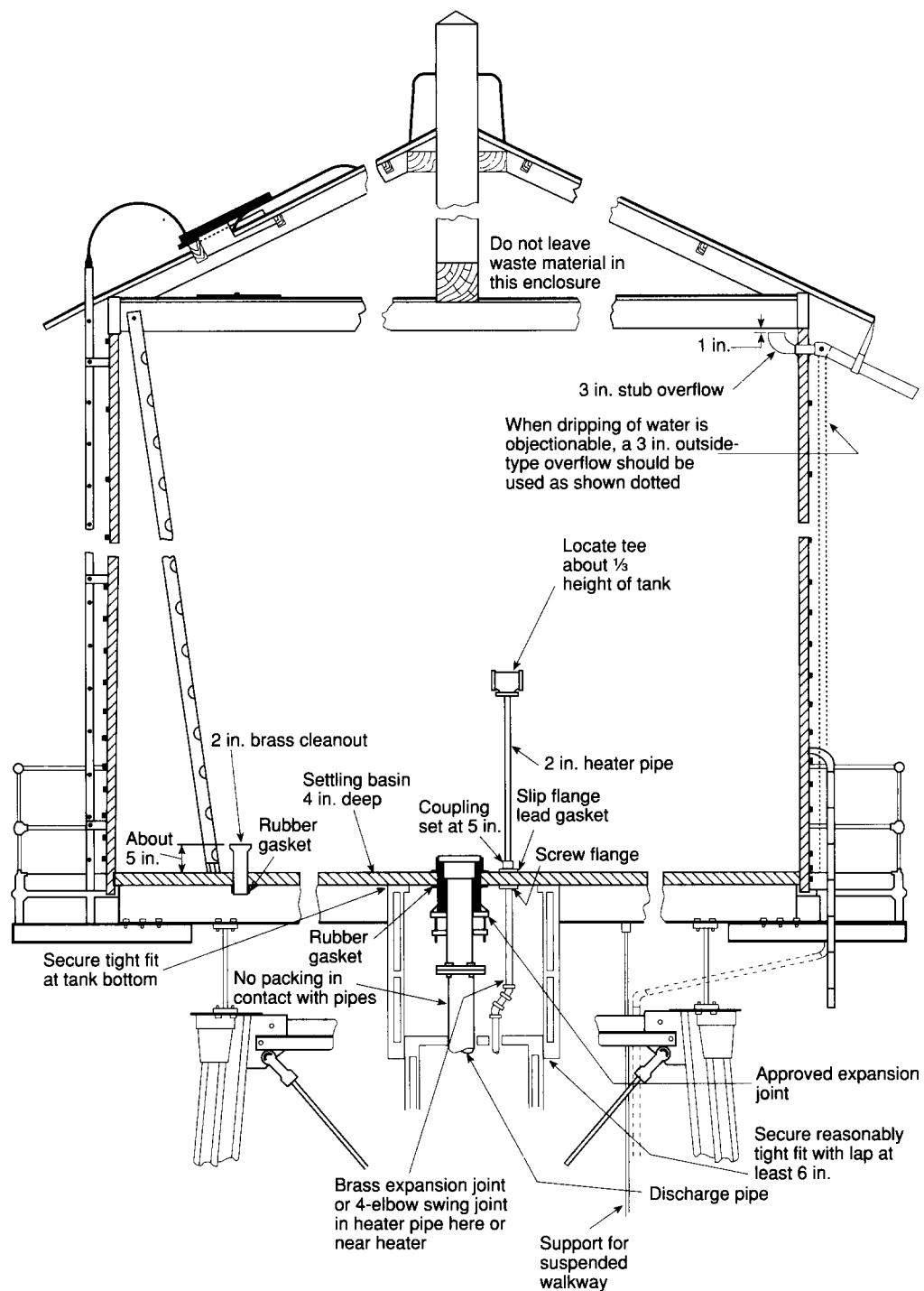
For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

Figure B-9 Valve pit and tank connections at base of riser.



For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

Figure B-10 Connections for tank located over building.



For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

Figure B-11 Typical tower-supported wood tank.

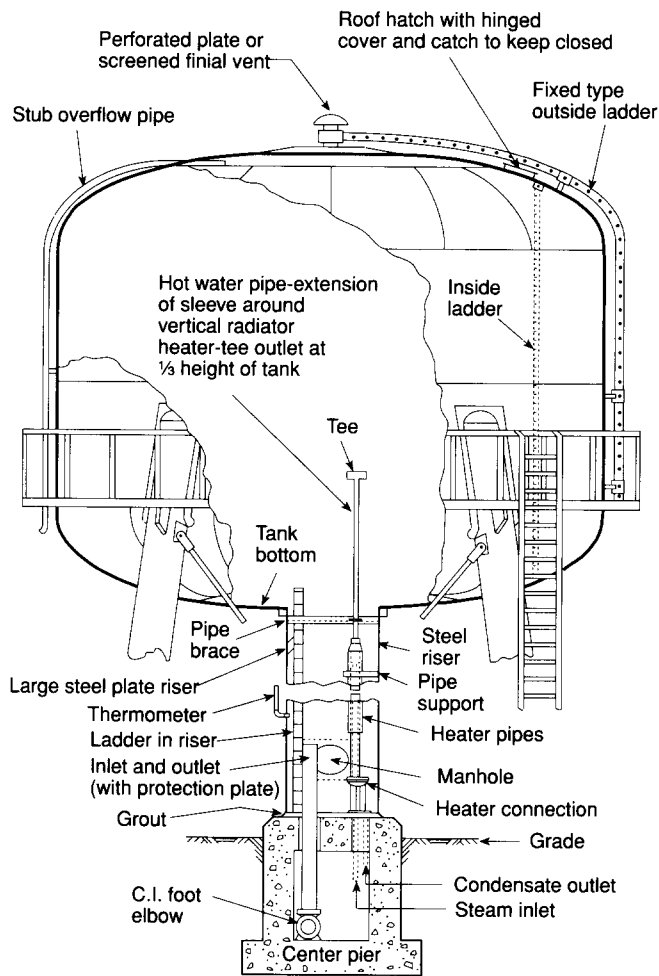
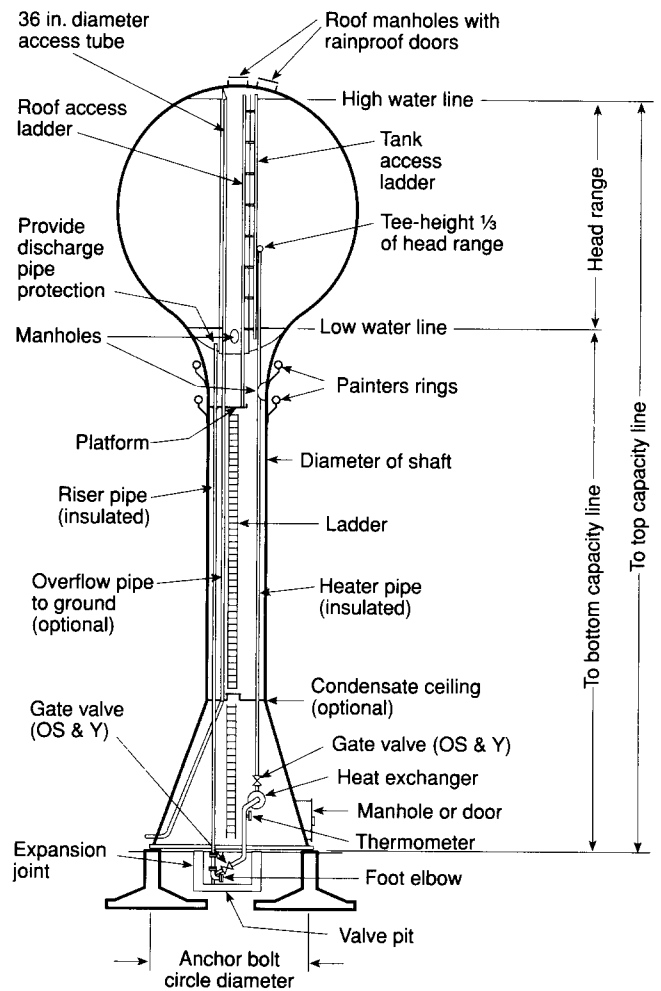
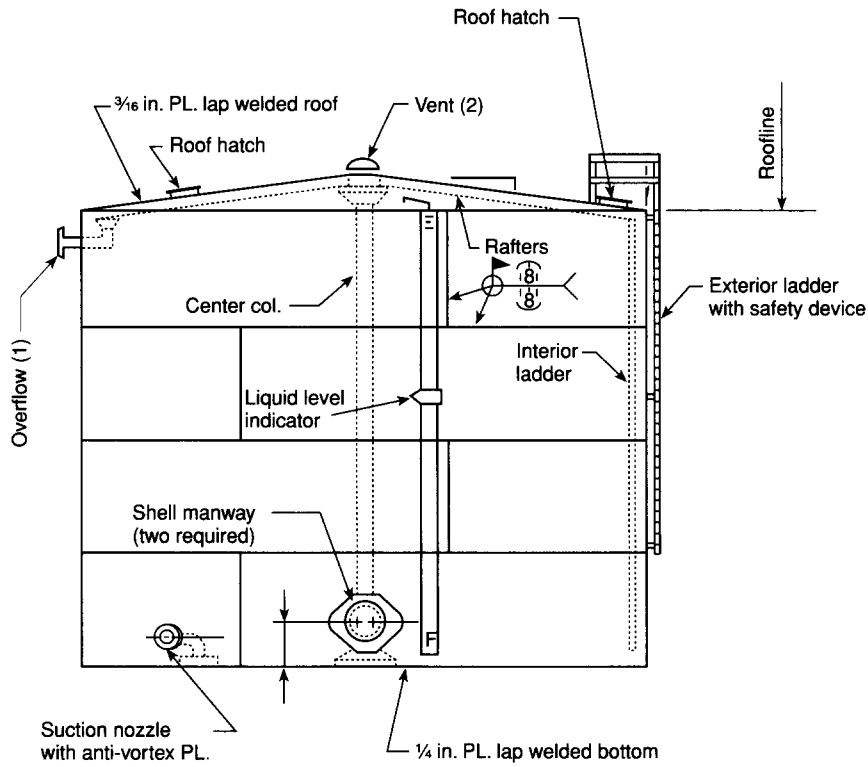


Figure B-12 Typical tower-supported double ellipsoidal tank.

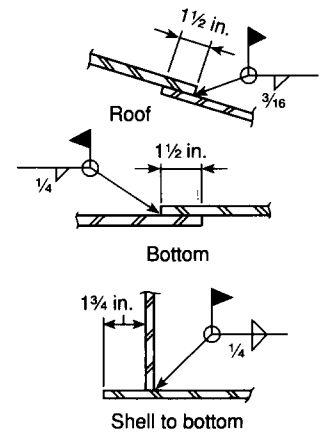


For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

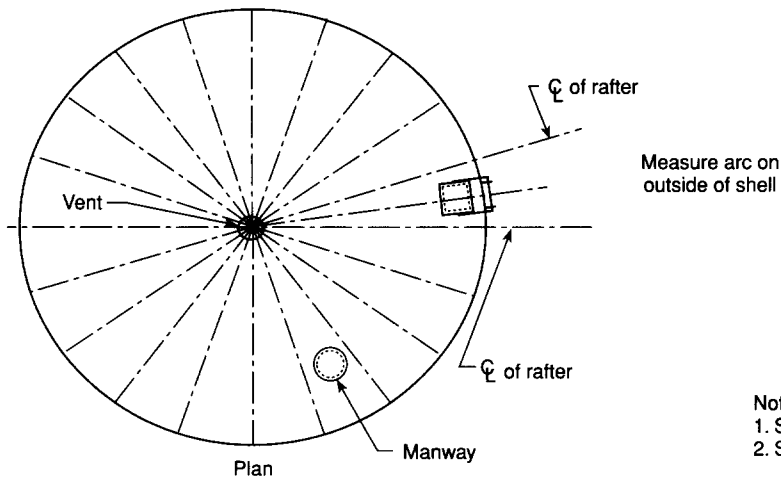
Figure B-13 Typical pedestal tank.



Elevation



Welding detail



Plan

- Notes:
1. See Section 11-5.
 2. See Section 2-6.

Figure B-14(a) Welded steel suction tank.

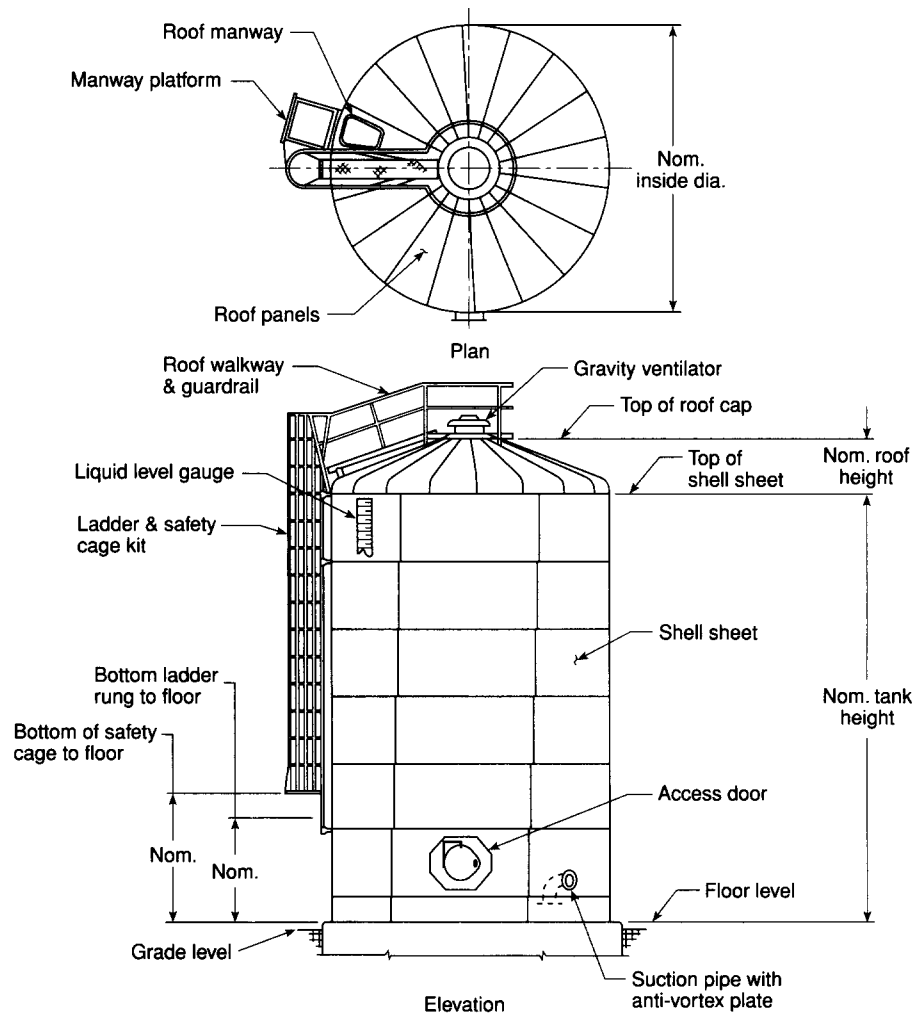


Figure B-14(b) Lap-jointed bolted steel tank.