ANSI/NFPA 22 An American National Standard June 10, 1987

NFPA 22
Water Tanks for Private Fire Protection
1987 Edition

NFPA

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

NOTICE

All questions or other communications relating to this document should be sent only to NFPA Headquarters, addressed to the attention of the Committee responsible for the document.

For information on the procedures for requesting Technical Committees to issue Formal Interpretations, proposing Tentative Interim Amendments, proposing amendments for Committee consideration, and appeals on matters relating to the content of the document, write to the Secretary, Standards Council, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

A statement, written or oral, that is not processed in accordance with Section 16 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Users of this document should consult applicable Federal, State and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action which is not in compliance with applicable laws and this document may not be construed as doing so.

Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

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.

Statement on NFPA Procedures

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accepts any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

NFPA has no power or authority to police or enforce compliance with the contents of this document and any certification of products stating compliance with requirements of this document is made at the peril of the certifier.

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 3376 QUINCY, MA

POSTAGE WILL BE PAID BY ADDRESSEE

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269-9904

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 3376 QUINCY, MA

POSTAGE WILL BE PAID BY ADDRESSEE

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269-9904

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 3376 QUINCY, MA

POSTAGE WILL BE PAID BY ADDRESSEE

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269-9904

NFPA 22

Standard for

Water Tanks for Private Fire Protection

1987 Edition

This edition of NFPA 22, *Standard for Water Tanks for Private Fire Protection*, was prepared by the Technical Committee on Water Tanks, released by the Correlating Committee on Water Extinguishing Systems, and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 18-21, 1987 in Cincinnati, Ohio. It was issued by the Standards Council on June 10, 1987, with an effective date of June 30, 1987, and supersedes all previous editions.

The 1987 edition of this standard has been approved by the American National Standards Institute.

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.

Origin and Development of NFPA 22

In 1909, the NFPA Committee on Gravity Tanks presented a *Standard on Gravity Tanks* which, 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.

Committee on Water Extinguishing Systems and Related Equipment

Correlating Committee

Paul D. Smith, *Chairman*
Gage-Babcock & Associates, Inc.

John K. Bouchard, *Secretary*
National Fire Protection Association
(Nonvoting)

Wayne E. Ault, Rolf Jensen & Assoc., Inc.
Thomas J. Brown, Jr., Factory Mutual Research Corp.
Casmir J. Drygas, Jr., M&M Protection Consultants
Robert H. Merz, Moorestown, NJ
James W. Nolan, James W. Nolan Co.
Chester W. Schirmer, Schirmer Engineering Corp.
J. Samuel Slicer, West Chatham, MA

Technical Committee on Water Tanks

Robert H. Merz, *Chairman*
Moorestown, NJ

Harry Blumenfeld, Stone & Webster Engineering Corp.
Richard J. Davis, Factory Mutual Research
Ladell R. Milam, Automatic Sprinkler Corp. of America
Rep. NFSA
John C. Murphy, Pitts-Des Moines Inc.
Rep. Steel Plate Fabricators Assn. Inc.
Edward C. Nieshoff, Owens-Corning Fiberglas Corp.
Rep. SPI
Charles R. Prasso, Industrial Risk Insurers
Wallace Rosenwach, Rosenwach Tank Co., Inc.
Rep. Nat'l. Wood Tank Inst.
Isaac Siskind, IRM Insurance

Alternates

Jane I. Lataille, Industrial Risk Insurers
(Alternate to C. R. Prasso)
Harrison W. Riepen, Hall-Woolford Wood Tank Co., Inc.
(Alternate to W. Rosenwach)
William Testa, Grinnell Fire Protection Systems Co., Inc.
(Alternate to L. Milam)

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.

Contents

NFPA 22

Standard for

Water Tanks for Private Fire Protection

1987 Edition

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 11.

Chapter 1 Introduction

1-1 Scope. This standard is the minimum for the design, construction, installation, and maintenance of tanks and accessory equipment supplying water for private fire protection, including gravity, suction, and pressure 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 covers 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."

NOTE: 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 or 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 which is in a position to determine compliance with appropriate standards for the current production of listed items.

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.

NOTE: 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.

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*, Sections 2-4, 2-5, and 2-6.

1-5.2 Whenever possible, standard sizes of tanks and heights of towers shall be used as given in 2-1.3, 3-1.2, 4-1.3, and 5-2.1.

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-7-1.1.*) 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 When steel or iron is used for supports inside the building near combustible construction or occupancy, it shall be fireproofed inside the building, 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-7-1.1.*) Steel beams or braces joining two building columns which support a tank structure shall also be suitably fireproofed when 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. Types of materials include steel, wood, concrete, and embankment-supported rubberized fabric. The elevated wood and steel tanks are supported on steel or reinforced concrete towers.

1-8 Welding. Steel gravity and suction tanks and steel plate risers shall preferably be of welded construction and the joint design and the welding shall fully conform to the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2). The tank builder shall present to the authority having jurisdiction evidence that said rules have been complied with. The authority may accept a written certificate from the builder as evidence that said rules have been complied with or may require a certificate from a qualified consulting engineer or commercial testing laboratory. In either case the certificate shall be supplemented with evidence satisfactory to the authority that the said rules have been complied with in the following four particulars:

1-8.1 That all welding procedures used have been qualified in accordance with the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2). The evidence of such qualification shall be presented in the form of a report bearing proper witness certification of a reputable testing laboratory.

NOTE: See also NFPA 422M, *Manual for Aircraft Fire and Explosion Investigators*.

1-8.2 That all welding operators employed on the job were qualified in accordance with the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2).

1-8.3 That welded joints have been tested by the sectioning or radiographic methods as required by the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2).

1-8.4 That the tank has been subjected to the required hydrostatic test.

1-9 Bolting. Factory-coated bolted-steel tank construction may be employed in special situations for grade level gravity and pump suction tanks, subject to the authority having jurisdiction. In such cases, bolted designs shall comply with AWWA D103, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*. The work shall be handled by experienced contractors who will ensure that careful workmanship and expert supervision is employed and who can provide a bond guaranteeing the watertightness of the tank.

1-10 Workmanship.

1-10.1 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; also, that they shall replace all parts that may be found defective from faulty materials or workmanship, or that are not in accordance with this standard.

1-10.2 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 when 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.

1-11 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.

1-12 Engineer's Authority.

1-12.1 The engineer shall have the power to reject materials and workmanship that do not conform to this standard, but, in case of dispute, the contractor may appeal to the authority having jurisdiction.

1-12.2 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 made good by the contractor.

1-12.3 Facilities for Inspection. Material and workmanship shall at all times be subject to the inspection of engineers representing the purchaser.

1-13 Tank Contractor Responsibility.

1-13.1 Upon completion of a tank construction contract, and having tested the tank and made it watertight, the tank contractor shall notify the authority having jurisdiction so that the tank can be inspected and given the formal approval necessary.

1-13.2 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.

1-14 Inspection of Completed Equipment.

1-14.1 A joint inspection of the tank shall be made by a representative of the tank contractor and a representative of the owner prior to placing the tank in service.

1-14.2 Written reports of these inspections shall be made in triplicate and a copy signed by the contractors and the owners shall be sent to the authority having jurisdiction.

1-15 Attachments to Tank Structures. Tank structures shall not be employed to support signs, flagpoles, steel stacks, etc., unless particulary designed for the purpose.

1-16 Lightning Protection. To prevent lightning damage to tanks, protection shall be installed to conform to Section 4-4 of NFPA 78, *Lightning Protection Code*.

1-17 Care and Maintenance.

1-17.1 No waste material such as boards, roofing, paint cans, etc., shall be left in the tank or in the space at the top of the tank since it may get into the water and obstruct the piping.

1-17.2 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.

1-17.3 Ice that may cause injury to personnel or damage to property shall not be allowed to collect in or on any part of the tank or structure.

1-17.4 Bases of the 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.

1-17.5 Coal or ashes or combustible material or construction of any kind shall not be piled near the columns. This may cause failure of the steelwork due to fire, heating, or corrosion. The tank site shall be kept cleared of weeds and brush.

1-17.6 Examination of all points, including the inside of steel tanks without corrosion protection (*see A-2-7.13*) and the hoops and grillage of a wood tank, shall be made at least once in two years. Steelwork without corrosion protection shall be kept painted to prevent the formation of rust. Frequent repainting may be necessary when the paint is exposed to conditions causing rapid disintegration.

1-17.7 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 may be necessary or economical to repaint the entire inside surface. On the exterior, normal maintenance will involve local patching and periodic application of one complete finish coat when the preceding has weathered thin or for improved appearance after patching.

1-17.8 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 the completion of the job.

1-17.9 If corrosion protection is maintained in a steel tank (*see A-2-7.13*), the tank shall be cleaned often enough to prevent sediment and scale from entering the discharge pipe.

1-17.10 Repairs to the interior of the tank shall not be made with materials that may become dislodged and obstruct the outlet pipe. The authority having jurisdiction shall always be notified in advance when and for how long the tank is to be out of service.

1-18 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI).[1] One unit (bar) outside of, but recognized by SI, is commonly used in international fire protection. These units are listed in Table 1-18 with conversion factors.

Table 1-18

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

[1]For additional conversions and information see ASTM E380, *Standard for Metric Practice.*

1-18.1 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

1-18.2 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 Steel Gravity and Suction Tanks

2-1 General.

2-1.1 This chapter applies to the design, fabrication, and erection of steel gravity water tanks, including pump suction tanks.

2-1.2 Capacity. The capacity of the tank is the number of U.S. gallons (cubic meters) 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 (cubic meters) 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 (cubic meters) between the inlet of the overflow and the level of the vortex plate.

2-1.3 Standard Sizes. The standard sizes of steel tanks are: 5000 (18.93), 10,000 (37.85), 15,000 (56.78), 20,000 (75.70), 25,000 (94.63), 30,000 (113.55), 40,000 (151.40), 50,000 (189.25), 60,000 (227.10), 75,000 (283.88), 100,000 (378.50), 150,000 (567.75), 200,000 (757.00), 300,000 (1135.50), and 500,000 (1892.50) U.S. gallons (cubic meters) net capacity. Tanks of other sizes are built.

2-1.4 Form. Steel tanks may be of any form desired provided they conform to this standard throughout.

2-1.5 Strength. The material as specified shall be without defects affecting its strength or service. The workmanship shall be good, so that defects or injuries are not produced during manufacture or erection. Unit stresses as specified shall not be exceeded. This structure and its details shall possess the requisite strength and rigidity.

2-2 Materials.

2-2.1 Plates, Shapes, and Tubular Columns.

2-2.1.1 Plates. Plate materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to the following ASTM Specifications: A36; A283, Grades A, B, C, and D; except that when plates of thickness greater than ¾ in. (19.1 mm) are used, A283, Grade D steels shall not be specified; as alternatives, A285, Grades A, B, and C; A516, Grades 55 and 60; A442, Grades 55 and 60; or A131, Grades A, B, and C may be used.

2-2.1.2 Basis of Furnishing Plates. Plates may be furnished on the weight basis with permissible underrun and overrun according to the tolerance table for plates ordered to weight published in ASTM Specification A6.

2-2.1.3 Shapes. Structural materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to ASTM A36, A113, Grades A and B; or A131, Grades A, B, and D.

2-2.1.4 Tubular Columns. Steel pipe may be used as tubular columns or other structural members, provided it complies with specifications ASTM A139, Grade B; ASTM A53, Type E or S, Grade B; API Specification 5L, Grade B; and providing 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 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.

2-2.1.5 Copper-bearing steel with content of about 0.20 percent copper may be used. In other particulars the steel shall conform to the specifications enumerated above.

2-2.2 Bolts, Anchor Bolts, and Rods. Bolts and anchor bolts shall conform to ASTM Specification A307, Grade A or B. ASTM A36 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 A36.

2-2.3 Forgings. Forgings shall conform to the following Specifications of the American Society for Testing and Materials. Steel shall be made only by the open-hearth process.

Forgings for Piping Components — A105.

Forgings for General Use — A668 — Class B.

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

Forgings for General Purpose Piping — A181 — Class 60 and 70.

Forgings for Piping Components — A105.

2-2.4 Castings. Castings shall conform to ASTM Specifications A27, Grade 60-30 full annealed.

2-2.5 Reinforcing Steel. Reinforcing steel shall comply with ASTM Specification A615, Grade 40 or Grade 60.

2-2.6 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.

2-2.7 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 are acceptable when approved by the authority having jurisdiction.

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/cu ft and of concrete, 144 lb/cu ft (7849 and 2307 kg/m^3, respectively).

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 as 62.4 lb/cu ft (1000 kg/m^3). Proper provisions 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/sq ft (122 kg/m^2) on the horizontal projection.

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

2-3.4 Earthquake Load. Tanks shall meet requirements for resisting earthquake damage by complying with the earthquake design provisions of American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2).

2-3.5 Balcony and Ladder Loads. A vertical load of 1,000 lb (454 kg) shall be assumed to be applied to any 10 sq ft (0.93 m^2) of area on the balcony floor and on each platform; 500 lb (227 kg) applied to any 10-sq ft (0.93-m^2) area on the tank roof; 350 lb (159 kg) on each vertical section of ladder; and all of the structural parts and connections shall be designed to withstand such loads. The above loadings need not be combined with snow loading.

2-4 Unit Stresses.

2-4.1 General. The maximum stresses in pounds per square inch (MPa) produced by the foregoing loads, or any combination of them, shall not exceed the values in Table 2-4.1.

2-4.2 Stress Increases. When wind or earthquake loads are considered in calculating stresses, the permissible working unit stresses may be increased 25 percent, provided that the resulting section is not less than that required for dead and live loads alone; however, in the design of concrete foundations the increase may be 33.3 percent. Wind and earthquake loads need not be considered simultaneously.

Table 2-4.1

	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	$\frac{9{,}000{,}000}{\frac{ld}{bt}}$	$\frac{62\ 055}{\frac{(l)(d)}{(b)(t)}}$

in which l is the unsupported length and d the depth of the member; b is the width; and t the thickness of its compression flange; all in inches (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.

	PSI	MPa
Pins, extreme fiber	22,500	155.15
Cast steel	11,250	77.57

2-5 Details of Design.

2-5.1 Minimum Thickness.

2-5.1.1 The minimum thickness for any part of the structure shall be 3/16 in. (4.8 mm) for parts not in contact and 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 for tubular columns and struts shall be 1/4 in. (6.4 mm). Round or square bars used for wind bracing shall have a minimum diameter or width of 3/4 in. (19.1 mm). Bars of other shapes, if used, shall have a total area at least equal to a 3/4-in. (19.1-mm) round bar.

Exception: Roof plates for suction tanks with cone roofs may be 7 gage (0.1792 in.) sheet.

2-5.1.2 Cylindrical shell plates in contact with water shall have minimum thicknesses as specified in Table 2-5.1.2.

Table 2-5.1.2

	Diameter			
	<50 ft	50-120 ft	120-200 ft	>200 ft
Bottom ring	1/4 in.	1/4 in.	5/16 in.	3/8 in.
Upper rings	3/16 in.	1/4 in.	5/16 in.	3/8 in.

2-5.2 Thickness for Corrosion. Interior bracing required to support the water content, if unavoidable, shall always have 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 which must be hermetically sealed to prevent internal corrosion. The plates of tanks to contain salt or alkaline water shall be 1/16 in. (1.6 mm) thicker than calculated.

2-5.3 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 the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2).

2-5.3.1 Plate surfaces susceptible to complete stress analysis shall be designed on the basis of a maximum membrane tensile stress of 15,000 lb/sq in. (103.43 MPa). Such plate surfaces include those not stressed by the concentrated reaction of supporting members or riser pipes.

2-5.3.2 Plate surfaces not susceptible to complete stress analysis shall also be designed on the basis of a maximum membrane tensile stress of 15,000 lb/sq in. (103.43 MPa) after making reasonable allowances for such loads and stresses as cannot be accurately determined. The maximum membrane tensile stress shall in no case exceed 11,000 lb/sq in. (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 lb/sq in. (75.85 MPa) reduced for the joint efficiencies.

2-5.3.3 As an alternate to 2-5.3.1 and 2-5.3.2, tank shell plates for suction tanks may be designed on the basis of the stresses, material selection, and inspection set forth in Appendix C of the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2) provided all requirements of that Appendix are met.

2-5.3.4 Where compressive stresses exist, plate thickness shall be chosen to prevent local buckling.

2-5.4 Thickness of Flat Bottoms. The thicknesses of plates in flat bottoms shall be not less than those given in Table 2-5.4.

2-5.5 Accessibility of Bottoms. Grillages shall be designed so that the tank bottom and beams will be accessible for inspection and painting.

2-5.6 Net Sections. Net sections shall be used in calculating the tensile stress in plates and members.

2-5.7 Load Location. In calculating the thickness of plates (except as specified in 2-5.3) 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 area of the ring. In welded tanks the longitudinal joints in adjacent circumferential courses may be either staggered or in alignment. Welded joints crossing each other shall be grooved and welded continuously through the intersections.

2-5.8 Opening Reinforcement. 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 may be 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 attach-

Table 2-5.4

Thickness in Inches of Bottom Plates for Flat-Bottom Tanks

Type of Support		Depth of Water (ft) 10	12	14	16	18	20	22	24	26	28	30	40
Steel or Concrete Beams	12	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16	3/8
	14	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16	3/8	3/8	7/16
	16	5/16	5/16	5/16	5/16	5/16	5/16	3/8	3/8	3/8	3/8	3/8	7/16
Distance in clear between Beams in inches	18	5/16	5/16	5/16	5/16	3/8	3/8	3/8	3/8	7/16	7/16	7/16	1/2
	20	5/16	5/16	3/8	3/8	3/8	7/16	7/16	7/16	7/16	1/2	1/2	9/16
	24	3/8	3/8	7/16	7/16	7/16	1/2	1/2	1/2	9/16	9/16	9/16	11/16
Concrete Slab or Earth Grade		1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

ment. 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.

2-5.8.1 Sufficient welding shall be provided to transmit to the plate the full net strength of the reinforcing ring or flange. 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 may 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.

2-5.9 Roofs. All tanks shall have roofs.

2-5.10 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, except that 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 may be considered as adequately laterally braced by friction between the roof plate and the top flange; and except that the roof purlin depth may be less than 1/30 of the span length; and, except that 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.

2-5.11 Welded Joints. The types of joints used and their design shall conform to the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2).

2-6 Workmanship.

2-6.1 Plate Edges. The plate edges to be welded may be universal mill edges or they may be prepared by shearing, machining, chipping, or mechanically guided oxygen cutting, except that edges of irregular contour may be prepared by manually guided oxygen cutting. When edges of plates are oxygen cut, the surface obtained shall be uniform and smooth and shall be cleaned of slag accumulations before welding.

2-6.2 Rolling. Plates shall be cold rolled to suit the curvature of the tank and the erection procedure in accordance with Table 2-6.2:

Table 2-6.2

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

2-6.3 Double-Curved Plates. Plates which are curved in two directions may be pressed either cold or hot or may be dished with a "mortar and pestle" die by repeated applications.

2-6.4 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.

2-6.5 Welding. Welding shall conform to the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2). (*See Chapter 3.*)

2-6.6 Fitting Roofs. The roof shall fit tightly to the top of the tank to prevent circulation of air over the surface of the water. When a spider is used it shall not obstruct the flow of water into the overflow inlet.

2-6.7 Preventing Ice Damage. The contractor shall keep the tank, structure, and building roofs free of ice caused by leakage during the construction and until the tank equipment is made watertight.

2-6.8 Coating for Bottom Plates on Soil or Concrete. (*See also Sections 6-1 and 6-2.*)

2-6.8.1 The underside of all bottom plates shall be protected against corrosion by one of the following methods: (a) apply two coats of paint after the bottom has been completely welded, (b) erect bottom on oil-saturated sand cushion.

2-6.8.2* When 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.

2-6.9 Testing.

2-6.9.1 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:

(a) Air pressure or vacuum may be applied to the joints, using soap suds, linseed oil, or other suitable material for the detection of leaks.

(b) The joints may be tested by the magnetic particle method.

2-6.9.2 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 that are disclosed in this test in the shell, bottom, or roof (if the roof contains water) 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.

2-6.9.3 Disposal of Test Water. The purchaser shall provide means for disposing of test water up to the tank inlet or drain pipe.

2-7 Accessories.

2-7.1 Connections. Connections shall be provided on the tank for the necessary pipes, braces, frost-casting, and walkway supports.

2-7.2 Roof Vent.

2-7.2.1 When 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 ⅜-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 may be combined with the roof finial. Equivalent venting may be used provided the area cannot be obstructed by sleet and the ingress of birds or other animals is prevented.

2-7.2.2 When 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.

2-7.3 Roof Anchorage. Each roof plate shall be securely fastened to the top of the tank.

2-7.4 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 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 may be bolted to the hatch if required for ventilation during painting. The flange shall be drilled with at least four 13/16-in. (20.6-mm) diameter holes on a 30¼-in. (768-mm) diameter bolt circle.

2-7.5 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 opening 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.

2-7.6 Outside Fixed Shell and Roof Ladder.

2-7.6.1 The outside tank ladder for suction and multiple-column-supported gravity tanks shall be fixed at least 7 in. (178 mm) between the tank side and 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, and there shall be at least 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.

2-7.7 Inside Ladder.

2-7.7.1 The inside fixed ladder provided for passage between the roof hatch and tank bottom shall not be rigidly connected to the bottom plates.

2-7.7.2 A ladder shall extend from the top to the bottom of the inside of 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 being located at the top of the riser.

2-7.7.3 All ladders exceeding 20 ft (6.1 m) shall be equipped with a cage, a rigid notched rail, or other listed ladder safety device.

2-7.8 Ladder Bars and Rungs. Ladder side bars shall be not less than 2 in. (51 mm) × ½ in. (12.7 mm) or 2½ in. (64 mm) × ⅜ in. (9.5 mm). Side bars shall be spaced at least 16 in. (406 mm) apart. Rungs shall be at least ¾ 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).

2-7.9 Repainting. (*See 1-17.7.*)

2-7.10 Painting Inaccessible Parts. Parts inaccessible after fabrication, but subject to corrosion, shall be protected by paint before assembly, except surfaces in watertight joints shall be coated with clear oil or lacquer. This requirement is not applicable to the overlapping surfaces of single-welded lap joints above the high water line.

2-7.11 Painting.

2-7.11.1 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 per SSPC-SP10 or Pickling per SSPC-SP8 and primed in accordance with the requirements for Inside Paint System No. 2 (wash primer per SSPC-PT3 plus one coat of vinyl per SSPC — Paint No. 9) or inside paint system No. 4 (one coat of vinyl paint per Bureau of Reclamation Specification VR-3) of AWWA Standard D102.

2-7.11.2 All exterior surfaces and inside dry surfaces (pedestal tanks) shall be cleaned by commercial blasting per SSPC-SP6 or Pickling per SSPC-SP8 and primed with one coat of red lead alkyd per Type II or III of Federal Specification TT-P-86 or a suitable proprietary primer, all in accordance with the requirements for Outside Paint System No. 1 of AWWA Standard D102.

2-7.11.3 The appropriate primers for other interior and exterior paint systems may be used provided permission is first obtained from the authority having jurisdiction.

2-7.11.4 After construction, all weld seams, unprimed margins, and any areas on which the primer (if preprimed) has been damaged shall be blast cleaned and patch primed with the same primer.

2-7.11.5 All finish coat painting for interior (wet) surfaces shall be in accordance with the requirements for Inside Paint Systems No. 2 or No. 4 of AWWA Standard D102, utilizing the same basic system throughout. For System No. 2, one complete field coat of vinyl per SSPC — Paint No. 9 and two complete coats of vinyl aluminum per SSPC — Paint No. 8 shall be used to provide a minimum total system dry film thickness of 4.5 mils (112 microns). As an alternate, the two final coats may be white vinyl per Bureau of Reclamation Specification VR-3 to provide a minimum total system dry film thickness of 5.0 mils (125 microns). A 5.0-mil (125-micron) minimum total thickness with one additional coat may be specified by the purchaser. For System No. 4, three complete field coats in contrasting colors of vinyl paint per Bureau of Reclamation Specification VR-3 shall be used to provide a minimum total system dry film thickness of 6.0 mils (150 microns).

2-7.11.6 All exterior and inside dry finish coat painting shall be in accordance with the requirements for Outside Paint System No. 1 of AWWA Standard D102 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 microns) for aluminum finishes and 4.5 mils (112 microns) for alkyd enamels. As provided for by Outside Paint System No. 4 of AWWA D102, the purchaser may specify an extra complete coat of primer for a total minimum system dry film thickness of 5.0 mils (125 microns) for aluminum finishes and 6.0 mils (150 microns) for alkyd enamels for the more severe atmospheric exposures.

2-7.12 Other finish coats may be used provided they are compatible with the primers and provided permission is first obtained from the authority having jurisdiction.

2-7.13* Painting Application. All painting shall be accomplished in accordance with the appropriate requirements of *Steel Structures Painting Council Paint Application Specification No. 1 (Shop, Field and Maintenance Painting).*

Chapter 3 Pressure Tanks

3-1 General.

3-1.1 Service. Pressure tanks may 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.

3-1.2 Capacity. The capacity shall be as approved by the authority having jurisdiction.

3-1.3 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 psi (5.2 bars) by the gage shall be maintained. As the last of the water leaves the pressure tank, the residual pressure shown on the gage shall not be less than zero, and shall be sufficient to give not less than 15 psi (1.0 bars) pressure at the highest sprinkler under the main roof of the building.

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

3-1.4* Airlock. Methods used for prevention of airlock shall be as approved by the authority having jurisdiction in each particular case.

3-1.5 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 may be located in the basement or elsewhere. (See 3-1.9.)

Exception No. 2.: Subject to the approval of the authority having jurisdiction, tanks may be buried in accordance with the requirements of 3-1.10.

3-1.6 Construction.

3-1.6.1 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 permits the fusion process of welding with certain regulations for strength, qualification of welders, and tests.

3-1.6.2 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 psi (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 ½ psi (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 may 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.

3-1.6.3 Supports. The supports shall be steel or reinforced concrete, 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 7-4 for steel towers. For horizontal tanks there shall be at least one support near each end of the tank and these supports so located that combined stresses in any part of the tank shall not exceed those specified in 3-1.6.1.

3-1.6.4 Painting. Tanks shall be cleaned and painted inside and outside in accordance with the requirements of 2-7.11, 2-7.12, and 2-7.13. One of the stamps required by the ASME Specifications for Material and also one of the ASME Standard Pressure Vessel stamps shall not be rendered illegible.

3-1.7 Care and Maintenance. 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.

When repainting is needed, the basic procedures set forth by 1-17.7 shall be followed. Each relief valve shall be tested at least once each month.

3-1.8 Marking.

3-1.8.1 General. All stamps required by the ASME Specification shall be applied. The nameplate or water-level marking (*see 3-1.8.2 and 3-1.8.3*) 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.

3-1.8.2 Nameplate. A metal nameplate large enough to contain the following information, with raised or stamped letters and numbers of sufficient size to be easily read, shall be provided:

Name and location of manufacturer;
Year of erection;
Length and diameter;
Total capacity [gal (m^3)];
Working pressure [psi (bars)].

3-1.8.3 Water-level Indicator. The nameplate shall also serve for the water-level indicator bearing an easily observed raised arrow, and raised or stamped lettering "⅔ capacity line" shall be secured to the tank plate behind the gage 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: When the design water level is at some point other than the ⅔ level, the nameplate should be so lettered and positioned behind the gage glass accordingly.

3-1.9 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.

3-1.10 Buried Tanks.

3-1.10.1 Where lack of space or other conditions require it, pressure tanks may be buried if the following requirements are satisfied.

3-1.10.2 For protection against freezing the tank shall be below frost line.

3-1.10.3 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-3-1*).

3-1.10.4 The exterior surface of the tank shall be fully coated as follows for protection against corrosion conditions indicated by a soil analysis:

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

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

3-1.10.5 The tank shall be above the maximum ground water level so that buoyancy of the tank where empty will not force it upward. An alternative would be to provide a concrete base and anchor the tank to it.

3-1.10.6 The tank shall be designed with strength to resist the pressure of earth against it.

3-1.10.7 A manhole shall be located preferably on the vertical centerline of the tank end to clear the knuckle while remaining as close as possible to it (*see Figure B-3.1*).

3-2 Pipe Connections and Fittings.

3-2.1 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.

3-2.2 Tank Discharge. The discharge pipe shall be sized to supply the required amount of water for the fire protection system, but in no case less than 4 in. in size. 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 O.S.&Y. gate valve shall be located in the discharge pipe, directly under or near the tank. The pipe shall be adequately supported.

3-2.3 Filling Pipe. The water-filling pipe shall be at least 1½ in. 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 may be connected to the top or bottom of the tank as required by the authority having jurisdiction. (*See Figures B-3-1 and B-3-2.*) 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 being placed between the check valve and the tank.

3-2.4 Air Pipe. The air supply pipe shall be at least 1 in. in size, well-supported, and protected from breakage. It shall be connected to the tank above the water level (*see Figures B-3-1 and B-3-2*). A horizontal bronze-seat swing-check valve and a listed renewable-disc globe valve, both of reliable make, shall be provided in the pipe near the tank, the globe valve being placed between the tank and the the check valve.

3-2.5 Water-level Gage. A ¾-in. (19.1-mm) water-level gage with a listed valve at each end shall be provided with the center of the glass tube at the normal water level. The gage glass shall be not over 12 in. (305 mm) long for horizontal tanks or 18 in. (457 mm) for vertical tanks. Listed angle globe valves with renewable discs shall be installed in the connections from the gage to the tank independent of the shutoff valves that are a part of the gage fittings. The water-level gage shall be connected through valves into the tank (*see Figures B-3-1 and B-3-2*). A petcock shall be provided for draining the glass. All fittings and nipples shall be of brass, not less than ¾ in. in size, except that the nipple extending into the tank may be ½ in. in size.

3-2.5.1 The glass gage tube shall be protected from mechanical injury by a guard consisting of at least three ³⁄₁₆-in. (4.8-mm) brass rods.

3-2.5.2 The valves on the water-level gage connections shall be opened only when ascertaining the amount of water in the tank.

3-2.6 Air-pressure Gage. A listed 4½-in. (114-mm) dial, double-spring gage 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 gage and the tank (*see Figures B-3-1 and B-3-2*). The pressure gage 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. in size shall be provided between the valve and the gage for the inspector's gage.

3-2.7 Safety Appliances. A brass relief-valve not less than ¾ in. 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 shall also be a brass relief valve not less than 1½ in. 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.

3-2.8 Emergency Drain. Provision shall be made to drain each tank independently of all other tanks and the sprinkler system by a pipe not less than 1½ in. in size. The drain valve shall be a globe valve with renewable disc, and shall be located near the tank. (*See Figures B-3-1 and B-3-2.*)

3-2.8.1 Use of a drain other than shown in Figures B-3-1 and B-3-2 below the pressure tank, after shutting off other water supplies, is not permitted under any condition, as collapse of the pressure tank may result.

3-2.9 Water Filling Supply. The filling supply or pump shall be reliable and capable of replenishing the water required to be maintained in the tank with the required air pressure restored in not more than 4 hours. A properly designed relief valve shall be provided at the pump as specified in 3-2.7.

3-2.10 Air Compressor. An air compressor, capable of delivering not less than 16 cu ft (0.45 m^3) of free air per minute for tanks of 7,500 gal (28.39 m^3) total capacity and not less than 20 cu ft per minute (0.57 m^3/min) for larger sizes, shall be provided. The compressor must be located in the tank house, unless otherwise permitted by the authority having jurisdiction. A safety valve shall be provided, as specified in 3-2.7.

3-2.11 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.

3-2.12 Watertight Intersections at Roofs and Floors. The intersections of all piping with the building roof and concrete or waterproof floors shall be watertight. (*See 8-1.1.*)

3-2.13 Fire Protection. If there are combustible contents or construction that might heat the tank in case of fire, the tank shall be protected by automatic sprinklers.

Chapter 4 Wood Gravity and Suction Tanks

4-1 General.

4-1.1 This chapter applies to the design, fabrication, and erection of wood gravity water tanks, including pump suction tanks.

4-1.2 Capacity. The capacity of the tank is the number of U.S. gallons (cubic meters) 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.

4-1.3 Standard Sizes. The standard sizes of wood tanks are 5000 (18.93), 10,000 (37.85), 15,000 (56.78), 20,000 (75.70), 25,000 (94.63), 30,000 (113.55), 40,000 (151.40), 50,000 (189.25), 60,000 (227.10), 75,000 (283.88) and 100,000 (378.50) U.S. gallons (cubic meters) net capacity. Tanks of other sizes are built.

4-1.4 Strength. The materials as specified shall have no defects other than those permitted by the grading rules for the lumbers listed in 4-2.2. The use of second-hand materials, including hoops, lumber, etc., is not permitted. The workmanship shall be good so that defects or injuries are not produced during manufacture or erection. Unit stresses, as specified in 4-4.1, shall not be exceeded except where additionally reinforced. (*See 4-6.3, Chime.*) The structure and its details shall possess the requisite strength and rigidity.

4-2 Material.

4-2.1 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.

4-2.2 Lumber—Staves and Bottom.

4-2.2.1 Untreated lumber in the staves and the bottom shall be thoroughly air dried "all heart" or "tank stock" without any sapwood after shaping. Acceptable untreated species are western yellow cedar, redwood, southern white cedar (Dismal Swamp), western red cedar, and Douglas fir (coast type), the varieties being arranged in the order of preference.

4-2.2.2 Western yellow cedar, redwood, or southern white cedar (Dismal Swamp) are advised 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 10-1.9.*)

4-2.2.3 Acceptable treated species include all those listed in 4-2.2.1 and yellow pine, all without sapwood restriction. Treatment shall consist of a 6- to 8-lb/cu ft (96- to 128-kg/m^3) retention of creosote or pentachlorophenol applied after shop fabrication, according to the American Wood Preservers Association by the empty-cell process.

4-2.3 Timber Supports. Wooden dunnage beams when 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 may be used if treated with a 6- to 8-lb/cu ft (96- to 128-kg/m^3) retention of creosote or pentachlorophenol applied according to the standard specifications of the American Wood Preservers Association by the empty-cell process. (*See 4-4.1 and 4-5.8.*) Dunnage beams, if of wood, shall be at least 4 × 6 in. (102 × 152 mm) nominal size.

4-2.4 Hoops. Hoops shall be round bars of steel. Steel bars shall conform to Specifications A675, A36, or A502 of the American Society for Testing and Materials. Steel shall be made only by the open-hearth or electric-furnace processes.

4-2.5 Hoop Lugs. The lugs shall be malleable iron, cast steel, or fabricated steel and shall have equal or greater ultimate strength than the A675, A36, or A502 steel hoop they are used with.

4-2.6 Steel Shapes. The steel for structural shapes shall conform to Specification A36 structural steel of the American Society for Testing and Materials.

4-3 Loads.

4-3.1 Dead Load. The dead load shall be the estimated weight of all permanent construction and fittings.

4-3.2 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/cu ft (1000 kg/m^3). Proper provision shall 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/sq ft (122 kg/m^2) on the horizontal projection.

4-3.3 Wind Load. Under normal conditions the wind load or pressures shall be assumed to be 30 lb/sq ft (147 kg/m^2) on vertical plane surfaces, 18 lb/sq ft (88 kg/m^2) on projected areas of cylindrical surfaces, and 15 lb/sq ft (73 kg/m^2) on projected areas of conical and double-curved plate surfaces. When designing for wind velocities over 100 miles per hour (161 km/hr), all above-mentioned unit pressures shall be adjusted in proportion to the square of the velocity assuming that the above pressures are for 100 miles per hour (161 km/hr).

4-3.4 Earthquake Load. Tank structures shall meet local requirements for resisting earthquake damage.

4-3.5 Balcony and Ladder Loads. A vertical load of 1,000 lb (454 kg) shall be assumed to be applied to any 10 sq ft (0.93 m^2) of area on the balcony floor and on each platform; 500 lb (227 kg) applied to any 10 sq ft (0.93 m^2) area on the tank roof; 350 lb (159 kg) on each vertical section of ladder; and all of the structural parts and connections shall be designed to withstand such loads. The above loadings need not be combined with snow loading.

4-4 Unit Stresses.

4-4.1 General. The following stresses in psi (MPa) apply particularly to wood tanks and shall not be exceeded. (Unit working stresses for steel supporting construction are given in Section 7-4.)

4-4.1.1 Tension Hoops. The unit stress for tension hoops of ASTM A675 steel shall be 15,000 psi (103.43 MPa) (use with hydrostatic load and neglect initial tension). A36 or A502 shall be 20,000 psi (137.90 MPa).

4-4.1.2 Timber. The allowable working stresses for timbers mentioned in 4-2.3 and 4-5.8 shall be as specified in Table 4-4.1.2.

Table 4-4.1.2 Working Stresses for Timber (Select Grade)

	Allowable Stress Lb. per Sq. In. (MPa)			
	Bending		Compression perpendicular to grain	Compression parallel to grain; short columns
Species	In extreme fiber	Horizontal Shear		
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)

4-4.2 Wind and Earthquake Allowance. For stresses due to a combination of wind or earthquake with other loads, the above working unit stress may be increased 25 percent. Wind and earthquake loads need not be considered simultaneously. In no case shall the strength of the member be less than that required for dead and live loads alone.

4-5 Details of Design.

4-5.1 Lumber Thickness. The lumber in the staves and the bottom shall be at least 2½ in. (64 mm) (nominal) dressed to not less than 2⅛ 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 2⅜ in. (60 mm) thickness.

4-5.2 Hoop Sizes. Hoops shall be not smaller than the pitch diameter of ¾-in. (19.1-mm) thread. Not more than two sizes of hoops shall be used on a tank.

4-5.3* Hoop Schedules. A hoop is 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-4-5.3, based on the area at the root of cut threads. Other schedules are satisfactory provided the unit stress as stated in Section 4-4 is not exceeded.

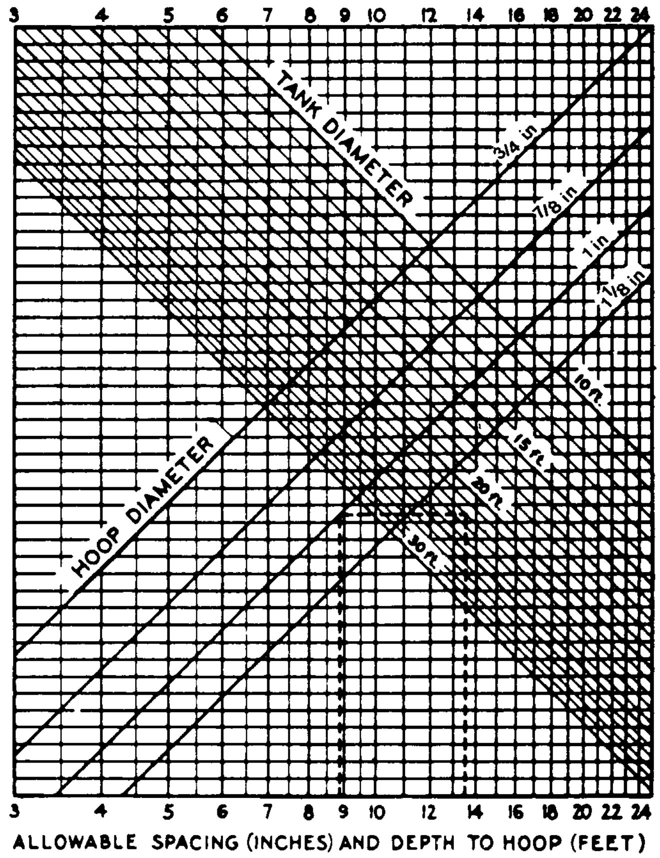


Figure 4-5.3 Hoop Spacing Diagram for Wood Tanks.

Note to Figure 4-5.3: "Hoop spacing" is one-half the distance from the hoop next above to the one next below the one being considered; "tank diameter" is the average "outside diameter"; "depth" is the distance from the hoop being considered to the top of the stave or, if the staves are notched for flat cover joists, to the bottom of the notch.

The diagram is computed by the following formula assuming plain-threaded ends using the area at the roof of the thread.

$$\text{Spacing (inches)} = \frac{12{,}500 \times \text{area of hoop (sq in.)}}{2.6 \times \text{tank diam. (ft)} \times \text{depth (ft)}}$$

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m

4-5.4 Hoops at Bottom.

4-5.4.1 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.

4-5.4.2 Two hoops of equal size shall be placed opposite the tank bottom on tanks with diameters of over 19 ft (5.8 m). The stress in the upper hoop shall be limited as stated above.

4-5.5 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).

4-5.6 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 A36 or A502 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.

4-5.7 Main Supports. Steel I-beams or reinforced concrete beams shall be used for the main supports on which the dunnage beams rest.

4-5.8 Spacing of Supports. The maximum distance in the clear between the beams on which 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).

4-5.9 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.

4-6 Workmanship.

4-6.1 Lumber Edges and Surfaces. Planks for staves and bottom shall be planed on both sides. The edges of 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 may be used for smoothing up the edges. The last stave to be placed in the tank shall be carefully planed to the required size.

4-6.2 Croze. The croze shall be cut at right angles to the center line 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 ¾ in. (19.1 mm) and 2⅛ in. (54 mm), respectively, for 3-in. (76-mm) nominal staves, and ⅝ in. (15.9 mm) and 2 in. (51 mm) for 2½-in. (64-mm) nominal staves.

4-6.3 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.

4-6.4 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.

4-6.5 Splices. Finger joint splices may 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).

4-6.6 Joints at Bottom. The joints between staves shall not come nearer than ½ in. (12.7 mm) to a joint between the bottom planks.

4-6.7 Extra Staves. One or more extra staves shall be shipped with each tank.

4-6.8 Marking of Staves. The proper hoop spacing shall be plainly marked on at least six staves before shipment.

4-6.9 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.

4-6.10 Hoop Forming. Hoops shall be cut to proper length and bent in the shop to the radius of the tank.

4-6.11 Hoop Threads. The threads shall have a tight fit in the nuts and shall be U.S. Standard.

4-6.12 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.

4-6.13 Removal of Rubbish. All waste lumber and rubbish shall be removed from inside of the tank and from the flat cover, if provided, before filling to prevent possible obstruction of piping.

4-7 Accessories.

4-7.1 Roof—General. When the tank is located out of doors it shall have a flat wooden cover over the top and above this a conical roof, except that the flat cover may 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-4-1 and B-4-2 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 ⅜-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 nonferrous metals.

4-7.2 Flat Cover. The flat cover, if provided, shall rest on parallel joists, spaced not over 36 in. (914 mm) on centers. The nominal size of joists shall be at least 2 × 6 in. (51 × 152 mm) for lengths up to 18 ft (5.5 m), 3 × 6 in. (76 × 152 mm) for lengths up to 22 ft (6.7 m), and 3 × 8 in. (76 × 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.

4-7.3 Conical Roof. (*See Figure B-4-2.*)

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

4-7.3.2 Although the rafter and header type of construction is considered preferable, other types of roof construction may be acceptable, provided approval of design is first obtained from the authority having jurisdiction.

4-7.3.3 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.

4-7.4 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.

4-7.5 Roof Hatches.

4-7.5.1 A hatch not less than 20 × 22 in. (508 × 559 mm) shall be built in the conical roof, 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.

4-7.5.2 The four sides of the hatch shall be of not less than 1½-in. (38-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 ⅜-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-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.

4-7.5.3 Other forms of hatch covers may be acceptable provided approval is first obtained from the authority having jurisdiction.

4-7.5.4 A hatch not less than 20 × 22 in. (508 × 559 mm) shall be built in the flat cover, if provided, 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 ⅜-in. (9.5-mm) Exterior Grade Plywood, and shall be of sufficient size to prevent its falling through the hatch.

4-7.6 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 opening 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.

4-7.7 Outside Ladders.

4-7.7.1 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 4-7.9.*)

4-7.7.2 The outside ladder shall have not less than 2- × ½-in. (51- × 12.7-mm) or 2½- × ⅜-in. (64- × 9.5-mm) flat side bars, spaced at least 16 in. (406 mm) apart and at least ¾-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 centerline of 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 4-7.9*) 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 ⅜ in. (9.5 mm) in diameter.

4-7.8 Inside Ladder.

(a) A wooden ladder made of the same type wood as the tank shall be provided on the inside of the tank extending from the hatch to the tank bottom with a slope of about 10 degrees from the vertical.

(b) The inside ladder, up to 16 ft (4.9 m) in height, shall have 2- × 4-in. (51- × 102-mm) side pieces. Ladders over 16 ft (4.9 m) shall have 2- × 6-in. (51- × 152-mm) side pieces. All side pieces shall be spaced at least 16 in. (406 mm) apart. Rungs shall be 1¼ × 3 in. (32 × 76 mm) spaced 12 in. (305 mm) on centers, securely spiked with noncorrosive nails into slots not less than ¾ in. (19.1 mm) and 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.

4-7.9 Balcony—General. A wooden or steel balcony shall be placed around the base of the tank when the tank bottom is elevated more than 25 ft (7.6 m) above the main building roof. For tanks of diameter in excess of 15 ft 6 in. (4.7 m), the width of balcony shall be 24 in. (607 mm), and for smaller tanks, not less than 18 in. (457 mm).

4-7.10 Balcony Floor. If the balcony is of wood, the plank shall be at least 2-in. (51-mm) nominal dressed lumber of good, sound quality spaced ½ in. (12.7 mm) apart. The planks may be laid crosswise on stringers or lengthwise on cross beams, spaced not over 4 ft (1.2 m) apart; if of steel it shall be built of at least ¼-in. (6.4-mm) plate and shall be provided with drain holes.

4-7.11 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.

4-7.12 Balcony Supports. The balcony supports shall be built of structural steel shapes except that reinforced concrete supports may be used when the tank is located on a concrete tower.

4-7.13 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 1½-in. pipe or of angles not lighter than 2 × 2 × ⅜ in. (51 × 51 × 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.

4-7.14 Balcony Opening. When a hole is cut in the balcony for the tower ladder it shall be at least 18 × 24 in. (457 × 607 mm).

4-7.15 Painting Inaccessible Parts. Portions of steelwork inaccessible after erection shall be painted before assembling.

4-7.16 Painting. All steelwork, except where encased in concrete, and threads at ends of hoops, shall be cleaned by commercial blasting per SSPC-SP6 or Pickling per SSPC-SP8 and primed with one coat of red lead alkyd per Type II or Type III of Federal Specification TT-P-86, or a suitable proprietary primer, all in accordance with the requirements for Outside Paint System No. 1 of AWWA D102. The appropriate primers for other exterior paint systems may be used, with the approval of the authority having jurisdiction.

4-7.17 Field Painting—Steelwork. After erection, a patch coat of the same kind of paint as the coat shall be applied to all steel surfaces from which 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 (*see 2-7.12.3*). Other finish coats may be used provided they are compatible with the primer and provided permission is obtained from the authority having jurisdiction.

4-7.18 Painting Applications. All painting shall be accomplished in accordance with the appropriate requirements of Steel Structures Painting Council Application - Specification No. 1 (*Shop Field and Maintenance Painting*).

4-7.19 Painting—Woodwork. Exposed woodwork such as balconies, stringers, and supporting beams shall be given at least two coats of a good grade lead-free preservative. While the painting of a wood tank is usually desirable from the standpoint of appearance, its value in increasing the life of the tank has not been definitely determined.

4-7.20 Lightning Protection. (*See Section 1-16.*)

Chapter 5 Embankment-supported Rubberized-fabric Tanks

5-1 General.

5-1.1 This section applies to the materials, embankment preparation, and installation of embankment-supported rubberized-fabric tanks.

Table 5-1 Physical Properties of the Finished Embankment Tank Assembly

		Federal Standard 191 Method	ASTM Method	
Weight		5041	D751	40.5 ± 2 oz./sq. yd.
Thickness		5030	D751	0.042″ ± 0.003″
Breaking Strength	Warp	5100	D751	300 lb Avg.
	Fill	5100	Grab	300 lb Avg.
Tear Strength	Warp	5134	D2261	20 lb Avg.
	Fill	5134	Tongue	20 lb Avg.
Adhesion of Coating to Fabric: Jaw Separation Speed 12″/min.		5970	D751	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° to cords				90 lb min.
Abrasion Resistance, Wheel—H-22 Weight—100 gms/wheel		5306	D1175 Taber	No fabric showing after 4000 cycles
Blocking Resistance		5872		Rating of 1—max.
Seam strength 2″ wide specimen		8311*		No seam slippage
Low Temperature Flexibility Paragraph 4.4.4.2 of MIL-C-8068A (ASG)				No cracking at −20° F

*Federal Test Method Standard 601

For SI Units: 1 oz. = 28,350 gr; 1 lb = 0.454 kg; 1 in. = 25.4 mm; C = 5/9(°F − 32)

5-2 Standard Capacities.

5-2.1 The standard capacities are in increments of 100,000 to 1,000,000 gal (378.5 to 3785 m³).

5-3 Materials.

5-3.1. Construction. The material shall be a nylon fabric, coated with an elastomer compounded to provide abrasion and weather resistance. *(See Table 5-1.)*

5-3.2 Design. The tank shall be designed as follows.

5-3.2.1 The tank shall be designed to result in an assembly that will have seams of a strength equal to or greater than the strength of the basic tank construction.

5-3.2.2 The top surface of the tank shall be coated with a weather-resistant elastomeric paint as recommended by the tank manufacturer.

5-3.2.3 The tank shall be designed to accommodate the field attachment of inlet/outlet fittings during installation.

5-3.2.4 The tank shall be tested for leakage prior to shipment.

5-4 Embankment Preparation and Tank Installation Procedure.

5-4.1 Foundation. The embankment and earth base that support the tank shall be installed in accordance with Figure B-5-1.

5-4.1.1 The embankment shall be designed for stability and drainage. Where two tanks are installed with a single embankment between tanks, such embankment shall be designed to resist load of a full single tank when one tank is drained.

5-4.1.2 A shallow excavation may be made below nominal grade level where local soil and groundwater conditions permit. The removed soil, if suitable, may be used to extend the embankment above grade for the required height (cut and fill method).

5-4.1.3 The internal and external slopes of the embankment shall be 1½ to 1. The slope shall be maintained in original design conditions to assure the integrity of the embankment. Also, the soil shall provide a stable embankment. All of the above is subject to verification by a qualified professional soils engineer.

5-4.1.4 The inside corners of the embankment at intersections of dike walls may 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 top of dike with uniform gradation from bottom to top, as approved by an authorized design or soils engineer.

5-4.1.5 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.

5-4.1.6 Earth dike construction tolerances may be: 6 in. (152 mm) ± for surface variance on interior slope of dike walls; plus two percent on specified vertical dimension for dike height; plus or minus one percent on horizontal dimensions specified for dike length and width if approved by the soils engineer.

5-4.1.7 A 6-in. (152-mm) thick layer of fine sand or top soil shall be used for surface layer of the floor, underlaid by a 3-in. (76-mm) thickness of selected pea gravel, to provide firm, smooth bed and good drainage.

5-4.1.8 The finished surfaces of inside dike walls and floor shall be free from sharp rocks and debris.

5-4.1.9 Provide a 4-in. (102-mm) diameter porous drain pipe 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 serves as "telltale leak detector" for the tank.

5-4.1.10 Provide a cement-lined gutter shown on Figure B-5-1 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.

5-4.1.11 The exterior sides and top of dike walls shall be protected against surface erosion.

5-4.2 Installation.

5-4.2.1 Installation of the tank in the prepared embankment shall be accomplished with the assistance of the tank manufacturer's field technician.

5-4.2.1.1 The tank as shipped to the site shall be packaged in a material designed for ease of handling by a crane and winch and to facilitate efficient placement in the enclosure.

5-4.2.1.2 The fittings shall be installed on site.

5-4.2.1.3 The tank is filled and final adjustments on the tank shall be made to ensure 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-5-1. The tank is secured all around the top periphery of the embankment walls utilizing ropes that pass through straps built on to the outer surface of the tank and that are tied around the stakes. The tank shall also be tested for leakage after installation. This entire operation is to be carried out under the direction of the tank manufacturer's field technician.

5-5 Tank Sump and Support for Bottom Fittings.

5-5.1 Inlet/Outlet. The concrete pad which 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-5-1.*)

5-5.2 Finish. The surface of the concrete pad shall be smooth with the edges 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.

5-6 Pipe Connections and Fittings.

5-6.1 General Information. The tank fittings, accessories, and piping connections shall be as shown in

Figure B-5-2. The fittings attached to the tank shall be flanged type. All metal parts shall be corrosion resistant.

5-6.2 Fittings Attached to Tank.

5-6.2.1 The tank shall include either one or two access manhole fittings with cover plates in the top surface, to each of which is attached a vent pipe with a pressure-relief cap.

5-6.2.2 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.

5-6.2.3 A vortex-plate assembly, as shown in Figure B-5-2, shall be bolted to the combination inlet/outlet fitting. This assembly, in addition to controlling vortex flow, also serves as a guard to make it possible to pump the calculated water capacity out of the tank at a high rate of flow.

5-6.2.4 An overflow shall be provided sized for the filling rate or 2 in. (51 mm) larger than the fill line. (*See Figure B-5-4.*)

5-6.3 Water-level Gage. Provide a water-level gage for the tank consisting of a sight glass, constructed of clear acrylic tubing of 2⅜-in. (60-mm) outside diameter. Where subject to freezing, the water gage assembly shall be installed in the heated pump house.

5-7 Care and Maintenance of Embankment-supported Rubberized-fabric Suction Tanks.

5-7.1 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.

5-7.2 The access fitting(s) in the top of the tank shall be kept securely fastened as a protection against freezing and windstorm damage.

5-7.3 Large accumulations of ice shall not be allowed to collect on the top of the tank. This may be overcome by maintaining the temperature of the water above freezing and keeping the tank filled to capacity.

5-7.4 The tank shall be located in a protected area or be enclosed by a manproof fence.

5-7.5 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.

5-7.6 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.

5-7.7 Before painting, the surface of the tank shall be thoroughly cleaned with detergents and washed and allowed to thoroughly dry.

5-7.8 A paint and procedures of application recommended by the manufacturer shall be used to refurbish the top surface of the tank.

5-7.9 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 assure adequate grass cover.

Chapter 6 Tank and Tower Foundations in the Ground

6-1 Concrete Specifications.

6-1.1 Concrete foundations 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 the *American Concrete Building Code Requirements for Reinforced Concrete* (ACI 318) with water considered as a live load.

6-2 Suction Tank Foundations. Steel suction tanks shall be set on a compacted, crushed stone or granular base or on concrete foundations. At least 4 in. (102 mm) of crushed stone or sand, mixed with oil and laid on the compacted grade, shall be provided at the finished tank grade.

6-2.1 A reinforced concrete ring-wall extending below the frost line and at least 2.5 ft (0.76 m) deep 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 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 reinforcing shall be 0.25 percent of the cross-sectional area, with additional reinforcement as may be required for resisting lateral earth pressure. Tops of ring-wall foundations shall be level within ¼ in. (6.4 mm) [± ⅛ 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 ½ in. (12.7 mm) [± ¼ in. (6.4 mm)].

6-2.2 For soil unsuited to provide direct support for the tank without excessive settlement, shallow foundation construction may not be adequate, and a proper foundation shall be designed by a foundation engineer. (*See Section 6-6.*)

6-3 Foundation Piers for Elevated Tanks.

6-3.1 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.

6-3.2 Pier foundations may be of any suitable shape and may be either plain or reinforced concrete. When supporting a tower, the center of gravity of the pier shall lie in the continued center of 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.

6-4 Anchorage.

6-4.1 The weight of 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 may be included.

6-4.2 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 anchor plate.

6-4.3 Anchor bolts shall be accurately located with sufficient free length of thread to fully engage their nuts. Expansion bolts are not acceptable. The minimum size of anchor bolts shall be 1¼ in. (32 mm).

6-5 Grouting. Bearing or base plates shall have complete bearing on the foundation or 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 unless they are accessible for complete cleaning and painting.

6-6 Soil-bearing Pressures.

6-6.1 The design soil-bearing pressure and 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 to 30 ft (6.1 to 9.1 m) minimum].

6-6.2 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.

6-6.3 The design soil-bearing pressure shall not exceed that which would cause settlements that impair the structural integrity of the tank.

6-6.4 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.

6-6.5 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 7 Steel Towers

7-1 General.

7-1.1* This section defines the design, fabrication, and erection of steel towers to support water tanks.

7-1.2 Height. The height of tower is the vertical distance from the top of the foundations to the bottom capacity line of the tank.

7-1.3 Strength. The material as specified shall be without defects affecting the strength or service of the structure. The workmanship shall be good, so 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.

7-1.4 Details. The details shall conform to the following rules and, where not covered therein, to the *Structural Welding Code*, AWS D1.1.

7-2 Material.

7-2.1 Plates, Shapes, and Tubular Columns.

7-2.1.1 Plates. Plate materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to the following ASTM Specifications: A36; A283, Grades A, B, C, and D; except that when plates of thickness greater than ¾ in. (19.1 mm) are used, A283, Grade D steels shall not be specified; as alternatives A285, Grades A, B, and C; A516, Grades 55 and 60; A442, Grades 55 and 60; or A131, Grades A, B, and C may be used.

7-2.1.2 Shapes. Structural materials shall be open-hearth, electric furnace, or basic oxygen process steel conforming to ASTM A36; or A131, Grades A, B, or C. Copper-bearing steel with content of about 0.20 percent copper may be used. In other particulars the steel shall conform to the specifications enumerated above. (*See 2-2.1.*)

7-2.1.3 Tubular Columns. Steel pipe may be used for tubular columns or other structural members provided it complies with specifications ASTM A139, Grade B; ASTM A53, Type E or S, Grade B; API Specification 5L, Grade B; and providing 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 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.

7-2.2 Bolts, Anchor Bolts, and Rods. Bolts and anchor bolts shall conform to ASTM Specification A307, Grades A or B. ASTM A36 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 A36. (*See 2-2.2.*)

7-2.3 Pins. Pins shall comply with any of the following ASTM Specifications: A307, Grades A or B; A108, Grades 1018 or 1025; or A36. Size and diameter tolerances on turned pins shall be equal to that of cold-finished shafting. Surface finish shall depend on application, but in no case be rougher than 125 micro-in. (3.18 μm).

7-2.4 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 are acceptable when approved by the authority having jurisdiction.

7-3 Loads.

7-3.1 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 and of concrete as 144 lb/cu ft (7849 and 2307 kg/m^3, respectively).

7-3.2 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/cu ft (1000 kg/m^3). 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/sq ft (122 kg/m^2) on the horizontal projection.

7-3.3 Live Load—Large Risers.

7-3.3.1 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.

7-3.3.2 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 can be deducted from the weight of the tank water when designing the tower unless the riser is suspended from the tower.

7-3.3.3 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 except that it may 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.

7-3.3.4 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 the diameter of the riser. This load can be deducted from the weight of the tank water when designing the tower.

7-3.4 Wind Load. The wind pressure shall be assumed to be 30 lb/sq ft (147 kg/m^2) on a vertical plane surface. In calculating the wind load on a cylindrical surface, 18 lb/sq ft (88 kg/m^2) 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 miles per hour (161 km/hr) all abovementioned unit pressures shall be adjusted in proportion to the square of the velocity assuming that the above pressures are for 100 miles per hour (161 km/hr).

7-3.5 Balcony and Ladder Loads. A vertical load of 1,000 lb (454 kg) shall be assumed to be applied to any 10 sq ft (0.93 m^2) of area on the balcony floor and on each platform; 500 lb (227 kg) applied to any 10 sq ft (0.93 m^2) area on the tank roof; 350 lb (159 kg) on each vertical section of ladder; and all of the structural parts and connections shall be designed to withstand such loads. The above loadings need not be combined with snow loading.

7-3.6 Earthquake Load. Tank towers shall meet the requirements for resisting earthquake damage by complying with the earthquake design load provisions of American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2), and 7-4.7.2 of this standard.

Table 7-4.1

Axial Tension: On net section, rods and A36 structural steel shapes 15,000 psi

Axial Compression: Gross section of columns and struts of structural shapes:

$$\frac{P}{A} = \left\{ \frac{18{,}000}{1 + \dfrac{L^2}{18{,}000r^2}} \right\} \text{ or 15,000 psi, whichever is the smaller.}$$

For tubular columns and struts: $\frac{P}{A} = XY$, **in which** $X = \dfrac{18{,}000}{1 + \dfrac{L^2}{18{,}000r^2}}$ **or 15,000 psi, whichever is the smaller, and**

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

(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 meanings:

- P = total axial load in pounds.
- A = cross-sectional area in square inches.
- L = effective length in inches.
- r = least radius of gyration in inches.
- R = radius of the tubular member to the exterior surface in inches.
- t = thickness of the tubular member in inches; minimum allowable thickness— ¼ inch.

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

Compression on short lengths 18,000 psi (124.11MPa). (See 7-5.4.)

For SI Units: 1 lb = 0.45 kg; 1 in. = 25.4 mm; 1 $in.^2$ = 645.16 mm^2; 1000 psi = 6.895 MPa

7-4 Unit Stresses.

7-4.1 General. The maximum stresses in psi produced by the above loads shall not exceed the values specified in Tables 7-4.1, 7-4.3, 7-4.4, and 7-4.5.

7-4.2 Slenderness Ratio. The maximum permissible slenderness ratio L/r for compression members carrying weight or pressure of tank contents shall be 120.

The maximum permissible slenderness ratio L/r for compression members carrying 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.

7-4.3 Bending.

Table 7-4.3

	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	$\frac{9{,}000{,}000}{\frac{ld}{bt}}$	$\frac{62\ 055}{\frac{(l)(d)}{(b)(t)}}$

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 inches (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.

	psi	MPa
Pins, extreme fiber	22,500	155.14
Cast steel	11,250	77.57

7-4.4 Shearing.

Table 7-4.4

Pins and turned bolts in reamed or drilled holes	11,250	77.57
Unfinished bolts	7,500	51.71
Webs of beams and plate girders, gross section	9,750	67.23
Cast steel	7,325	50.51
Tank plates and structural connection materials	11,250	77.57

7-4.5 Bearing.

Table 7-4.5

	Double Shear psi	MPa	*Single Shear* 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 (pounds per linear inch) where d is the diameter of roller or rocker in inches			600d	0.163(d)

7-4.6 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.

7-4.7 Wind and Earthquake Allowances.

7-4.7.1 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 may be increased a maximum of 25 percent. In no case shall the resulting sections be less than that required for dead and live loads alone.

7-4.7.2 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 may be increased up to 33⅓ percent. In no case shall the resulting section be less than that required for dead and live loads alone.

7-4.7.3 Wind and earthquake need not be considered as acting simultaneously.

7-4.8 Fillet and Groove Welds. Welded joints shall be proportioned so that the loads specified in Section 7-3 shall not cause stresses therein in excess of design stresses obtained by applying to the allowable working stresses in the base material the efficiencies in the American Water Works Association *Standard for Welded Steel Tanks for Water Storage*, AWWA D100 (AWS D5.2).

7-5 Details of Design.

7-5.1 Sections. Sections shall preferably be symmetrical. Members shall preferably 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.

7-5.2 Mimimum Thickness—General. The minimum thickness of metal shall be ¼ 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 ¾ in. (19.1 mm).

7-5.3 Columns.

7-5.3.1 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 may be either butt welded with a backer strip or spliced by plates welded to both sections being joined. Where a horizontal plate ¼ in. (6.4 mm) minimum thickness is used to seal the top and bottom of a column section, the backing strip or splice plate may be omitted.

7-5.3.2 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. When a horizontal plate [minimum thickness ¼ 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 is not necessary.

7-5.4 Combined Shapes. The shapes shall be separated at least ⅜ in. (9.5 mm) if they are not in contact. For tension members, the component parts of which 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.

7-5.5 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), 24 in. (0.61 m) for the 4-in. (102-mm), 36 in. (0.91 m) for the 5-in. (127-mm), 42 in. (1.07 m) for the 6-in. (152-mm) 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 may be used.

7-5.6 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, transmitting stress into that member shall have its center of gravity in the line of the center of gravity of the member; if not, provision shall be made for the effect of the resulting eccentricity. Connections between the columns, struts, and tension members shall be made by gusset plates which may also serve as splice plates. Diagonal bracing shall, when possible, be connected to the same gusset plates that connect the columns and struts. Bolts shall not be subjected to tensile stress.

7-5.7 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.

7-5.8 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.

7-5.9 Clevises, Forked Ends, Turnbuckles.

7-5.9.1 Bar or plate clevices, 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.

7-5.9.2 Clevis plates may 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 rod and clevis plates. The plates shall be bent in easy lines to reduce to a minimum the stretch under 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 overstressing.

7-5.9.3 Turnbuckles shall be of the open type and shall have a strength not less than that of the tension member.

7-5.10 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 33⅓ percent in excess of the allowable axial working-stress which, in the case of compression, is that allowed for short lengths.

7-5.11 Tie Plates. The main constituent parts of columns shall be solidly tied together at points of connection of tension or compression members.

7-5.12 Length of Tension Members. The horizontal projection of the unsupported length in inches (mm) of a nonadjustable tension member in a horizontal or inclined position shall not exceed 200 times the radius of gyration about the horizontal axis.

7-5.13 Column Bases and Caps.

7-5.13.1 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 either be filled with concrete and flashed with asphalt to prevent the collection of dirt and moisture inside.

7-5.13.2 When 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.

7-5.14 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 shall preferably 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 may be used as a balcony. Drain holes shall be provided in the web plate.

7-5.15 Circular Girder with Vertical Columns. If the columns are vertical and the tank bottom is suspended, the circular girder shall be as stated in 7-5.14 or shall be a structural shape connected to the tank by welding.

7-5.16 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.

7-5.17 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.

7-5.18 Grillage. When 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.

7-5.19 Base Braces. When 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 horizonal to 12 vertical.

7-5.20 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.

7-5.21 Large Risers; Water Spheres.

7-5.21.1 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 also the load imposed on the top of the riser pipe by the tank bottom or by members supporting the tank bottom as specified in 2-3.2. 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 7-4.1.

7-5.21.2 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.

7-5.21.3 For the design of water spheres and conical frustums at the base of the sphere, the symbol R representing the radius in 7-4.1 shall be taken as either the radius of the sphere or the radius of the cone perpendicular to the conical surface.

7-5.21.4 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 inches (mm) of each plate at the joint that may be considered as contributing to this required reinforcing shall be limited to the square root of the product of each plate thickness in inches (mm) and its respective inside radius in inches (mm).

7-5.22 Anchor Bolts. In earthquake locations there shall be at least two anchor bolts per column.

7-6 Workmanship.

7-6.1 Shearing. All shearing shall be done neatly, and material over ¾ in. (19.1 mm) thick, except base plates or other plates not carrying actual stress, shall have ⅛ in. (3.2 mm) planed from the sheared edges.

7-6.2 Straightening and Fitting. The several pieces forming built sections shall be straight and shall fit closely together.

7-6.3 Use of Bolts and Welding. Members shall be welded throughout, except in field connections of nonadjustable tension members carrying wind stress only, and of compression members and grillages in towers supporting tanks of 30,000 gal (113.55 m^3) or less capacity, where unfinished bolts may be used. The threads of unfinished bolts shall be burred outside of the nuts. High-tensile bolts or the equivalent may be used in field connections of towers supporting tanks of 100,000 gal (378.50 m^3) or less capacity. Where machined bolts are needed, the bolt holes shall be reamed parallel and the bolts machined to a driving fit, burring the threads outside the nuts unless special listed locking devices are provided.

7-6.4 Threads and Nuts. Screw threads on rods shall be cut or rolled to the United States Standard or shall have self-locking threads, and shall 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 ⅛ 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.

7-6.5 Grouting of Base Plates. During field erection the columns shall be built on thin metal wedges which, after structure is completed, shall be driven to equal resistance so that all columns will be loaded equally and then the spaces beneath the base plates and the anchor bolt holes completely filled with portland cement mortar, consisting of a minimum of one part portland cement to three parts clean sand.

7-6.6 Assembly.

7-6.6.1 Component parts of built-up members shall be held in firm contact by adequate clamps or other means. Spaces in which inaccessible corrosion can form shall not be left between component parts of members.

7-6.6.2 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.

7-6.7 Alignment. Members and all component parts shall be straight and free from appreciable buckles or warping.

7-6.8 Tubular Column Distortion. The column axis shall not deviate from a straight line more than 1/1000 of the laterally unsupported length. At no cross-section shall the difference between the maximum and minimum outside diameters exceed 2 percent of the nominal outside diameter. Local dents shall be no deeper than the plate thickness.

7-7 Accessories.

7-7.1 Connections. Connections shall be provided on the tower for the necessary pipe and frostproof casing braces.

7-7.2 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. When the tower supports a wood tank or when the balcony is not used as a circular girder, the ladder may pass through an opening in the balcony not less than 18 × 24 in. (457 × 609 mm) in the clear. The ladder shall be securely fastened at its upper end. Welding of ladders and their connections is permitted. Ladders for pedestal-supported tanks shall preferably be placed inside the pedestal.

7-7.3 Ladders—Details.

7-7.3.1 The ladder shall have not less than 2- × ½-in. (51- × 12.7-mm) or 2½- × ⅜-in. (64- × 9.5-mm) flat side bars spaced at least 16 in. (406 mm) apart and at least ¾-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 ½-in. (12.7-mm) bolts shall be used on each side of each splice.

7-7.3.2 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 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.

7-7.3.3 Other arrangements of tower ladders may 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 × 3 × ⅜ in. (76 × 76 × 9.5 mm) or their equivalent.

7-7.4 Walkway.

7-7.4.1 A walkway at least 18 in. (457 mm) wide, extending from a point accessible from the tower ladder to an expansion joint located under the tank and terminating 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 ½ in. (12.7 mm) apart, or ¼-in. (6.4-mm) steel plate with drain holes. The walkway and platform shall be rigidly supported and braced laterally to prevent swinging.

7-7.4.2 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 1½-in. pipe or of angles not lighter than 2 × 2 × ⅜ in. (51 × 51 × 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.

7-7.5 Balcony.

7-7.5.1 Towers over 20 ft (6.1 m) high, and having 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 1½-in. pipe or 2 × 2 × ⅜ in. (51 × 51 × 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.

7-7.5.2 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.

7-7.6 Painting Inaccessible Parts. Parts inaccessible after fabrication, but subject to corrosion, shall be protected by paint before assembly.

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

7-7.7 Painting. All steel, except where encased in concrete, or where edges are to be welded, shall be cleaned by commercial blasting per SSPC-SP6 or Pickling per SSPC-SP8 and primed with one coat of red lead alkyd per Type II or III of Federal Specification TT-P-86, or a suitable proprietary primer, all in accordance with the requirements for Outside Paint System No. 1 of AWWA D102. The appropriate primers for other exterior paint systems may be used, provided permission is first obtained from the authority having jurisdiction. In any event, primer shall be the same as selected for exterior tank surfaces (*see 2-7.11*).

7-7.8 Field Painting. After construction, all weld seams, unprimed margins, field bolts, and any areas on which 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 purchaser, shall be used in accordance with the requirements for Outside Paint System No. 1 of AWWA D102. The total system dry film thickness shall be 3.5 mils (87 microns) for aluminum finishes and 4.5 mils (112 microns) for alkyd enamels. As provided for by Outside Paint System No. 4 of AWWA D102, the purchaser may specify an extra complete coat of primer for a total minimum system dry film thickness of 6.0 mils (150 microns) for alkyd enamels for the more severe atmospheric exposures. Other finish coats may 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 2-7.12*).

7-7.9 Painting Application. All painting shall be accomplished in accordance with the appropriate requirements of *SSPC Paint Application Specification No. 1 (Shop, Field and Maintenance Painting)*.

Chapter 8 Pipe Connections and Fittings

(For embankment-supported rubberized tanks see Section 5-6.)

8-1 General Information.

8-1.1 Watertight Intersections at Roofs and Floors.

8-1.1.1 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, each of which has first been wrapped with two or three thicknesses of building paper. If concrete is used, the upper side of the intersection shall then be well flashed with a suitable firm, waterproof material that will be noncracking and will retain its adhesion and flexibility. Wood roofs shall also be built tightly around the pipes and made watertight by fittings caulked with oakum or by adequate flashing.

8-1.1.2 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 flow down the pipe to lower floors or the basement.

8-1.2 Rigid connections to steel tanks shall be made by means of a welded joint with approval of the details 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.

8-1.3 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 may be greatly damaged by shrinkage if left empty after being erected.

8-1.4 The Contract. To ensure installation of adequate equipment, the contract shall specify that the finished work shall conform with this standard in all respects.

8-1.5 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 frostproof casing.

8-1.6 Inspection of Completed Equipments.

8-1.6.1 Immediately after the work is finished, a joint inspection of the tank piping shall be made by a representative of the contractor and a representative of the owner.

8-1.6.2 Written reports of these inspections shall be made in triplicate and a copy signed by the contractor and the owner shall be sent to the authority having jurisdiction.

8-1.6.3 This joint inspection will provide reasonable assurance 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.

8-1.7 Care and Maintenance. 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 gage, 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 in service again. The heating system shall be given daily supervision during freezing weather. The expansion joint shall be repacked and adjusted if it binds or develops leaks.

8-1.8 Precautions During Repairs. Whenever the tank is drained, the authority having jurisdiction shall be notified well in advance. The following precautions shall be observed:

(a) Plan work 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 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.

8-1.9 Heater Thermometer. One of the chief advantages of the gravity circulation system of heating tanks is the fact that it permits 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 may result in freezing the equipment.

8-1.9.1 For a gravity circulating heating system (Figures B-8-1, B-8-2, B-8-3, B-8-4, B-8-5, B-10-1, B-10-2, and B-10-5), an accurate thermometer shall be located as specified in 10-1.7.2.

8-1.9.2 For a tank containing a radiator steam heater, an accurate socket thermometer shall be located as specified in 10-3.6.

8-1.10 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. Circulation of water through the tank causes an accumulation of sediment that may obstruct the piping or 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.

8-1.11 Filling. The tank shall be kept well filled, never allowing the water level to be lower than 3 or 4 in. (76 or 102 mm) below the designated fire service level. The filling bypass shall be kept closed when not in use.

8-1.12* Water-level Gage. A water-level gage of suitable design shall be provided. It shall be carefully installed and adjusted and then properly maintained.

8-1.12.1 If an altitude gage is used, it shall be at least 6 in. (152 mm) in diameter and be of noncorrodible construction.

8-1.12.2 The gage 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 gage and the connection to the tank.

8-1.12.3 A listed, closed-circuit, high- and low-water level electric alarm may be used in place of the gage if acceptable to the authority having jurisdiction. Provision shall be made for attachment of a calibrated test gage.

8-1.13 Frostproof Casing. The frostproof casing shall be kept in good repair and weathertight throughout. Its insulating qualities are greatly impaired if joints spring open or if the casing settles away from the tank or if rotting occurs around the base.

8-1.14 Tanks with Large Risers.

8-1.14.1 Large steel-plate riser pipes, 3 ft (0.91 m) or more in diameter without frostproof casing, are acceptable if properly heated. (*See Chapter 10.*) 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.

8-1.14.2 The check valve and gates in the discharge pipe, filling arrangement, overflow, drain, and mercury gage are generally provided and sometimes a blow-off valve is furnished near the base of the larger riser. A manhole at least 12 × 16 in. (305 × 406 mm) shall be provided with its lower edge level with the discharge piping protection specified.

8-1.15 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 may be done with an American National Standards Institute 125-psi (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 × ¼ in. (38 × 6.4 mm), ⅝-in. (15.9-mm) round rods, or equivalent, which 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 may 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.

8-1.16 Steel Pipe.

8-1.16.1 Steel pipe shall conform to ASTM A53, Type E, Type F, Type S, Grade A or B manufactured by the open-hearth, electric furnace, or basic oxygen process or to ASTM A106, Grade A or B.

8-1.16.2 For steel pipe in contact with storage water, the following shall apply: steel pipe smaller than 2 in. shall not be used. Steel pipe 2 to 5 in. shall be extra-strong weight. All steel pipe 6 in. and larger shall be standard weight.

8-2 Discharge Pipe.

8-2.1 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 8-1.1.*)

8-2.2 Size.

8-2.2.1 Conditions at each individual plant influence the size of discharge pipe needed. The size, however, shall not be less than 6 in. for tanks up to and including 25,000-gal (94.63-m^3) capacity and generally not less than 8 in. for 30,000 to 100,000 gal (113.55 to 378.50 m^3) inclusive or 10 in. for greater capacities.

8-2.2.2 Smaller pipe than specified above (not less than 6 in.) may be permitted in some cases if conditions are favorable and large flows of water are not needed. On the other hand, larger pipe may 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.

8-2.3 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 except that for steel-plate risers, standpipes, or suction tanks, the short length of vertical pipe from the base elbow through the bottom plate may be of cast iron with a spigot at the lower end.

8-2.4 Braces. Either the pipe or large steel-plate riser pipe or both shall be braced laterally by rods not less than ⅝ in. (15.9 mm) in diameter, connected to the tower columns near each panel point. End connection of braces shall be by eyes or shackles; open hooks are not permitted.

8-2.5 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 may have bell ends. The joint at the connection of yard piping to the base elbow shall be strapped or the base elbow 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 may not be required. Large steel riser pipes shall be supported on a reinforced concrete pier designed to support the load specified in 9-1.4. Concrete grout shall be provided beneath the large riser to give uniform bearing when empty.

8-2.6 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 shall also 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.

8-2.7 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, when 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 8-3.

8-2.8 Rigid Connection.

8-2.8.1 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 8-3 or shall be rigidly connected in accordance with 8-1.2. 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.

8-2.8.2 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 may be used between the discharge pipe and the bottom of a suction tank or standpipe or the base of a steel-plate riser of a tank on an independent tower, but special approval of details 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.

8-2.9 Swing Joints. If the vertical length of 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.

8-2.10 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.

8-2.11 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-8-1.*) When the tank is located over a building, the check valve shall ordinarily be placed in a pit, preferably outside the building. (*See Figure B-8-2.*) When yard room is not available, the check valve may be located on the ground floor or in the basement of a building provided that it is adequately protected against breakage.

8-2.12 Controlling Valves.

8-2.12.1 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-8-1.*) 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, may be used.

8-2.12.2 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-8-1.*) 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-8-2.*) For suction tanks, the valve shall be as close to the tank as possible.

8-2.13 Vortex Plate Assembly. When 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-8-7.*)

8-3 Expansion Joint.

8-3.1 Connection to Tank. A listed expansion joint shall be used when required by 8-2.7 or used per 8-2.8.1. The expansion joint may be placed immediately above the foot elbow or may 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.

8-3.2 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 two parts that slide, one on the other, shall be of brass or other noncorrodible metal of ample strength and wearing qualities.

8-3.3 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) between the cast iron body and an iron or steel slip-tube.

8-3.4 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 8-2.10*). Provision shall be made for a packing space of adequate size (*see 8-3.7*).

8-3.5 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.

8-3.6 Slip-tube. The sliding tube at the top of the discharge pipe shall be brass or iron with triple-plated brass outer surface, if the gland is iron. If the gland is brass, the slip-tube may be cast iron or steel, but in this case, the top of the packing space shall be formed with brass and a clearance of at least $\frac{1}{2}$ in. (12.7 mm) must be 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 permit 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.

8-3.7 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.

8-3.8 Connections for Use Other than Fire Protection. Connections for use other than fire protection shall preferably not be made, but when 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.

8-4 Filling.

8-4.1 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 shall preferably be a bypass around the check valve. (*See Figures B-8-1 and B-8-2.*) 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.

8-4.2 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 8 hours. The filling pipe shall be at least 2 in. in size and may, except as noted in 8-4.3, 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.

8-4.3 When a separate fill pipe is used, automatic filling may be provided.

8-4.4 Filling from Drinking Water Supply. When 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 regulations of the local health authority.

8-4.5 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 8-1.1.*)

8-4.6 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.

8-5 Overflow.

8-5.1 Size. The overflow pipe shall be of adequate capacity for operating conditions and shall be not less than 3 in. in size throughout.

8-5.2 Inlet. The inlet of the overflow pipe shall be located at the top capacity or high water line. Also the inlet shall be located at least 1 in. (25.4 mm) below the bottom of the flat cover joists in a wood tank, but never 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 than the diameter of the fill pipe. The inlet shall be arranged so that the flow of water is in no way retarded by any obstruction. On a steel tank an overflow pipe cut with the opening to fit the roof may be used, provided a suitable horizontal suction plate and vortex breaker are used to ensure full capacity flow for the overflow.

8-5.3 Stub Pipe. When dripping of water or small accumulation of ice is not objectionable, the overflow may, by the choice of the owner, pass through the side of the tank near the top. (*See Figures B-8-3 and B-8-4.*) 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. On column-supported tanks with outside overflow, vertical extensions of the pipe below the balcony are not recommended, as they may become plugged with ice.

Overflows for pedestal tanks shall preferably be extended to ground level within the access tube and pedestal. (*See Figure B-8-5.*)

8-5.4 Inside Pipe. When a stub pipe is undesirable, the overflow pipe shall extend down through the tank bottom and inside the frostproof casing or steel-plate riser, discharging 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 8-1.16*). Inside overflow pipes shall be braced at points not over 25 ft (7.6 m) apart to tank and riser plates 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.

8-6 Clean-out and Drain.

8-6.1 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, at the bottom of an elevated steel tank with a suspended bottom (*see Figure B-8-4*), unless the tank has a large riser pipe 3 ft (0.91 m) or more in diameter.

8-6.2 Shell Manholes. Two manholes shall be provided in the first ring of the suction tank shell at locations to be designated by the purchaser.

One of the manholes shall be flanged, with a bolted cover to provide for the attachment of a mechanically operated exhauster to remove evaporated paint solvents, abrasive blasting dusts, and other impurities during surface preparation and painting. The minimum opening shall be 24 in. (610 mm) with the bolts on a 30¼-in. (768-mm) diameter bolt circle, such that the bolts straddle horizontal and vertical center lines.

The other manhole may be either circular, 24 in. (610 mm) in diameter, or elliptical, 18 × 22 in. (457 × 559 mm) minimum size.

The shell where the manholes are located shall be adequately reinforced and all portions of the manholes, including reinforcing the neck, the bolting, and the cover shall be designed to withstand the weight and pressure of the tank contents.

8-6.3 For Elevated Flat-bottom Tanks. At least a 2-in. pipe clean-out shall also be provided outside of the frostproof casing, in the bottom of a wood tank or a flat-bottom steel tank, when elevated. 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-8-3.*)

8-6.4 Riser Drain.

8-6.4.1 A drain pipe at least 2 in. in size fitted with a reliable controlling valve and a ½-in. drip valve shall be connected into the tank discharge-pipe near its base, and when possible, on the tank side of all valves. If the outlet is an open end it shall be fitted with a 2½-in. hose connection unless it discharges into a funnel or cistern piped to a sewer. If the drain is piped directly to a sewer, a sight glass or a ¾-in. test valve on the underside of the pipe shall be provided. If the drain pipe is to be used for a hose stream, the controlling valve shall be a listed gate or angle valve.

8-6.4.2 When a circulation-tank heater is located near the base of the tank riser, the drain pipe shall, if possible, be connected from the cold-water return pipe between the cold-water valve and the heater to permit flushing water from the tank through the hot-water pipe heater and drain for clean-out purposes. (*See Figure B-8-1.*)

8-7 Connections for Other than Fire Protection.

8-7.1 Dual-service Tanks. The use of an elevated tank, in part, for purposes other than fire protection, is not advised. Frequent circulation of the water results in an accumulation of sediment that may obstruct the piping of sprinklers, and a fluctuating water level hastens decaying of wood and corrosion of steel. In the few cases where dual service is necessary, an adequate supply of water shall be constantly and automatically reserved in the tank for fire protection purposes.

8-7.2 Pipe for Purposes Other than Fire Protection. The pipe for purposes other than fire protection shall be entirely separate from fire-service pipes and shall extend to an elevation inside the tank below which an adequate quantity of water will be constantly retained for fire protection. The pipe for purposes other than fire protection inside the tank shall be brass, except that steel may be used if the pipe is larger than 3 in. in size, or cast iron if 6 in. or larger in size. The pipe inside the tank shall be braced near the top and at points not over 25 ft (7.6 m) apart. The expansion joint, if there is one, shall be of standard type, below the tank without connection to the tank plates. (*See 8-3.8.*)

8-7.3 At Roofs and Floors. Just as for other tank piping, the intersection of a pipe for purposes other than fire protection with a building roof or waterproof or concrete floor, shall be watertight. (*See 8-1.1.*)

Chapter 9 Valve Enclosures and Frost Protection

9-1 Valve Pit or House and Heater House.

9-1.1 General. When the tank is on an independent tower, a valve pit or house shall be built at the base of the discharge pipe to house the valves, tank heater, and other fittings. If a large valve pit below grade is provided it can contain all equipment, including the check valve in the horizontal run. If a house above grade with no large pit beneath it is used, it becomes necessary to place the O.S.&Y. gate valve in the vertical part of the tank discharge pipe and to construct a small brick or concrete pit or well to contain the check valve in the horizontal pipe below the frost line.

9-1.2* Materials. The valve pit below grade shall be built of portland cement concrete with a clean aggregate. Reinforced concrete shall be a 1:2:4 mixture. Plain concrete, when low stresses permit its use, may be a 1:3:5 mixture. A valve house above grade shall be constructed of concrete, brick, cement plaster on metal lath, or other noncombustible material with suitable heat insulating properties.

9-1.2.1 Material shall conform to ASTM Designation C578, *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 direct exposure to flame exists.

9-1.2.2 Material shall conform to ASTM Designation C591, *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 direct exposure to flame exists.

9-1.3 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 at such an elevation that connection to the system can be conveniently made. The necessary size of pit shall be carefully planned in advance for each equipment, but ordinarily a pit 7 ft (2.1 m) deep and 6 × 9 ft (1.8 × 2.7 m) horizontally inside will be of sufficient size. A valve house containing only the O.S.&Y. gate in the discharge pipe and the heater can usually be made smaller.

9-1.4 Design of Valve Pit.

9-1.4.1 All parts of the pit and soil beneath shall be adequate to resist all loads including the frostproof casing or large steel riser and contained water. This requires reinforced 1:2:4 concrete for the roof. The walls and floor shall also be reinforced 1:2:4 mixture if subjected to appreciable bending stresses from groundwater pressure or other loads. The walls and floor may be plain 1:3:5 concrete, usually not less than 8 in. (203 mm) thick, when bending stresses are insignificant.

9-1.4.2 The load considered in designing the pier and its bearing which supports a large steel-plate riser, when the hemispherical or ellipsoidal shape is continuous to the shell of the large riser without 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 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

Table 9-1.2 Frostproofing Materials and Required Minimum Thicknesses

Type of Insulation	Low One-Day Mean Temperature °F																	
	+30	+25	+20	+15	+10	+5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45	−50	−55
	None ↑																	
Insulated Metal Frostproof Casing		3 in. Thick Fiberglass in Metal Shield (Fig. B-9-1)																
Foamglass		2 in. Thick					3 in. Thick						4 in. Thick					
Fiberglass (Min. 3 # Density)		1 in. Thick				1½ in. Thick				2 in. Thick				2½ in. Thick				
Polystyrene 9-1.2.1		1 in. Thick				1½ in. Thick				2 in. Thick				2½ in. Thick				
Polyurethane 9-1.2.2	↓ None	1 in. Thick								2 in. Thick								

For SI Units: 1 in. = 25.4 mm; °C = 5/9 (°F − 32).

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/sq ft (19 548 kg/m^2) without negligible settlement.

9-1.5 Pit Manhole. A standard round manhole with cover at least 24 in. (610 mm) in diameter, a square metal manhole with 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.

9-1.6 Pit Ladder. A steel ladder, rigidly secured, shall extend from the manhole to the floor.

9-1.7 Waterproofing Pit. If the pit is below drainage level, the outside surface shall be thoroughly waterproofed. Waterproofing may be done either by painting with asphalt and then covering with at least two layers of felt and asphalt alternately, felt to be lapped 18 in. (457 mm) or by other suitable methods.

9-1.8 Pit Drain. A sump and drain shall be provided wherever a sewer is available or soil conditions make the arrangement possible. If suitable drainage cannot be obtained, an injector is sometimes advisable.

9-1.9 Heater House.

9-1.9.1 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.

9-1.9.2 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 which is over the pit shall be continuous concrete, tightly caulked around all pipes.

9-1.9.3 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.

9-1.10 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 most severe weather.

9-2 Frostproof Casing.

9-2.1 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 10-1.4, is 20°F (-6.7°C) or lower. Tank piping subjected to temperatures below freezing within unheated buildings, or dry risers of elevated tanks, shall also 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 8-2.4, and bracing shall be provided between the frostproof casing and the discharge pipe. Noncombustible construction is preferred throughout as indicated in Figure B-9-1 or equivalent.

9-2.2 Wood.

9-2.2.1 When special permission is obtained from the authority having jurisdiction, frostproof casings may be of wood. (*See A-9-1.2.*) All lumber must 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 ⅝ 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.

9-2.2.2 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 may be at the base of the casing. If the casing contains only water pipes, noncombustible insulating material at least 4 in. (102 mm) thick, 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, as covered in 2-7.11, after careful cleaning of the pipes with wire brushes and scrapers. At least 1½- × 1/16-in. (38- × 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, not over 16 ft (4.9 m) long.

9-2.3 Top. When 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.

9-2.4 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, and when the tank is over a building, the joint between the roof and pipes inside the casing shall also be watertight to keep water from draining into the building in case of a broken pipe. (*See 8-1.1.*) The lower end of the casing shall be protected from absorption of moisture.

9-2.5 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 2-7.11 and 2-7.12.

Chapter 10 Tank Heating

10-1* General.

10-1.1 Tanks that are subjected to freezing shall be heated. Heating requirements are set forth in Section 10-2. Heating methods are set forth in Section 10-3 through 10-4 except for embankment-supported rubberized-fabric tanks which are set forth in Section 10-5.

10-1.2* 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.

10-1.2.1* The coldest weather temperature used to determine the need of heating shall be based on the lowest mean temperature for one day as shown on the Isothermal Map, Figure 10-1.4.

10-1.2.2* A low-water-temperature alarm, set at 40°F (4.4°C), shall be provided.

10-1.3* The method of heating used shall conform to 10-2.1, 10-2.2, or 10-2.3 according to the type of tank and its geographical location.

10-1.4* The method of heating used shall employ one of the heaters described in 10-3.1, 10-3.2, 10-3.3, 10-3.4, 10-3.5, 10-3.6, or 10-3.7, which shall have a Btu capacity per hour (kw) according to Figure 10-1.4 and Tables 10-1.4(a), 10-1.4(b), 10-1.4(c), 10-1.4(d), 10-1.4(e), 10-1.4(f), 10-1.4(g), or 10-1.4(h) for determination of heater capacity.

10-1.4.1 The heater shall be plainly marked with a plate or cast lettering giving the Btu/hr (kw) input and type of heater and the manufacturer's name.

10-1.4.2 The allowable working pressure of the heater shall not be less than the maximum filling pressure sustained when tank is being filled.

10-1.5 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. When the tank is over a building the heater may be located in the top story. Heaters, when placed inside of combustible frostproof casings, shall not be in contact with any combustible material.

10-1.6 Heat Insulation. All heaters shall be insulated to prevent excessive heat losses. When the tank heater is the only source of heat in a valve pit or other heater room, enough of the heater or steam pipe may be left bare to keep the temperature of the air above freezing.

10-1.7* 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 10-1.7. The installation of the hot and cold water-circulating pipes shall be in accordance with 10-1.7.1 and 10-1.7.2. If the circulating pipes pass through the roof or waterproofed or concrete floors, the intersections shall be made watertight. (*See 8-1.1.*)

10-1.7.1 Hot-water Pipe. Copper tubing, steel conforming to Section 2-2, 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 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. Listed indicating valve of the nominal pipe size shall be placed in the pipe near the heater.

10-1.7.2 Cold-water Pipe. The cold-water return pipe shall be connected to the discharge pipe or tank side at a point that will assure circulation throughout the entire portion of the discharge pipe 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 permit flushing water from the tank through the hot-water pipe, heater, and drain for clean-out purposes. The drainpipe shall be arranged as specified in Figure B-8-1 and as shown in Figure B-8-2.

10-1.8 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 psi (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 may be subjected. If the heater is close to stock that might be damaged by water, the relief shall be piped to a safe point.

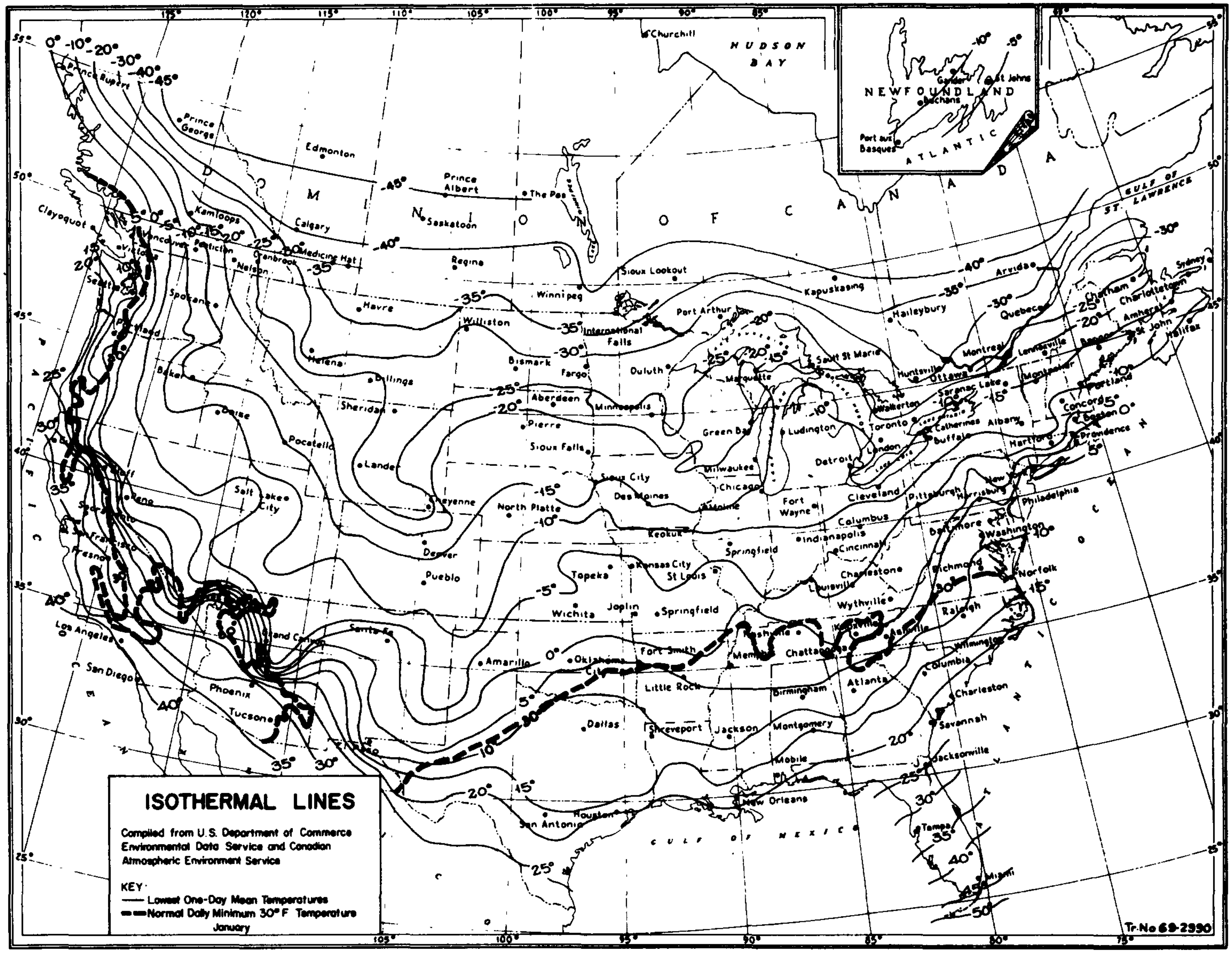


Figure 10-1.4 Isothermal Lines—Lowest One-Day Mean Temperatures (°F).
Compiled from United States Weather Bureau Records.
SI Units: °C = $5/9$ (°F − 32); 1 mi = 1.609 km.

Table 10-1.4(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 10-1.4(b) for wood tanks and Table 10-1.4(c) for steel standpipes]

To determine capacity of heater needed, find the minimum mean atmospheric temperature for one day from the Isothermal Map, Figure 10-1.4, and note the corresponding heat loss below.

TANK CAPACITIES—THOUSANDS U.S. GALLONS												
Atmospheric Temperature Deg. F	Heat (Btu/hr) Loss Per Sq Ft Tank Radiating Surface	25	30	40	50	75	100	150	200	250	Add Btu Per Lineal Ft Uninsulated Steel Riser	
		Square feet of tank surface*										
		1210	1325	1550	1800	2370	2845	3705	4470	5240	3 ft dia.	4 ft dia.
		Btu Lost per hour, Thousands										
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 square feet 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 to Table 10-1.4(a): 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 square foot 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 = 5⁄9 (°F − 32); 1000 gal = 3.785 m³.

Table 10-1.4(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 10-1.4(a) for elevated steel tanks and Table 10-1.4(c) for steel standpipes]

To determine capacity of heater needed, find the minimum mean atmospheric temperature for one day from the Isothermal Map, Figure 10-1.4, and note the corresponding heat loss below.

TANK CAPACITIES—THOUSANDS U.S. GALLONS									
Atmospheric Temperature Degrees 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 = 5⁄9 (°F − 32); 1000 gal = 3.785 m³.

Table 10-1.4(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 Tables 10-1.4(a) and 10-1.4(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 10-1.4, and note the corresponding heat loss below.

		TANK CAPACITIES—THOUSANDS U.S. GALLONS									
Atmospheric Temperature Deg. F	Heat (Btu/hr) Loss Per Sq Ft Tank Radiating Surface	100	125	150	200	250	300	400	500	750	1000
		Square feet 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 square feet of radiating surface used for each capacity to compute the tabulated heat loss values and are typical for cone roof reservoirs on grade.

Note to Table 10-1.4(c): 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 square foot 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 = ⅝ (°F − 32); 1000 gal = 3.785 m³.

Table 10-1.4(d)

Thousands of British Thermal Units Lost Per Hour from Embankment-Supported Rubberized-Fabric 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 10-1.4, and note the corresponding heat loss below.

		TANK CAPACITIES — THOUSANDS U.S. GALLONS							
Atmospheric Temperature Deg. F	Heat (Btu/hr) Loss Per Sq Ft Tank Radiating Surface	100	200	300	400	500	600	800	1000
		Square Feet 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 to Table 10-1.4(d): 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 sq ft 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 = ⅝ (°F − 32); 1000 gal = 3.785 m³.

Table 10-1.4(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/sq ft Tank Surface	Tank Capacity, U.S. gal × 1000: 50 (1,800)**	75 (2,370)	100 (2,845)	150 (3,705)	200 (4,470)	250 (5,240)	300 (5,905)	Add Btu/hr/lin ft Uninsulated Steel Riser: 3 ft dia	4 ft dia
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 square feet 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 10-1.4(f)

Heat Loss from Uninsulated* 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/sq m of Tank Surface	Tank Capacity, cu m: 189 (167)**	284 (220)	379 (264)	568 (344)	757 (415)	946 (437)	1136 (549)	Add W/lin m Uninsulated Steel Riser: 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 square meters 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 10-1.4(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/sq ft Tank Surface	Tank Capacity, U.S. gal × 1000: 100 (2,610)**	150 (3,505)	200 (4,175)	250 (4,795)	300 (5,360)	400 (6,375)	500 (7,355)	750 (9,650)	1,000 (11,740)
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 square feet of surface used for each capacity to compute the tabulated heat loss values.

Table 10-1.4(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/sq m of Tank Surface	Tank Capacity, cu m 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 $m^2 \cdot C°/W$

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

The "R" value of insulation (Tables 4 and 5) 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 × $\frac{(10)}{R}$ or Heat Loss Metric = Tabulated × $\frac{(176)}{R}$

Table 10-1.7

Minimum Size in Inches of Circulating Pipes Required for Elevated Steel Tanks. Tank Capacity (U.S. Gallons).

Minimum One-Day Mean Temp. Degrees 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 = 5/9 (°F − 32); 1000 gal = 3.785 m^3

10-1.9 Operation.

10-1.9.1* 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.

10-1.9.2 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.

10-1.9.3 When circulating systems are temporarily shut off, circulation shall be started and run for not less than 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.

10-1.9.3.1 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.

10-1.9.4 All air shall be blown from steam heaters, radiators, and traps by means of the air valve or vent on radiator or trap when first admitting steam.

10-2* Heating Requirements.

10-2.1* 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 10-1.4, 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 10-2.1.1 or 10-2.1.2.

10-2.1.1 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 7-1.2*), standpipes, and on-grade suction tanks, a steam-heated vertical radiator system may be used. For tower heights over 100 ft (30.5 m), a steam-heated vertical radiator system may also be used except that an open-ended pipe sleeve similar to that shown in Figure B-10-3 shall be used.

10-2.1.2 For suction tanks and standpipes having flat bottoms supported near ground level, immersed steam coils may be used if the tank is kept filled so that the steam coils are continuously submerged.

10-2.2 Where the lowest mean temperature for one day is 5°F (-15°C) or above as shown by the Isothermal Map, Figure 10-1.4, 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 may be 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 need no provision for heat.

10-2.3 Where the lowest mean temperature for one day is above 15°F (-9.4°C) as shown on the Isothermal Map, Figure 10-1.4, 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, inside the frostproof casing.

10-3 Heating Systems.

10-3.1* Steam Water Heaters. A steam water heater may consist of a cast iron or steel shell through which water circulates around steam tubes or coils of brass or copper. Galvanized steel or iron steam tubes are 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 psi (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.

10-3.1.1 Steam Supply. Steam water heaters shall be connected to a reliable steam supply with a pressure preferably not less than 10 psi (0.7 bars) and not over 50 psi (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 gage shall be provided preferably between the valve and the heater. When 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.

10-3.1.2 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 gage shall be provided near the heater whenever 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 shall also be placed on each side of the trap between the bypass connections.

10-3.1.2.1 A gravity return may be used only when the heater is located well above the boiler water-level and when 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.

10-3.1.2.2 Whenever 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.

10-3.1.3 Multiple Heaters. If two or more heaters are used, they shall be placed at one level and shall be 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.

10-3.2 Gas-fired Water Heaters. A gas-fired water heater of sufficient strength to resist the water pressure may 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 per hour (kw). The heater and accessories shall be installed in accordance with the manufacturer's recommendations and provided with listed combustion safeguards.

10-3.2.1 The gas-fired water heater shall be equipped to prevent abnormal discharge of gas, in event of ignition failure or accidental flame extinguishment, by automatic means specifically approved for the heater.

10-3.2.2 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).

10-3.2.3 Thermostatic control of the burner with temperature response element shall be located in the coldest water affected by atmospheric temperature, maintaining a minimum water temperature of at least 42°F (5.6°C).

10-3.3 Oil-fired Water Heaters. An oil-fired water heater of sufficient strength to resist the water pressure may 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 per hour (kw).

10-3.3.1 The heater and accessories shall be installed in accordance with the manufacturer's recommendations and provided with listed combustion safeguards.

10-3.3.2 The heater shall be equipped to prevent abnormal discharge of oil at the burner, in event of ignition failure or accidental flame extinguishment, by automatic means specifically approved for the heater.

10-3.3.3 A high-limit switch shall be provided in the hot-water pipe close to the heater to shut off the oil supply automatically when the water temperature exceeds 190°F (87.8°C).

10-3.3.4 Thermostatic control of the burner with temperature response element shall be located in the coldest water affected by atmospheric temperature, maintaining a minimum water temperature of at least 42°F (5.6°C).

10-3.3.5 The oil tank shall be buried outside the heater house.

10-3.4 Coal-burning Water Heaters. A coal-burning water heater of sufficient strength to resist the water pressure may be used. Water circulates through a chamber or 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.

10-3.5 Electric Water Heaters. An electric water heater of sufficient strength to resist the water pressure may be used. A water-circulating pump shall be used in conjunction with electric heating elements. A single water heater or boiler of adequate capacity may be used. However, to avoid sudden peak demands on the electric service, multiple heaters shall be installed in parallel (*see 10-3.1.3*) 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 temperature response element shall be located in the coldest water affected by atmospheric temperature.

10-3.5.1 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)].

10-3.5.2 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®*.

10-3.6 Vertical Steam Radiators. A vertical steam radiator, shown in Figure B-10-3, 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 7-1.2*), suction tanks, and standpipes. For tower heights over 100 ft (30.5 m), a steam-heated vertical radiator system may also be used except that an open-ended pipe sleeve similar to that shown in Figure B-10-3 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 to convey the steam required under worst conditions but never less than 1½ in. in size, 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-10-3.1*). 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 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 socket thermometer located in the coldest water.

10-3.6.1 The radiator shall be supplied from a reliable source with preferably at least 10 psi (0.7 bars) steam pressure. (*See A-10-3.1 for low-pressure steam.*) If steam pressure in excess of 100 psi (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 psi (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 gage 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-10-4*), 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-10-6. Other arrangements for disposing of condensate are acceptable provided approval is first obtained from the authority having jurisdiction.

10-3.6.2 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-10-4.

10-3.6.3 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.

10-3.7 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, and 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.

10-3.8 Steam Coils Inside Tanks.

10-3.8.1 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 psi (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 gage 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 note of caution in 10-1.5.*) The coil shall contain a sufficient area of heating surface explained in A-10-3.1 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 8,000 ft per min (2438 m/min) so that the pressure drop does not exceed ½ of the initial inlet pressure.

10-3.8.2 The surface water temperatures for elevated tanks and for 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 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.

10-3.9 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, in which case the steam pipe shall extend inside the frostproof casing, through the bottom to a point above the maximum water level, then horizontally a short distance, with an air vent and a check valve to keep the water from siphoning back and thence downward to a point 3 or 4 ft (0.9 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.

10-3.10 Solar Heating. Tanks may 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.

10-4 Tank Insulation. When permitted by the authority having jurisdiction, tanks may 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 10-1.4. Heat-loss calculations shall be based on an average water temperature of 55 °F (12.8 °C).

10-5 Heating for Embankment-supported Rubberized-fabric Tanks.

10-5.1 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 10-1.4, 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 per hour (kw) input.

10-5.2 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-5-3 for a typical installation.

10-5.3 The heater shall have a Btu per hour (kw) capacity according to Figure 10-1.4 and Table 10-1.4(d) for determination of heater capacity.

10-5.4 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.

10-5.4.1 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.

10-5.5 The heat exchanger/heater shall be located in a valve pit. See Figure B-5-3 for a typical installation.

10-5.5.1 The valve pit temperature shall be maintained above freezing at all times.

10-5.6 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 10-1.4 showing isothermal lines for the lowest one-day temperature.

Chapter 11 Referenced Publications

11-1 The following documents or portions thereof are referenced within this document 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. These references are listed separately to facilitate updating to the latest edition by the user.

11-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 13-1987, *Standard for the Installation of Sprinkler Systems*

NFPA 14-1986, *Standard for the Installation of Standpipe and Hose Systems*

NFPA 15-1985, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 70-1987, *National Electrical Code*

NFPA 78-1986, *Lightning Protection Code*

NFPA 422M-1984, *Manual for Aircraft Fire and Explosion Investigators*

11-1.2 Other Publications.

11-1.2.1 ACI Standard. American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, MI 48219.

ACI 318-1983, *Building Code Requirements for Reinforced Concrete*

11-1.2.2 API Specification. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005

Specification 5L-1985, *Specification for Line Pipe*

11-1.2.3 ASHRAE Handbook. American Society of Heating, Refrigerating and Air Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, GA 30329.

The Handbook of Fundamentals, 1985

11-1.2.4 ASME Code. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME Boiler and Pressure Vessel Code, 1986

11-1.2.5 ASTM Standards. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

A6/A6M-85, *Specifications for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use*

A27/A27M-85, *Specifications for Mild- to Medium-Strength Carbon-Steel Castings for General Application*

A36/A36M-84, *Specifications for Structural Steel*

A53-86, *Specifications for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*

A105/A105M-86, *Specifications for Forgings, Carbon Steel, for Piping Components*

A106-86, *Specifications for Seamless Carbon Steel Pipe for High Temperature Service*

A108-81, *Specification for Steel Bars, Carbon, Cold Finished, Standard Quality*

A131/A131M-85, *Specification for Structural Steel for Ships*

A139-85, *Specification for Electric-Fusion (arc)-Welded Steel Pipe (sizes 4 in. and over)*

A181/A181M-85, *Specifications for Forgings, Carbon Steel for General Purpose Piping*

A283/A283M-85, *Specification for Low- and Intermediate-Tensile Strength Carbon Steel Plates of Structural Quality*

A285/A285M-82, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

A307-86, *Specifications for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*

A442/A442M-86, *Specifications for Pressure Vessel Plates, Carbon Steel Improved Transition Properties*

A502-83, *Specifications for Steel Structural Rivets*

A516/A516M-86, *Specifications for Pressure Vessel Plates, Carbon Steel for Moderate- and Lower-Temperature Service*

A615/A615M-86, *Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement*

A663-85, *Specification for Steel Bars, Merchant Quality Subject to Mechanical Property Requirements*

A668-85, *Specification for Steel Forgings, Carbon and Alloy for General Industrial Use*

A675-85, *Specifications for Steel Bars and Bar Size Shapes, Carbon, Hot-Rolled, Special Quality, Subject to Mechanical Property Requirements*

C578-85, *Specifications for Preformed Block-Type Cellular Polystyrene Thermal Insulation*

C591-85, *Specifications for Rigid Preformed Cellular Urethane Thermal Insulation*

D751-79, *Testing Coated Fabrics*

D2261-83, *Test for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant Rate-of-Expansion Tensile Testing Machine)*

D4157-82, *Test for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)*

D4158-82, *Test for Abrasion Resistance of Textile Fabrics (Uniform Abrasion) Method*

E380-85, *Standard for Metric Practice*

11-1.2.6 AWWA Standards. American Water Works Association, Inc. 6666, W. Quincy Avenue, Denver, CO 80235.

D100-84, *AWWA Standard for Welded Steel Tanks for Water Storage*

D102-78, *AWWA Standard for Painting Steel Water Storage Tanks*

D103-80, *Standard for Factory Coated Bolted Steel Tanks for Water Storage*

11-1.2.7 AWS Code. American Welding Society, Inc., 550 NW LeJeune Road, P.O. Box 351040, Miami, FL 33135.

AWS A5.1-81, *Specifications for Covered Carbon Steel Arc-Welding Electrodes*

AWS D1.1-86, *Structural Welding Code*

AWS D5.2-84, *Standard for Welded Steel Tanks for Water Storage*

11-1.2.8 AWPA Standard. 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

11-1.2.9 NWTI Bulletin. National Wood Tank Institute, 848 Eastman Street, Chicago, IL 60622.

NWTI Bulletin S82, *Specifications for Tanks and Pipes*

11-1.2.10 SSPC Application Specification. 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, PA 1 — Shop, Field, and Maintenance Painting"

11.2.11 US Government Publications. Superintendent of Documents, US 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

Appendix A

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

A-2-6.8.2 Suitable petroleum-base oils include no. 2 fuel oil, drain oil, or other oils of equivalent viscosity.

A-2-7.13 Corrosion Protection. The following methods of corrosion protection may be used 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 shall be of suitable material and construction, approved by the authority having jurisdiction. Aluminum alloy 2107-T4 and high-silicon cast iron with a maximum of 14.35 percent silicon are considered suitable materials for impressed current systems. All anodes shall be provided with listed containment devices to prevent any portions thereof from separating and falling. All such containment devices shall be securely fastened to pin insulators hung from the roof of the tank. To ensure continued reliable operation of such cathodic protection equipment, the owner shall 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.

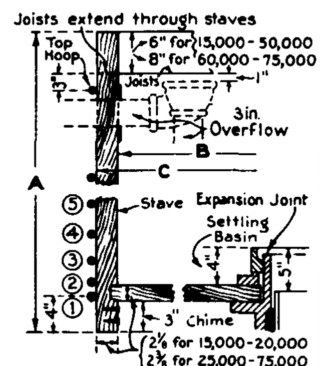
A-3-1.4 The condition known as airlock can occur when a pressure tank and a gravity tank are connected into the sprinkler system through a common riser if the gravity water pressure at the gravity-tank check valve is less than the air pressure trapped in the pressure tank and common riser by a column of water in the sprinkler system after water has been drained from the pressure tank. For instance, if the pressure tank is kept ⅔ full of water with an air pressure of 75 psi (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 psi (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 psi (1.0 bars) [35-ft (10.7-m) head].

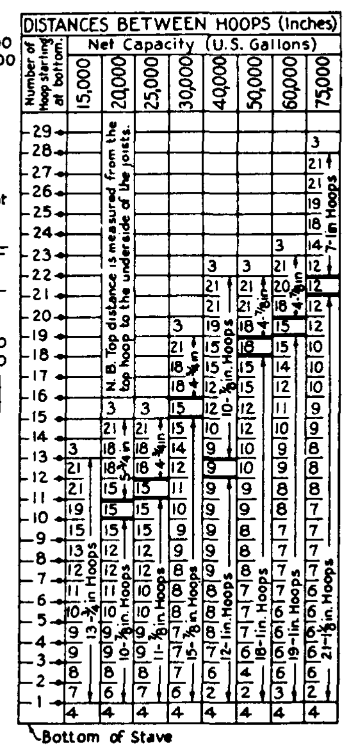
Airlock can be prevented by increasing the volume of water and decreasing the air pressure in the pressure tank, so that little or no air pressure remains after water has been exhausted. For instance, if the pressure tank is kept ⅘ full of water, with an air pressure of 60 psi (4.1 bars), the air pressure 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-4-5.3 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 4-5.3 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 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: Design spacing may exceed computed spacing a maximum of ½ in. (12.7 mm). Spacing as installed may exceed computed spacing a maximum of 1 in. (25.4 mm).





TANK DIMENSIONS				
Net Capacity (Gallons)	Stave Length A	Inside Diam. B	Outside Diam. C	Approx. Outside Circ.
15,000	14'-0"	14'-2½"	14'-7"	45'-9¾"
20,000	16'-0"	15'-3½"	15'-8"	49'-2¾"
25,000	16'-0"	17'-0½"	17'-6"	54'-11¾"
30,000	18'-0"	17'-6½"	18'-0"	56'-6½"
40,000	20'-0"	19'-1½"	19'-7"	61'-6¼"
50,000	20'-0"	21'-6½"	22'-0"	69'-1½"
60,000	20'-0"	23'-6½"	24'-0"	75'-4¾"
75,000	24'-0"	23'-10½"	24'-4"	76'-5¼"

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1000 gal = 3.785 m^3

Figure A-4-5.3 Hoop Schedules for Wood Tanks. (Dimensions are for cylindrical tanks.)

A-7-1.1 Fireproofing Tank Towers. *(See Section 1-5 for locations where fireproofing is needed.)*

Fireproofing, when 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 gage (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- or 5-ft (1.2- 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 weatherproof 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 fourteen-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-8-1.12 Water-level Gages.

General. A listed mercury gage as shown in Figure B-8-6 is considered the most reliable water-level indicator for elevated tanks. For suction tanks of low height other gage types may be more suitable.

Mercury Gage 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 gage 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 gage 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 gage exceeds 50 ft (15.2 m).

Mercury Catcher. Occasionally, fluctuating water pressures require a mercury catcher at the top of the gage glass, as shown in Figure B-8-6, to prevent loss of mercury. The catcher is not a standard part of the equipment and is not furnished by the gage 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 ⅛-in. pipe, vented at the top.

Water-Drain Plug. A plugged tee shown at "G" in Figure B-8-6 should be provided in the mercury pipe between the mercury pot and the gage glass to permit draining off water that sometimes accumulates on top of the mercury column.

Location. The gage 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 gage, 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 gage 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 gage 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-8-6, 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 gage 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-8-6.*)

(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 gage 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 gage 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 gage 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 ¾-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 waterpipe between the test cock and the tank riser.

(f) If there is water on top of the mercury column in the gage 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 gage is subjected to continual fluctuation of pressure, when it may be necessary to keep the gage shut off except when reading. Otherwise it may be necessary to frequently remove water from the top of the mercury column as in A-8-1.12(f), Testing.

A-9-1.2 Insulation.

(a) Layers of listed insulation may be constructed as follows: first, 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; second, wrap all pipes together with waterproof building paper applied over hardwood cleats equal in thickness to the projections of pipe flanges or couplings; third, 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; finally, 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 details from 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-9-2. 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-9-1*) are for weather-exposed pipes. Each of these casings can protect multiple piping systems. In A-9-1.2, 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 9-1.2 gives minimum thickness of various materials or types of construction.

Wood Preservatives. The lumber used in wood frostproof 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-10-1 Typical Examples.

Size of Water Heater for an Elevated Tank. Given a 75,000-gal (283.88-m^3) steel tank with an insulated riser pipe and 2,370 sq ft (220 m^2) of radiating surface at Duluth, Minnesota, what heater capacity would be needed? If the tank were wood, what heater capacity would be needed?

From Figure 10-1.4, the lowest one-day mean temperature is -28°F (-33.3°C). Interpolating from Table 10-1.4(a), the heat loss for a typical tank is approximately 659,000 Btu per hour (193 kw).

A heater should be capable of delivering 659,000 Btu per hour (193 kw) under field conditions. Table 10-1.7 shows that the size of the water-circulating pipe will be at least 2½ in. in size.

For a wood tank, other conditions as above, Table 10-1.4(b) shows a maximum heat loss of about 254,000 Btu per hour (74.4 kw) and the heater installed should be capable of delivering that amount of heat. Table 10-1.7 shows that the size of the water-circulating pipe will be at least 2 in. in size.

Table A-10-1

Approximate Heat Transfer From Coils and Pipe Radiators When Coldest Water is Just Safely Above Freezing

Steam Pressure Lbs. per sq in	kPa	Heat Transfer (*Steam to Water*) Btu per hr per sq ft	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-10-2 and B-10-5 or by a pipe radiator as indicated in Figures B-10-3 and B-10-4.

From Table 10-1.4(a), the heat loss is 659,000 Btu per hour (193 kw) as determined above plus approximately 2,057 × 100 = 205,700 Btu per hour (60.3 kw) additional for the riser for a total of approximately 861,700 Btu per hour (252 kw). A water heater should be capable of delivering this much heat.

For a pipe radiator the heat transfer for 15-psi (1.0-bars) steam is 22,000 Btu per hour (6.4 kw) from Table A-10-1. The required radiating surface is 864,700 divided by 22,000, or 39.3 sq ft (3.65 m).

From Table A-10-2 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-10-3 and B-10-4 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-10-1.2 Determination of Heater Capacity—General. To prevent freezing in any part of a 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-10-1.2.1 Atmospheric Temperature. The map, Figure 10-1.4, 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-10-1.2.2 The low-water-temperature alarm should be connected to the local proprietary alarm system or to a listed central station supervisory service.

A-10-1.3 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 10-1.4, and then determine the total heat loss from the tank equipment in Btu per hour (kw) from Table 10-1.4(a) for an elevated steel tank, Table 10-1.4(b) for an elevated wood tank, Table 10-1.4(c) for a steel suction tank or standpipe, or Table 10-1.4(d) for an embankment-supported rubberized-fabric 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-10-1.4 Heat Losses. Tables 10-1.4(a), 10-1.4(b), 10-1.4(c), 10-1.4(d), 10-1.4(e), and 10-1.4(f) show the heat losses from uninsulated elevated steel tanks, elevated wood tanks, steel suction tanks and standpipes, insulated steel gravity tanks, insulated steel suction tanks, and embankment-supported rubberized-fabric tanks, respectively, for common sizes exposed to various atmospheric temperatures between 35°F above and 60°F below zero (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 per hour that the heating system should supply when the atmospheric temperature is at any degree within the range of the tables.

A-10-1.7 Typical arrangements of the installation of heater water-circulating pipes are shown in Figures B-10-1, B-10-2, B-10-3, B-10-4, B-10-5, and B-10-6.

A-10-1.9.1 A recording thermometer with the sensitive bulb inserted in the coldest water is a valuable accessory, as a constant record of water temperatures is obtained and more careful supervision by the management made possible.

A-10-2 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 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 must be provided so that the temperature of the coldest water will be maintained safely above 42°F (5.6°C).

A-10-2.1 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 10-1.4(a), 10-1.4(b), 10-1.4(c), 10-1.4(d), 10-1.4(e), and 10-1.4(f). 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).

Table A-10-2

Square Feet of Heating Surface in Coils or Pipe Radiators of Various Lengths

Length Feet	Size of Pipe—Inches ¾	1	1¼	1½	2	2½	3	3½	4	5	6
1	.275	.346	.434	.494	.622	.753	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

A-10-3.1 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-10-1.4 by the heat transfer in Btu per hour, per square foot for the steam pressure available as given in Table A-10-1. 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 psi (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-10-3.1.

Table A-10-3.1

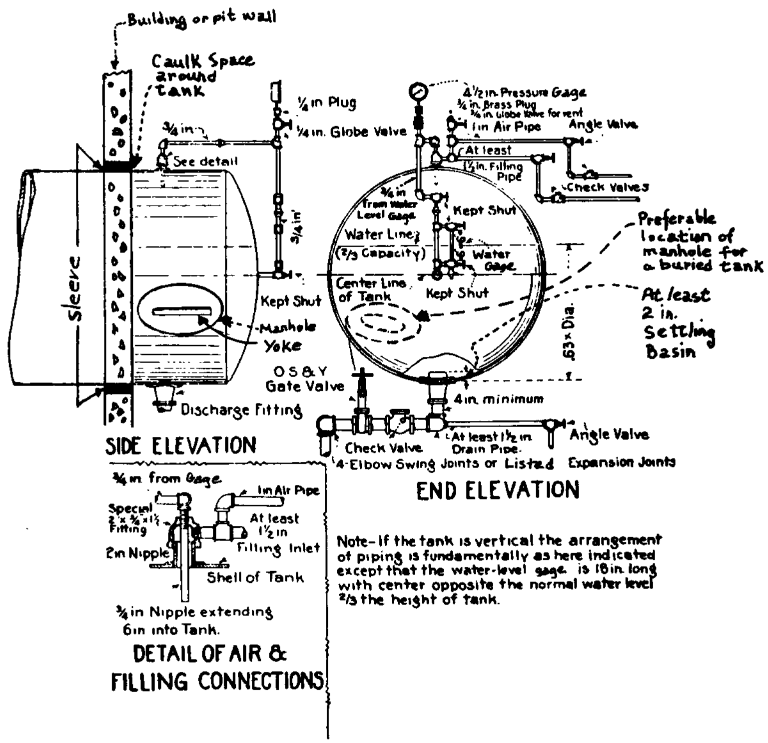
Average Efficiencies of Heaters and Heat Content of Fuels

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
Coal-burning Water Heaters	40% to 60%	Gas, Natural, *per cu ft (m³)*	1,100	41.0
		Gas, Artificial, *per cu ft (m³)*	600	22.4
		Electricity, *per kw hour*	3,415	3.6

For SI Units: 1 lb = 0.454 kg; 1 ft³ = 0.0283 m³

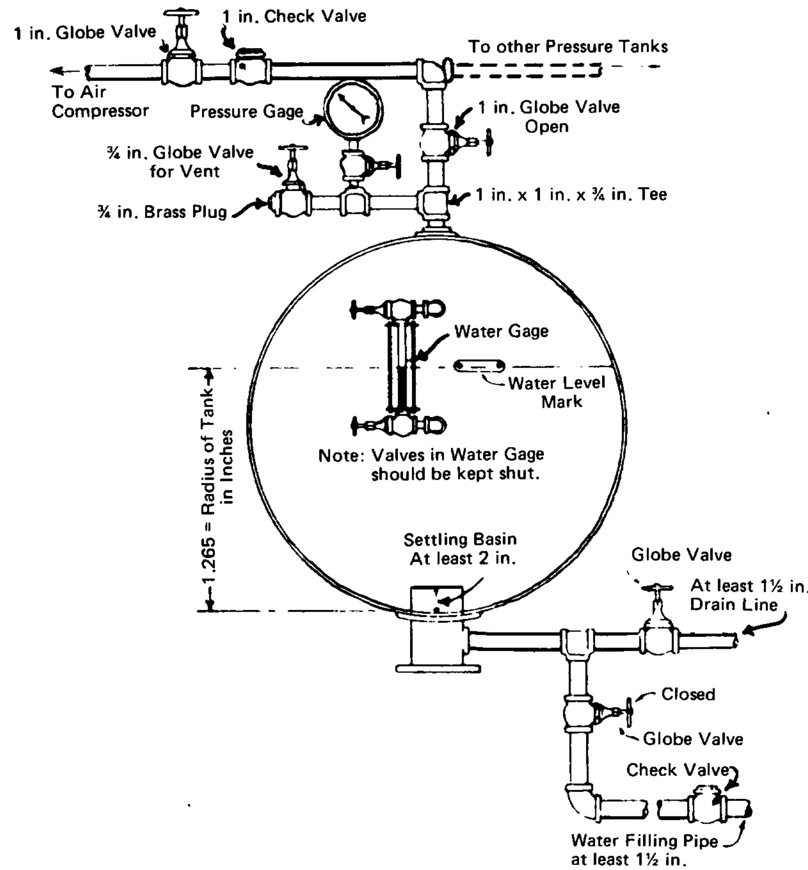
Appendix B Typical Installations

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



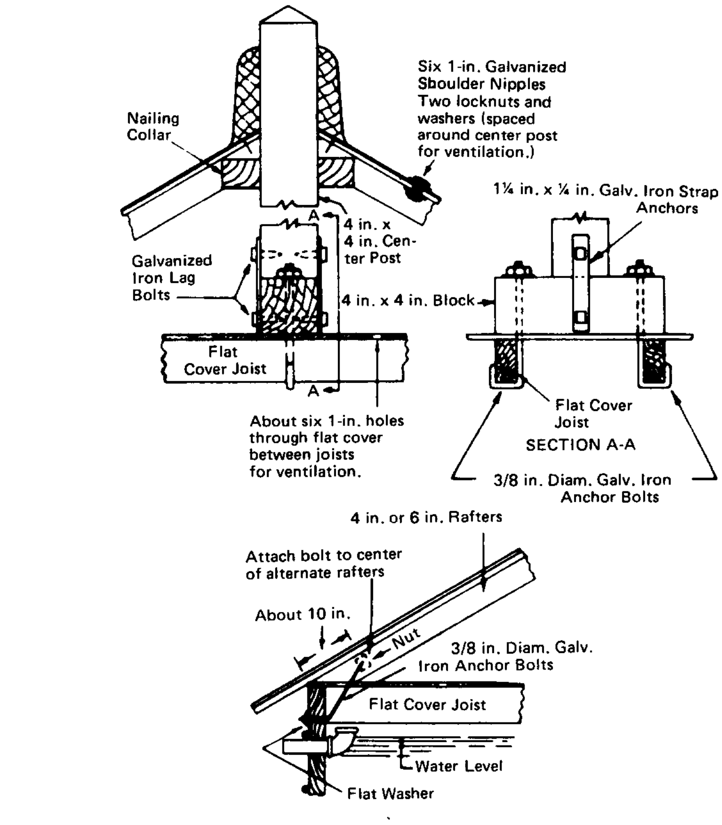
For SI Units: 1 in. = 25.4mm; 1 ft = 0.3048m

Figure B-3-1. Pipe Connections to Pressure Tanks.



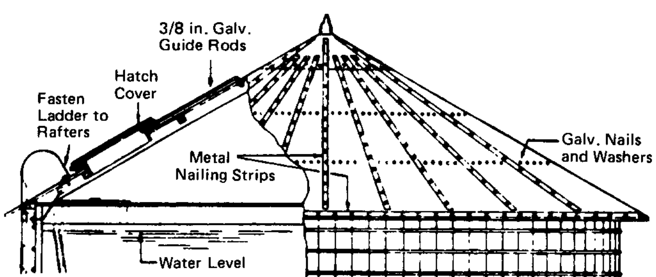
For SI Units: 1 in. = 25.4mm; 1 ft = 0.3048m

Figure B-3-2. Alternate Connections for Pressure Tanks.



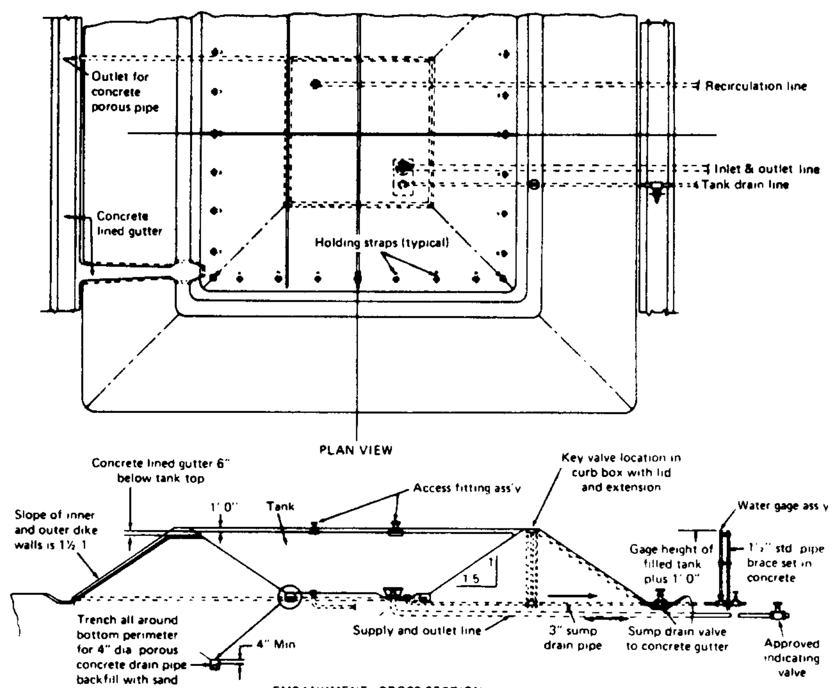
For SI Units: 1 in. = 25.4mm; 1 ft = 0.3048m

Figure B-4-1. Details of Tank Roof Construction.



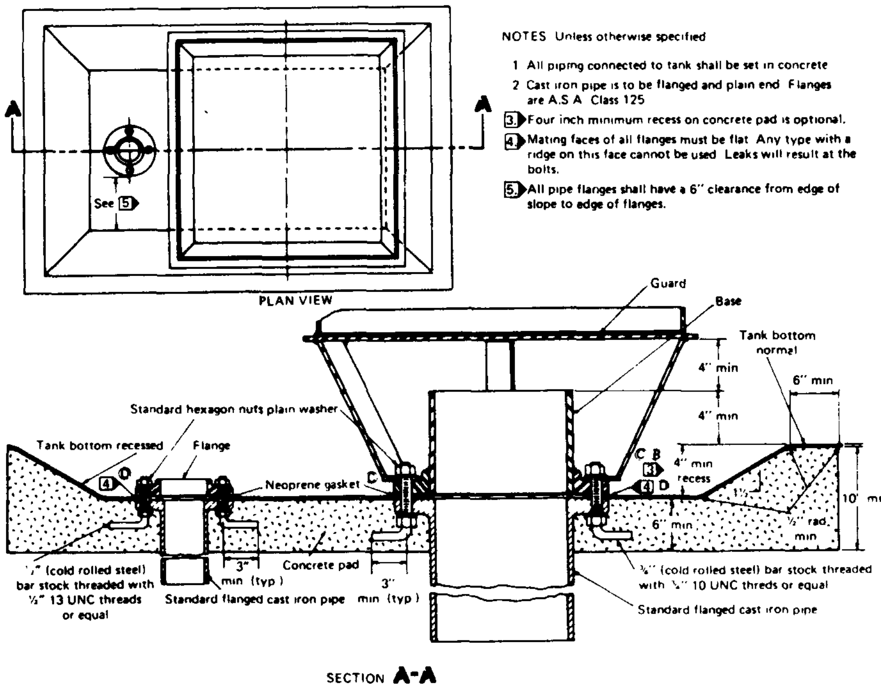
For SI Units: 1 in. = 25.4mm; 1 ft = 0.3048m

Figure B-4-2. Section of Conical Roof.



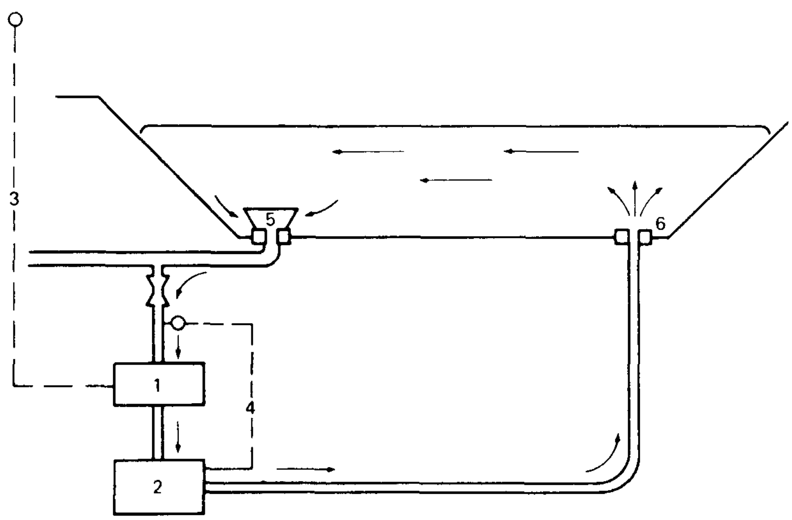
For SI Units: 1 in. = 25.4mm; 1 ft = 0.3048m

Figure B-5-1. Typical Installation Details of an Embankment-Supported Rubberized-Fabric Tank Including Fittings.



For SI Units: 1 in. = 25.4mm; 1 ft = 0.3048m

Figure B-5-2. Inlet-Outlet Fitting Assembly, Vortex Plate Assembly, and Sump Drain Fitting for Embankment-Supported Rubberized-Fabric Tank.



1. Recirculation pump.
2. Heat exchanger.
3. Unit sensing atmosphere temperature starts pump and water recirculation enabling heat stored in ground to transfer into water at higher rate.
4. Unit sensing water temperature starts heat exchanger when required.
5. Inlet-outlet fitting.
6. Recirculation fitting.

Figure B-5-3. Embankment-Supported Rubberized-Fabric Suction Tank Recirculation and Heating Schematic.

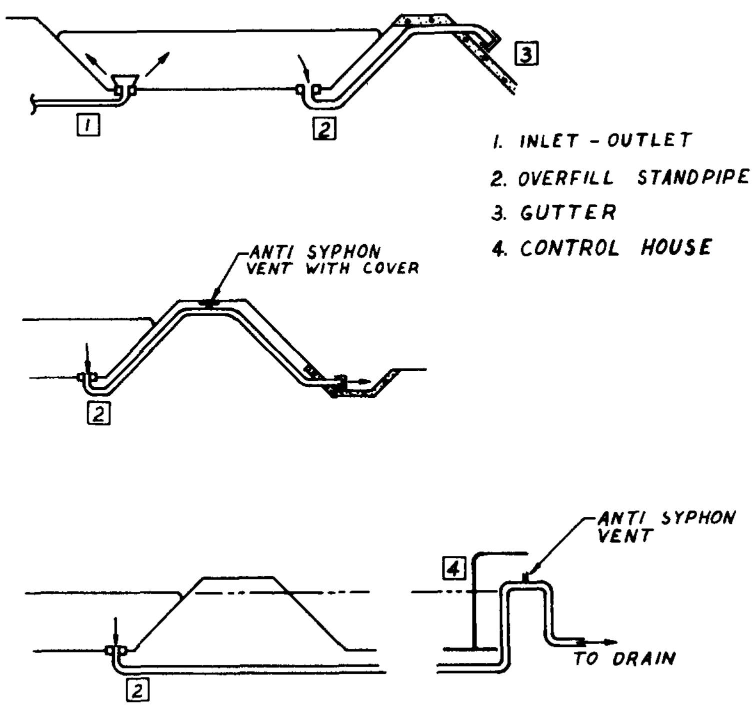
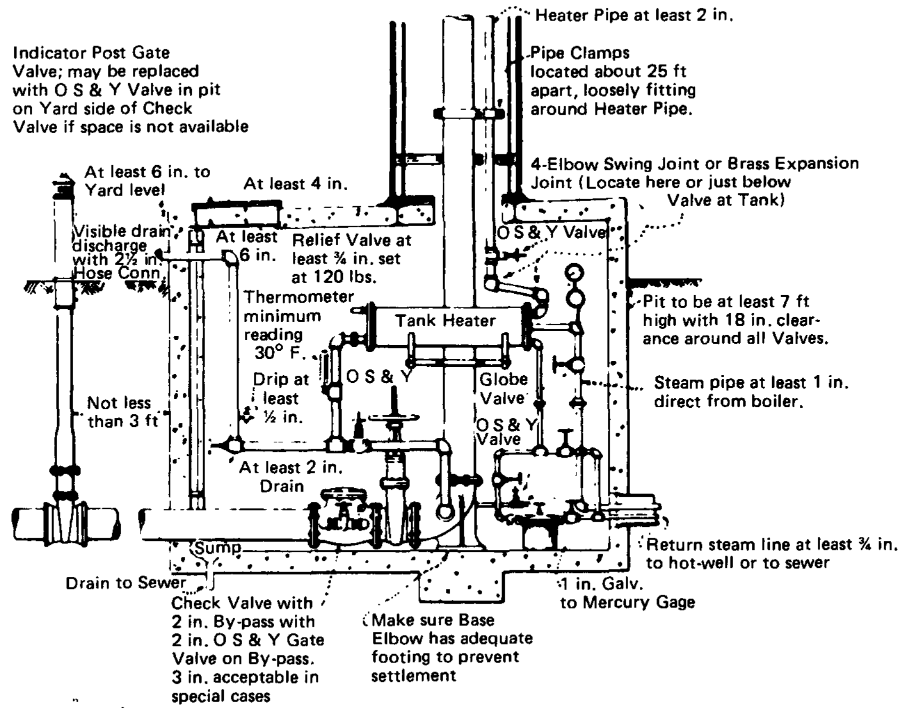


Figure B-5-4. Embankment-Supported Rubberized-Fabric Suction Tank Overfill Standpipe Alternates — Protect from Freezing.



For SI Units: 1 in. = 25.4mm; 1 ft = 0.3048m

Figure B-8-1. Valve Pit and Tank Connections at Base of Riser.