The Basics of API 650

National Institute for Storage Tank Management

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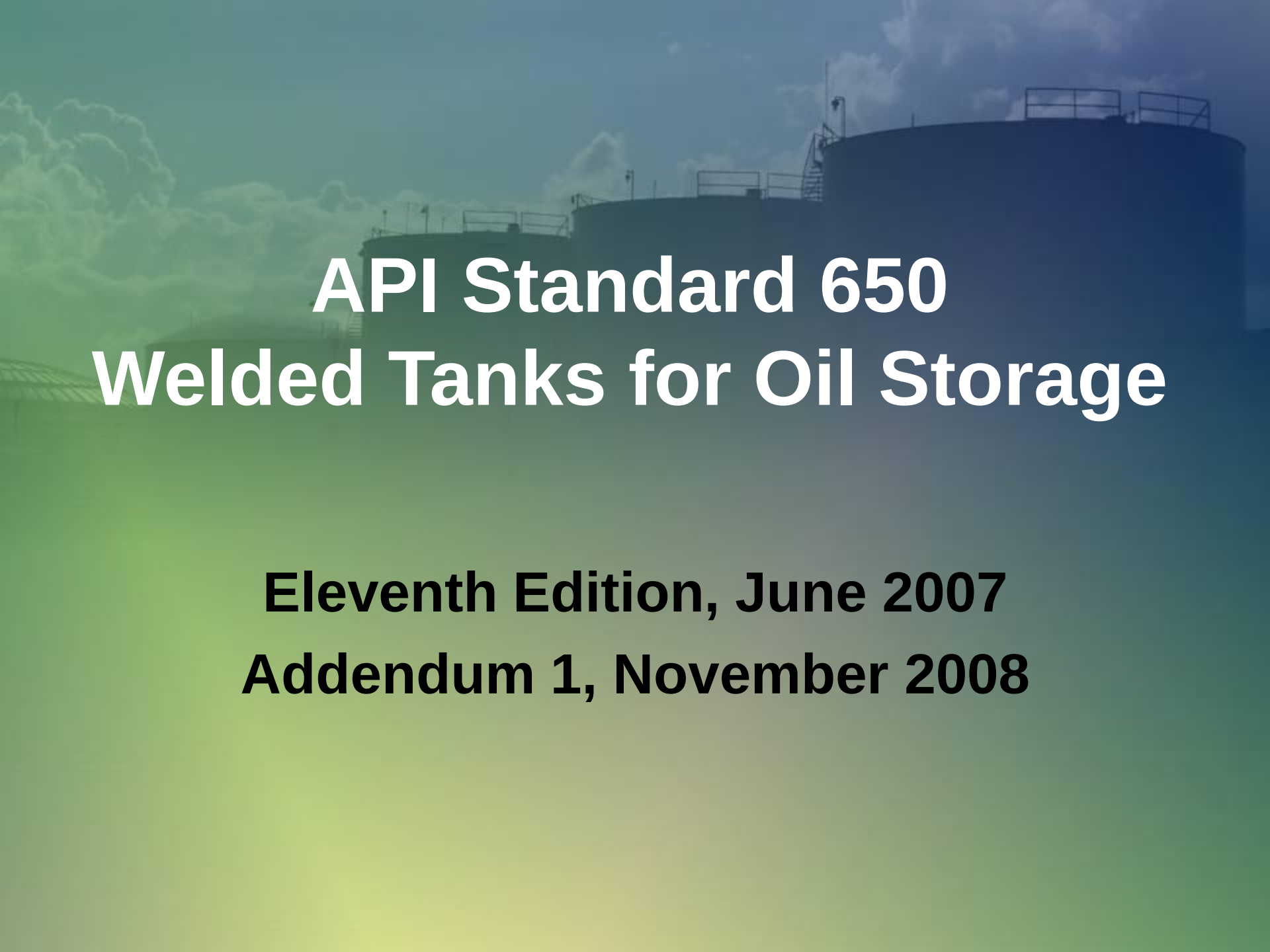
BAKER CONSULTING GROUP



API Standard 650
Welded Tanks for Oil Storage

Eleventh Edition, June 2007

Addendum 1, November 2008

Scope

- **Establishes minimum requirements for material, design, fabrication, erection, and testing for vertical, cylindrical, aboveground, closed- and open-top, welded carbon or stainless steel storage tanks in various sizes and capacities for internal pressures approximating atmospheric pressure (internal pressures not exceeding the weight of the roof plates)**

Scope

- **Applies only to tanks whose entire bottom is uniformly supported**

- **Tanks in non-refrigerated service that have a maximum design temperature of 93˚C (200˚F) or less.**

Scope

- **The Standard has requirements given in two alternate systems of units :**
  - **SI units, or**
  - **US Customary units.**

- **The Purchaser and Manufacturer shall mutually agree on the units that will be used.**

Table 1-1—Status of Appendices to API Std 650

Appendix	Title	Status
A	Optional design basis for small tanks	Purchaser's Option
B	Recommendations for design and construction of foundations for aboveground oil storage tanks	Recommendations
• C	External floating roofs	Requirements
D	Technical inquiries	Required Procedures
• E	Seismic design of storage tanks	Purchaser's Option
F	Design of tanks for small internal pressures	Requirements
• G	Structurally-supported aluminum dome roofs	Requirements
H	Internal floating roofs	Requirements
• I	Undertank leak detection and subgrade protection	Purchaser's Option
J	Shop-assembled storage tanks	Requirements
K	Sample application of the variable-design-point method to determine shell-plate thickness	Information
• L	API Std 650 storage tank data sheets	Requirements
M	Requirements for tanks operating at elevated temperatures	Requirements
N	Use of new materials that are not identified	Requirements
• O	Recommendation for under-bottom connections	Purchaser's Option
• P	Allowable external load on tank shell openings	Purchaser's Option
R	Load combinations	Requirements
S	Austenitic stainless steel storage tanks	Requirements
T	NDE requirements summary	Requirements
U	Ultrasonic examination in lieu of radiography	Purchaser's Option
• V	Design of storage tanks for external pressure	Purchaser's Option
• W	Commercial and Documentation Recommendations	Recommendations

Limitations

a) The face of the first flange in bolted flanged connections, unless covers or blinds are provided as permitted in this Standard.

b) The first sealing surface for proprietary connections or fittings.

c) The first threaded joint on the pipe in a threaded connection to the tank shell.

d) The first circumferential joint in welding-end pipe connections if not welded to a flange.

Responsibilities

- **The Manufacturer is responsible for complying with all provisions of this Standard.**
- **Inspection by the Purchaser's inspector does not negate the Manufacturer's obligation to provide quality control and inspection necessary to ensure such compliance.**

Design

Tank Capacity

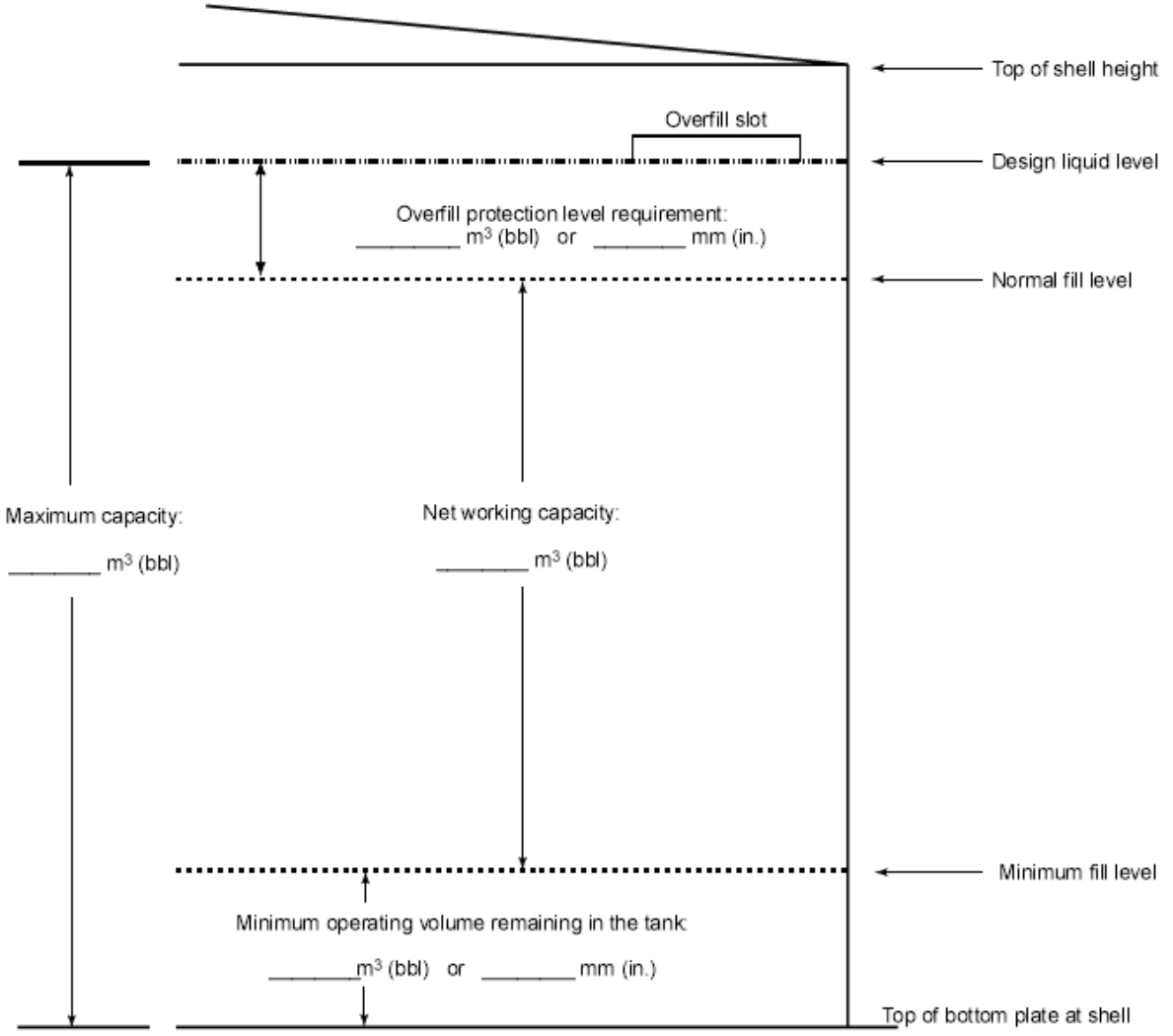


Figure 5-4—Storage Tank Volumes and Levels

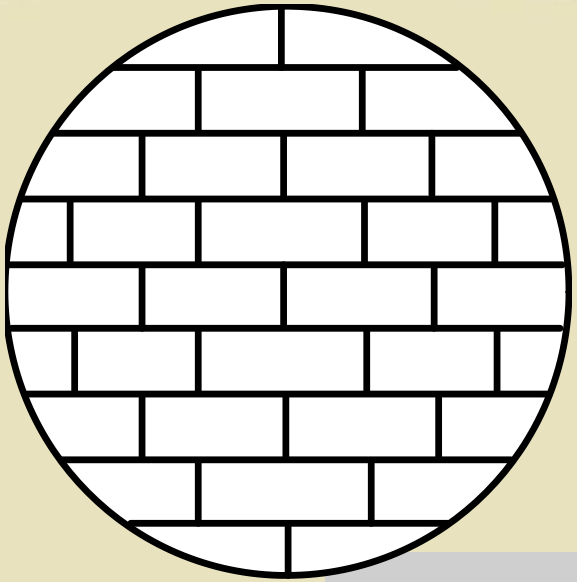
Special Considerations

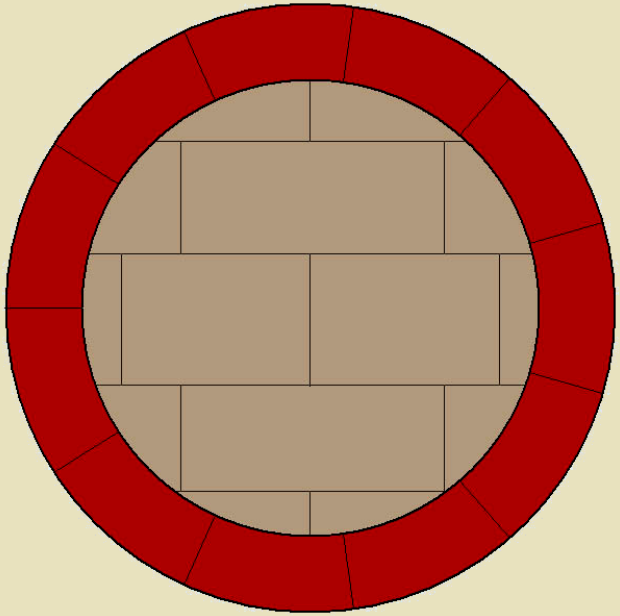
- **Foundation**
  - **The adequacy of the foundation is the responsibility of the Purchaser**
- **Corrosion Allowance**
  - **Guidance to the Purchaser for considering corrosion allowance**
- **Service Conditions**
  - **The Purchaser specify any special requirements as required by anticipated service conditions.**

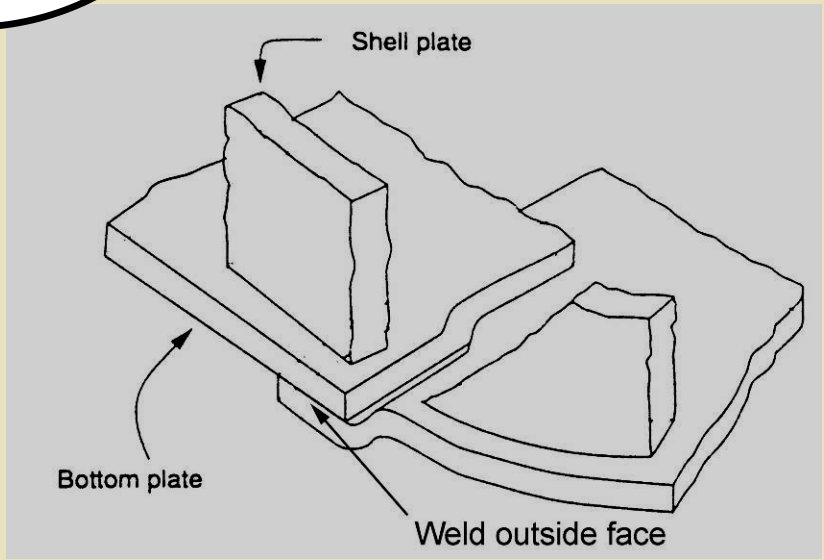
Foundation

- **Provides considerations for the design and construction of foundations.**
- **Outline good practices**
- **Precautions to be considered**
- **Tolerances for levelness of the final foundation**

Tank Bottoms







Shell Design

- **Shell Design**
  - **Shell designed on the basis that the tank is filled to level H with a specific gravity (SG) product value furnished by the customer.**
  - **Manufacturer must furnish a drawing that lists:**
    - **Required shell t (include CA) for both product and hydrotest**
    - **Nominal thickness used**
    - **Material specification**
    - **Allowable stresses**

Materials

Design Metal Temperature

- 8˚C (15˚F) above the lowest 1-day mean

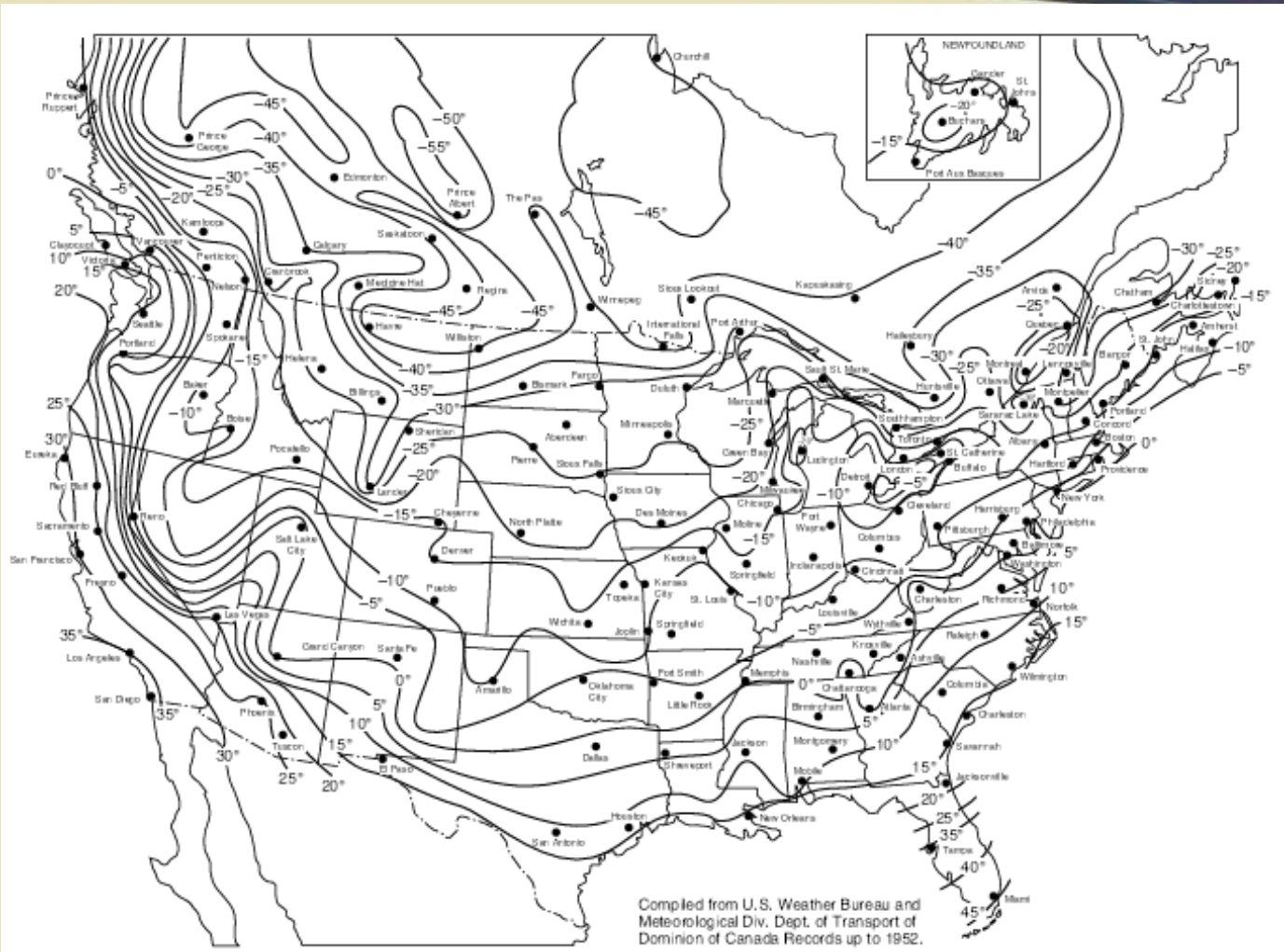
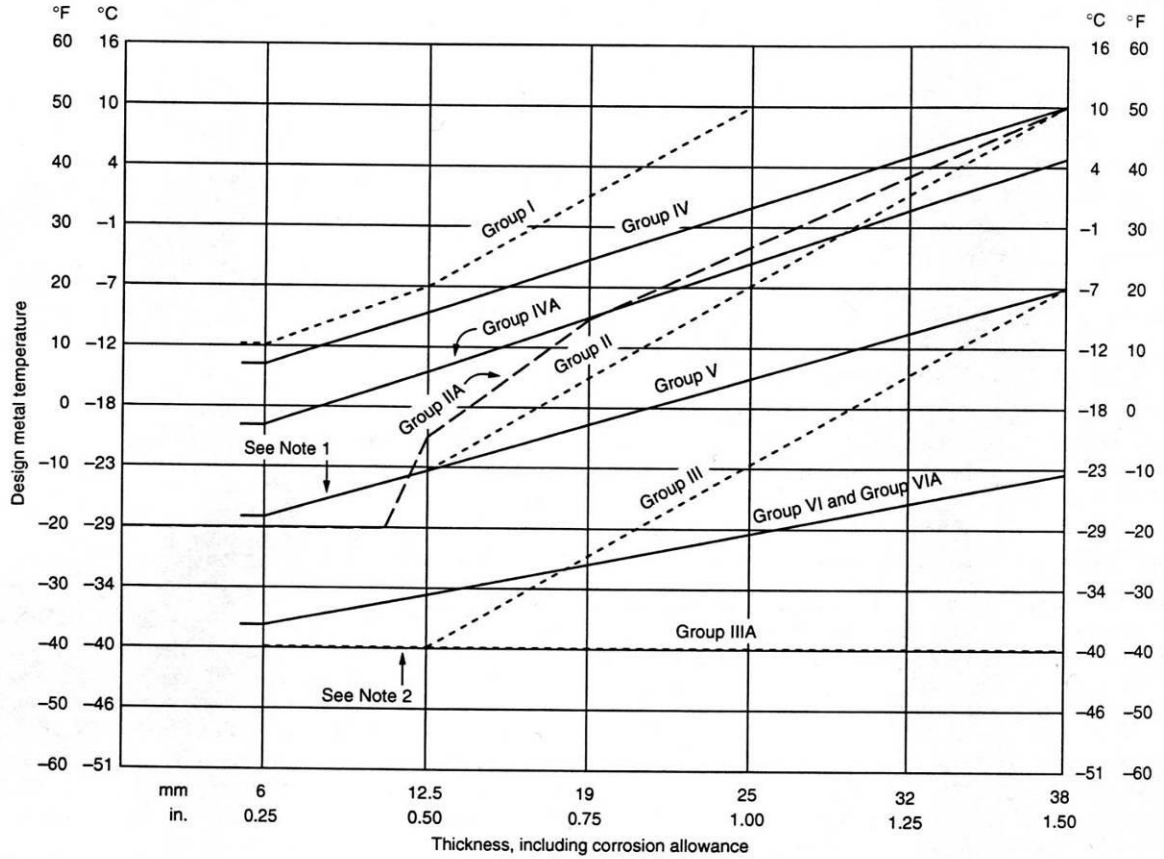


Figure 4-2—Isothermal Lines of Lowest One-Day Mean Temperatures (°F)
°C = (°F – 32)/1.8

Design

Material Group Selection



Notes:
1. The Group II and Group V lines coincide at thicknesses less than 12.5 mm ($^1/_2$ in.).
2. The Group III and Group IIIA lines coincide at thicknesses less than 12.5 mm ($^1/_2$ in.).
3. The materials in each group are listed in Table 2-3.
4. This figure is not applicable to controlled-rolled plates (see 2.2.7.4).
5. Use the Group IIA and Group VIA curves for pipe and flanges (see 2.5.5.2 and 2.5.5.3).

Figure 2-1—Minimum Permissible Design Metal Temperature for Materials Used in Tank Shells Without Impact Testing

Shell Design

S_d and S_t is selected from the table of permissible materials and allowable stresses is API Std 650

Table 3-2—Permissible Plate Materials and Allowable Stresses

	Plate Specification	Grade	Minimum Yield Strength MPa (psi)	Minimum Tensile Strength MPa (psi)	Product Design Stress S_d MPa (psi)	Hydrostatic Test Stress S_t MPa (psi)
	ASTM Specifications					
	A 283M (A 283)	C (C)	205 (30,000)	380 (55,000)	137 (20,000)	154 (22,500)
	A 285M (A 285)	C (C)	205 (30,000)	380 (55,000)	137 (20,000)	154 (22,500)
	A 131M (A 131)	A, B, CS (A, B, CS)	235 (34,000)	400 (58,000)	157 (22,700)	171 (24,900)
	A 36M (A 36)	—	250 (36,000)	400 (58,000)	160 (23,200)	171 (24,900)
	A 131M (A 131)	EH 36 (EH 36)	360 (51,000)	490[a] (71,000[a])	196 (28,400)	210 (30,400)
	A 573M (A 573)	400 (58)	220 (32,000)	400 (58,000)	147 (21,300)	165 (24,000)
	A 573M (A 573)	450 (65)	240 (35,000)	450 (65,000)	160 (23,300)	180 (26,300)
	A 573M (A 573)	485 (70)	290 (42,000)	485[a] (70,000[a])	193 (28,000)	208 (30,000)
	A 516M (A 516)	380 (55)	205 (30,000)	380 (55,000)	137 (20,000)	154 (22,500)
01	A 516M (A 516)	415 (60)	220 (32,000)	415 (60,000)	147 (21,300)	165 (24,000)
	A 516M (A 516)	450 (65)	240 (35,000)	450 (65,000)	160 (23,300)	180 (26,300)
	A 516M (A 516)	485 (70)	260 (38,000)	485 (70,000)	173 (25,300)	195 (28,500)
	A 662M (A 662)	B (B)	275 (40,000)	450 (65,000)	180 (26,000)	193 (27,900)
	A 662M (A 662)	C (C)	295 (43,000)	485[a] (70,000[a])	194 (28,000)	208 (30,000)
	A 537M (A 537)	1 (1)	345 (50,000)	485[a] (70,000[a])	194 (28,000)	208 (30,000)
	A 537M (A 537)	2 (2)	415 (60,000)	550[a] (80,000[a])	220 (32,000)	236 (34,300)
	A 633M (A 633)	C, D (C, D)	345 (50,000)	485[a] (70,000[a])	194 (28,000)	208 (30,000)
	A 678M (A 678)	A (A)	345 (50,000)	485[a] (70,000[a])	194 (28,000)	208 (30,000)
	A 678M (A 678)	B (B)	415 (60,000)	550[a] (80,000[a])	220 (32,000)	236 (34,300)
	A 737M (A 737)	B (B)	345 (50,000)	485[a] (70,000[a])	194 (28,000)	208 (30,000)
	A 841M (A 841)	Class 1 (Class 1)	345 (50,000)	485[a] (70,000[a])	194 (28,000)	208 (30,000)
	CSA Specifications					
	G40.21M	260W	260 (37,700)	410 (59,500)	164 (23,800)	176 (25,500)
	G40.21M	300W	300 (43,500)	450 (65,300)	180 (26,100)	193 (28,000)
	G40.21M	350WT	350 (50,800)	480[a] (69,600[a])	192 (27,900)	206 (29,800)
	G40.21M	350W	350 (50,800)	450 (65,300)	180 (26,100)	193 (28,000)
	National Standards					
00		235	235 (34,000)	365 (52,600)	137 (20,000)	154 (22,500)
		250	250 (36,000)	400 (58,300)	157 (22,700)	171 (25,000)
		275	275 (40,000)	430 (62,600)	167 (24,000)	184 (26,800)
	ISO 630					
00	E 275	C, D	265 (38,400)	425 (61,900)	170 (24,700)	182 (26,500)
	E 355	C, D	345 (50,000)	490[a] (71,000[a])	196 (28,400)	210 (30,400)

[a] By agreement between the purchaser and the manufacturer, the tensile strength of these materials may be increased to 515 MPa (75,000 psi) minimum and 620 MPa (90,000 psi) maximum [and to 585 MPa (85,000 psi) minimum and 690 MPa (100,000 psi) maximum for ASTM A 537M, Class 2, and A 678M, Grade B]. When this is done, the allowable stresses shall be determined as stated in 3.6.2.1 and 3.6.2.2.

Shell Design

One foot Method

$$t_d = \frac{(2.6)D(H-1)G}{S_d} + CA$$

$$t_t = \frac{(2.6)D(H-1)}{S_t}$$

Where -

t_d = thickness (in)

G = specific gravity

D = diameter (ft)

H = height (ft)

S_d = product design stress (psi)

CA = corrosion allowance

S_t = test design stress

- **use max of t_d or t_t**
- **S_d and S_t per Table 3-2**
- **add internal pressure to H**
- **must use min "t" per 5.6.1.1**
- **must check for wind buckling**

- **Not allowed for shells with diameters greater than 60m (200 ft).**

Shell Design

- **Shells with diameters greater than 60m (200 feet)**
  - **Variable Design-Point Method**
    - **See Appendix K**
  - **Elastic Analysis (Finite Element Analysis)**

Shell Design

Diameter	Minimum Thickness
≤ 15m (50')	5mm (3/16 in)
15m < D ≤ 36m 50' < D ≤ 120'	6mm (1/4 in)
36m < D ≤ 60m 120' < D ≤ 200'	8mm (5/16 in)
> 60m (200')	10mm (3/8 in)

Wind Girders

$$Z = 0.0001\ D^2H_2$$

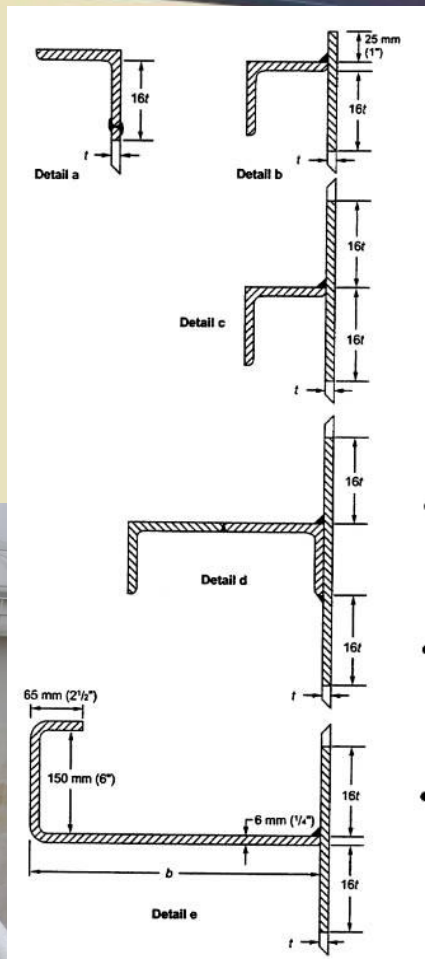
Where:

Z = Required section Modulus (in^3)

D = Nominal Tank Diameter

H_2 = Height of the tank, incl. Freeboard (ft)

Based on 120 MPH 3 sec gust



Note: The section moduli given in Table 3-20 for Details c and d are based on the longer leg being located horizontally (perpendicular to the shell) when angles with uneven legs are used.

Figure 3-20—Typical Stiffening-Ring Sections for Tank Shells (See Table 3-20)

Intermediate Wind Girders

$$H_1 = 600{,}000t\sqrt{\left(\frac{t}{D}\right)^3}\left(\frac{120}{V}\right)^2$$

$$W_{tr} = W\sqrt{\left(\frac{t_{uniform}}{t_{actual}}\right)^5}$$

Where

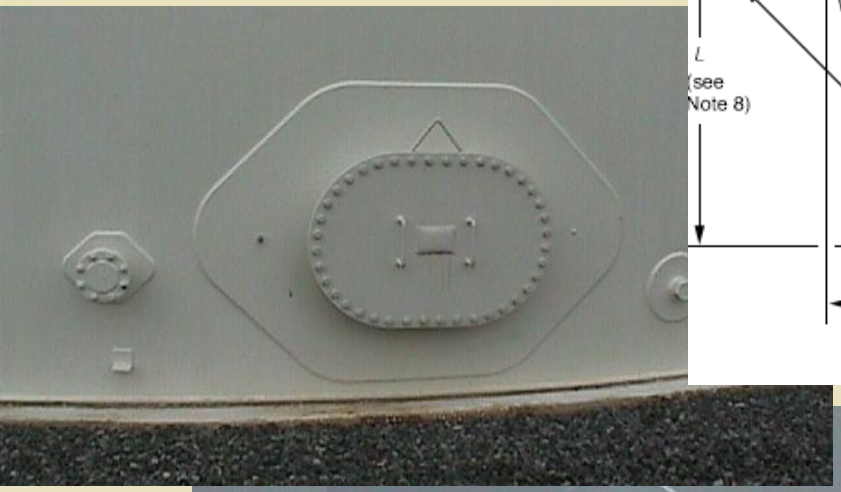
H_1 = vertical distance (ft) between intermediate wind girder and top angle or top wind gird

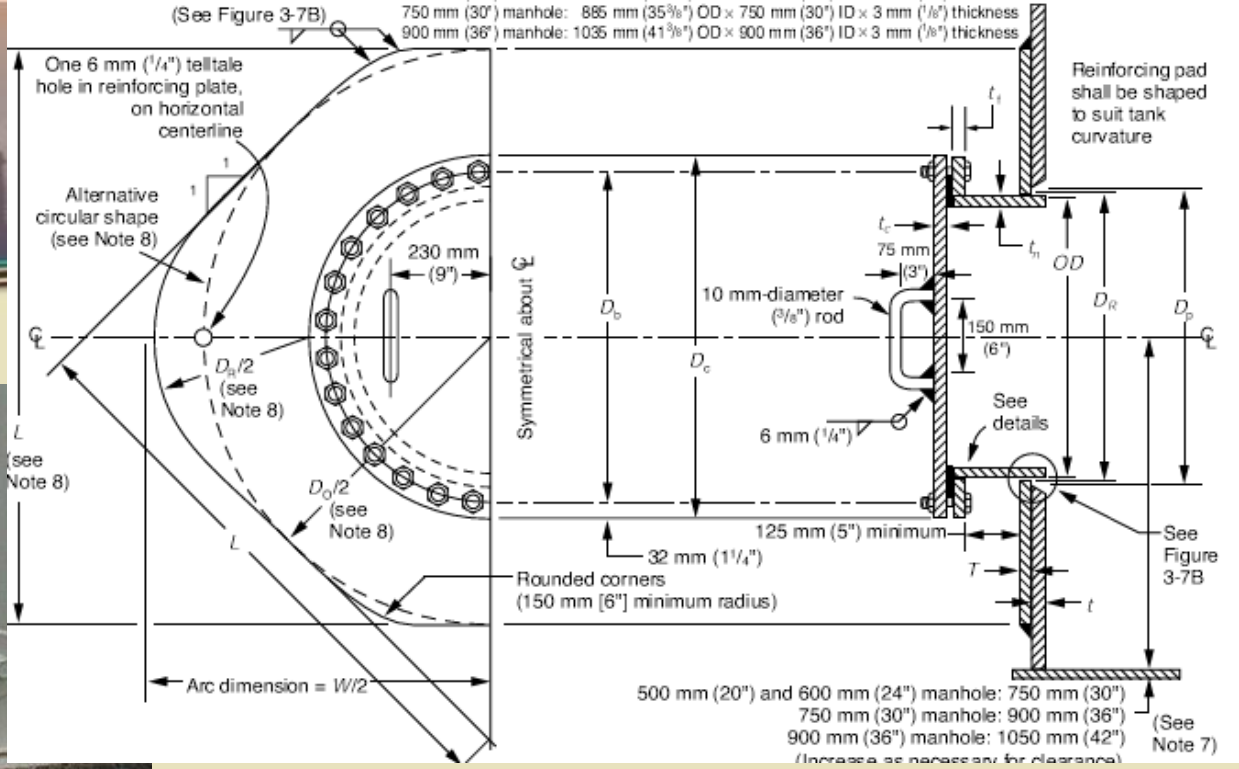
t = as ordered thickness (in) of the top shell course

D = nominal tank diameter (ft)

If the Transformed shell height is > H1 then an intermediate wind girder is required

Shell Openings



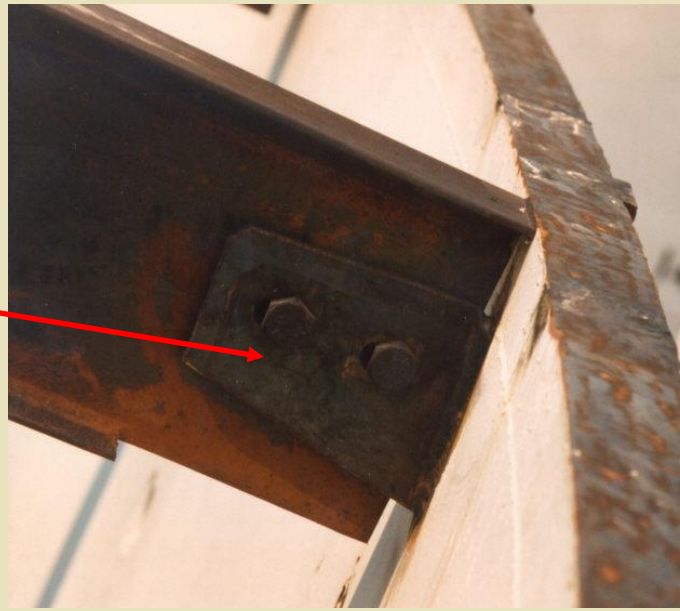


Roof Design

- **Roofs**
  - **Fixed roofs**
    - **Roofs and structure designed to support load combinations in Appendix R.**
    - **Roof Plates minimum of 5mm (3/16” or 7 gauge) sheet**
      - **Self supported roof plates may require thicker plate.**
      - **Supported cone roof plates shall not be attached to the supporting members unless the underside is to be painted.**

Fixed Roof Design

Cone Roof



Fixed Roof Design

Dome Roof

Minimum thickness = $\frac{r_r}{200}\sqrt{\frac{T}{45}} + \text{C.A.} \geq {}^{3}/_{16}$ in.

Maximum thickness = ${}^{1}/_{2}$ in., exclusive of corrosion allowance

where

D = nominal diameter of the tank shell (ft),

T = greater of load combinations (e)(1) and (e)(2) of Appendix R (lbf/ft^2),

r = roof radius (ft).

Umbrella Roof

- **Minimum radius = 0.8D (unless otherwise specified by the Purchaser)**
- **Maximum radius = 1.2D**

Wind Load

- **Provides a set of rules for evaluating the uplift or overturning stability of a tank**
- **If the design does not satisfy the uplift requirements**
  - **Increase shell weight**
  - **Provide anchorage**

Erection of Tanks

- **API 650 provides rules and tolerances for erecting tanks**
- **Rules for welding**
  - **Welding Procedure Specifications**
  - **Procedure Qualification Records**
  - **Section IX of the ASME Code**

Erection of Tanks

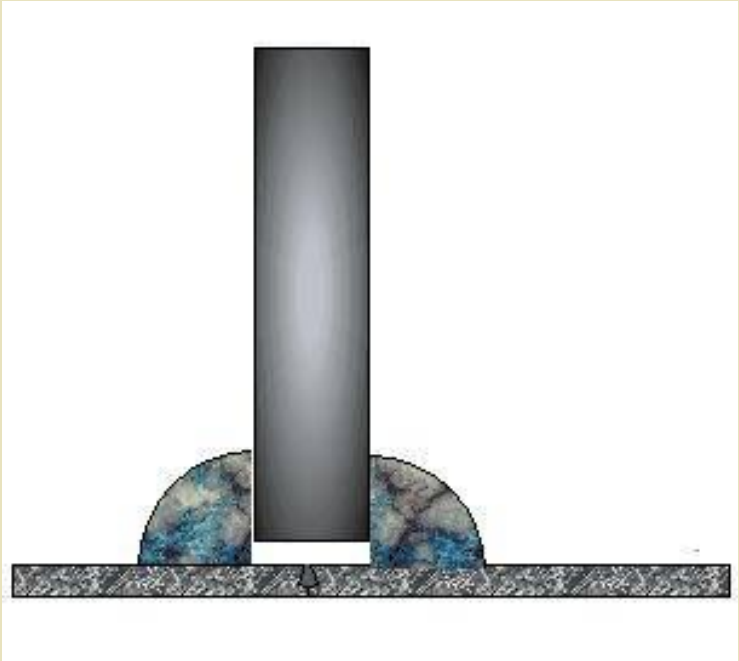
- **Welding of tank bottom**

- **Welding of tank shell**

Inspection Testing

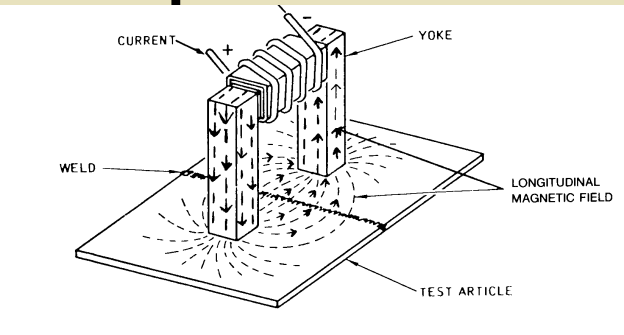
- **The standard provides details for the minimum testing to be performed to ensure quality workmanship of the tank**

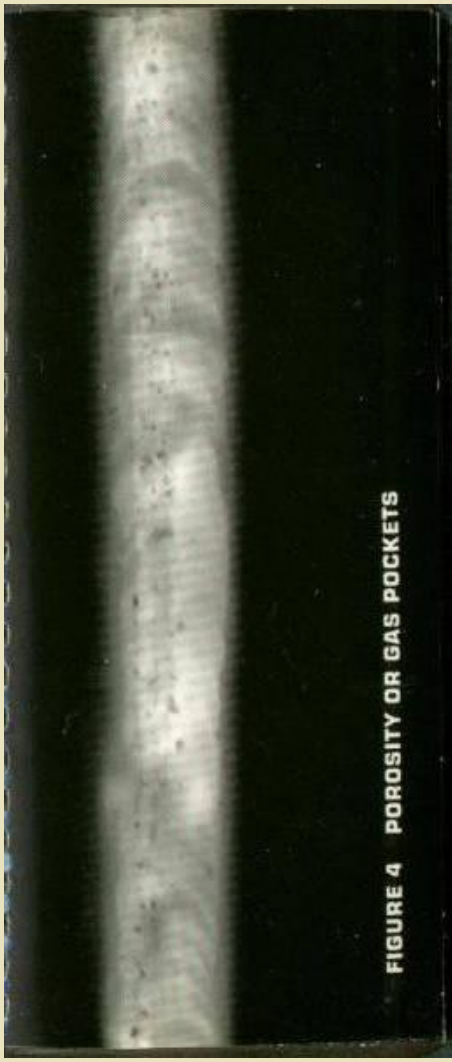
- **Shell-to-Bottom weld**
  - **Magnetic particle**
  - **Liquid penetrant**
  - **High flash-point oil**
  - **Leak test**
  - **Alternative pressure test**



Inspection Testing

- **Testing of the bottom**
  - **Visual**
  - **Vacuum box**
  - **Tracer gas**
- **Testing of the shell**
  - **Radiographic inspection**
  - **Ultrasonic inspection**
  - **Magnetic particle of root pass**





Inspection Testing

- Testing of the Roof
  - Gas tight roofs
    - Internal air pressure ≤ weight of roof plates
    - Vacuum box testing of weld seams
  - Non gas tight roofs
    - Visual inspection of weld seams

Inspection Testing

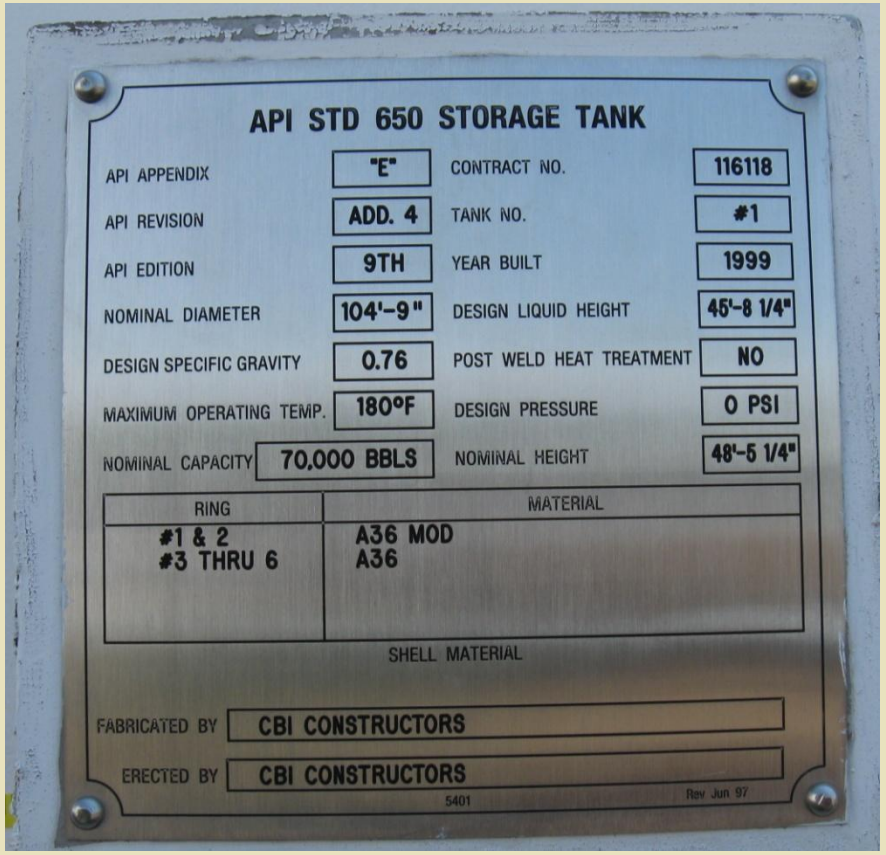
- **Testing of Penetrations**
- **Hydrostatic testing requirements**

Marking

API STANDARD 650

APPENDIX		YEAR COMPLETED	
EDITION		ADDENDUM NO.	
NOMINAL DIAMETER		NOMINAL HEIGHT	
MAXIMUM CAPACITY		DESIGN LIQUID LEVEL	
DESIGN SPECIFIC GRAVITY		DESIGN METAL TEMP.	
DESIGN PRESSURE		MAXIMUM DESIGN TEMP.	
MANUFACTURER'S SERIAL NO.		PARTIAL STRESS RELIEF	
		PURCHASER'S TANK NO.	
FABRICATED BY			
ERECTED BY			

SHELL COURSE	MATERIAL



Appendices

- **Optional Design Basis for Small Tanks**
  - **Maximum shell thickness of 13mm (1/2”)**
  - **Only applicable to lower strength materials**
  - **Design equations are simplified**
  - **Inspection requirements can be reduced**
  - **Provides a table of typical sizes, capacities, and shell plate thicknesses**

Appendices

Shop Assembled Storage Tanks

Appendices

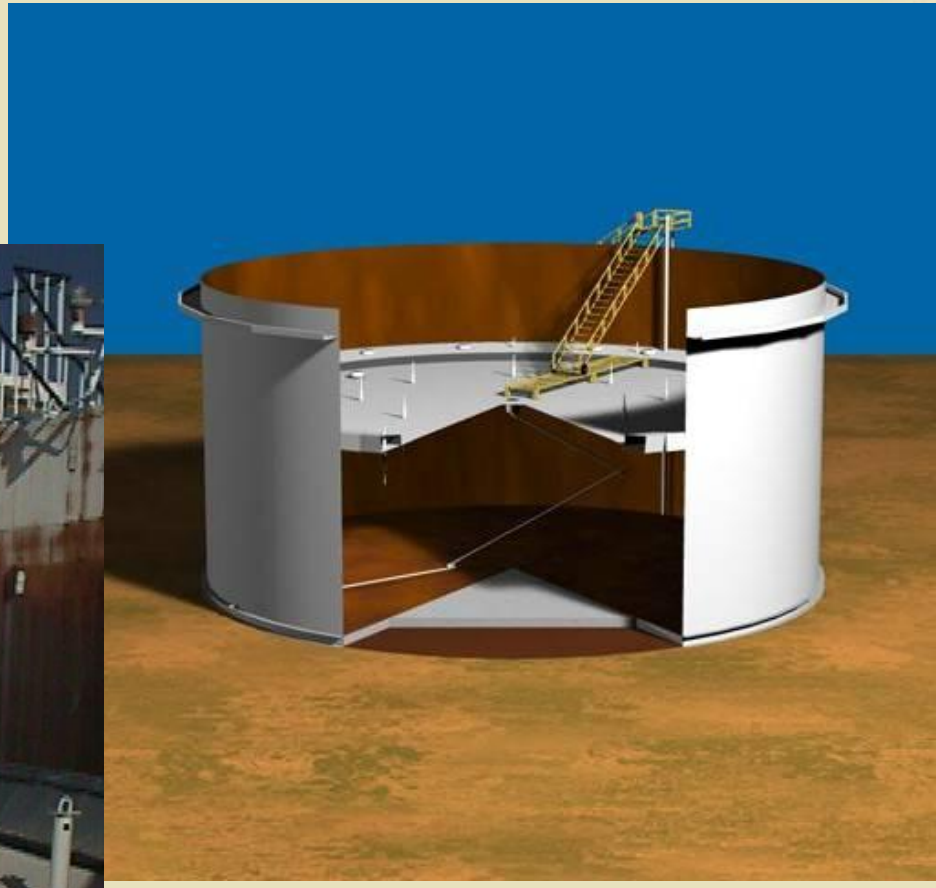
- **Stainless Steel Tanks**
- **This appendix covers materials, design, fabrication, erection, and testing requirements for austenitic stainless steel storage tanks constructed of material grades 304, 304L, 316, 316L, 317, and**

Appendices

- **Aluminum Tanks**
  - **Imported from ASME B96.1 Welded Aluminum Alloy Storage Tanks**
  - **ASME B96.1 has been withdrawn**

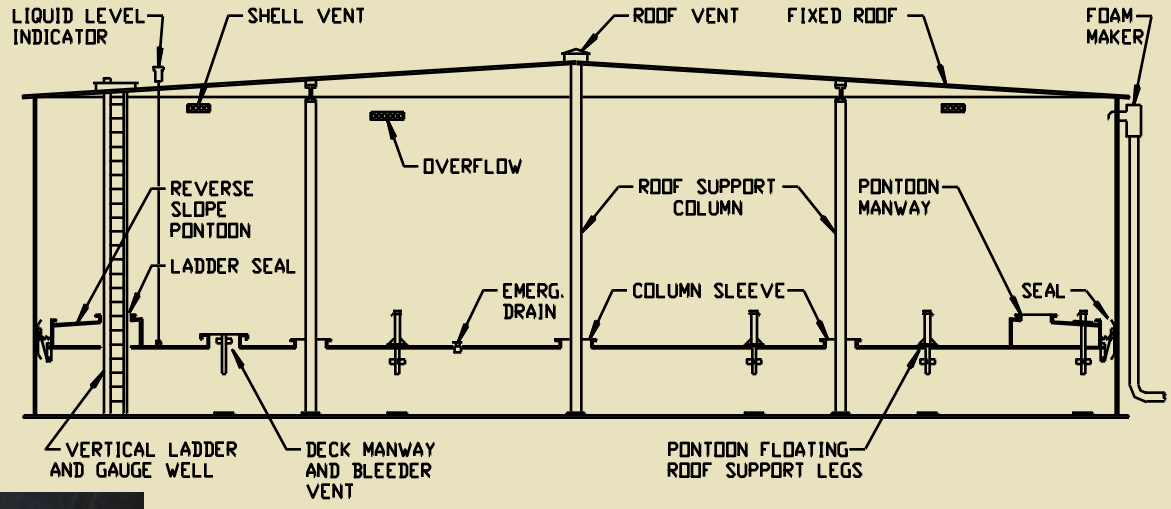
Appendices

External Floating Roofs



Appendices

Internal Floating Roofs

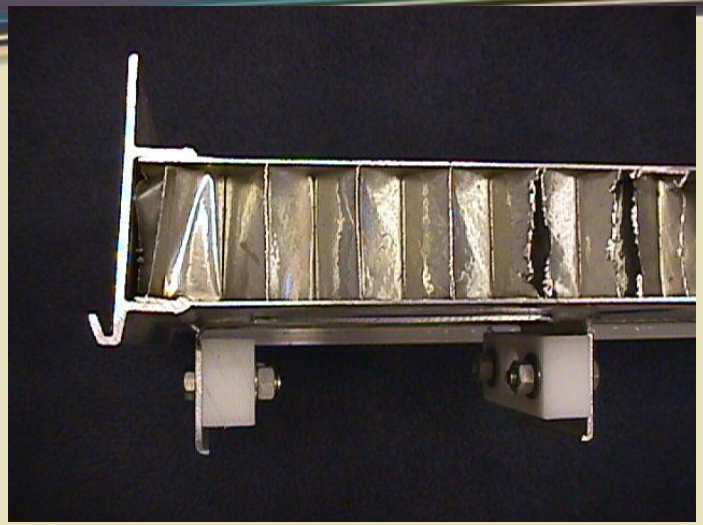


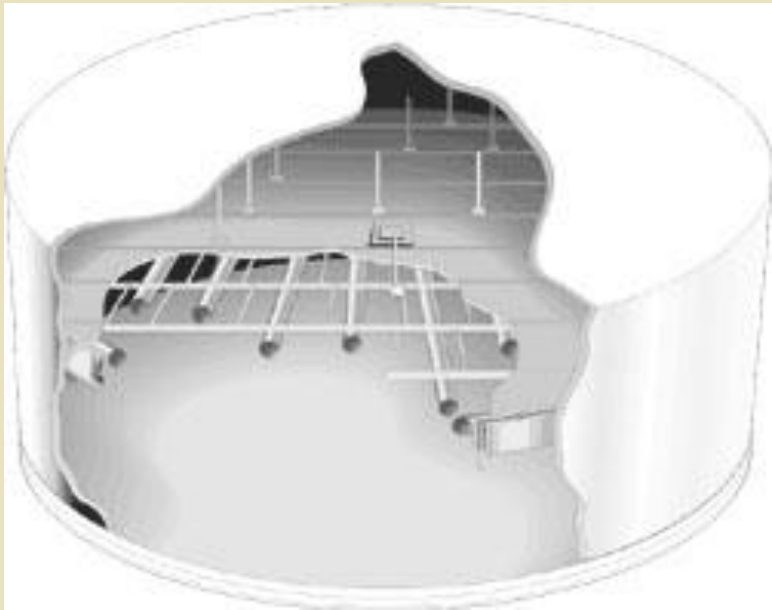
INTERNAL FLOATING ROOF
(REVERSE SLOPE PONTOON ROOF)

Appendices

- Internal
  - Floating Roofs

Appendices





Appendices

Cable suspended floating

Appendices

Perimeter Venting

- Spaced 10m (32 ft)
- Minimum 4
- Area - 0.2 m^2 (2 ft^2)

Shell Circulation Vents

- Can be used instead

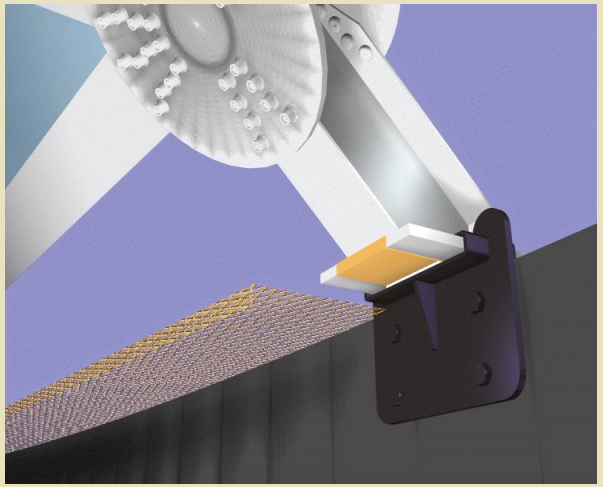
Appendices

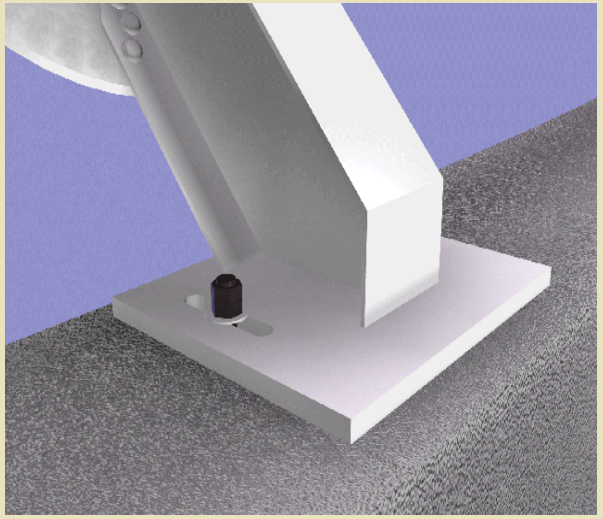
Aluminum Domes

Appendices

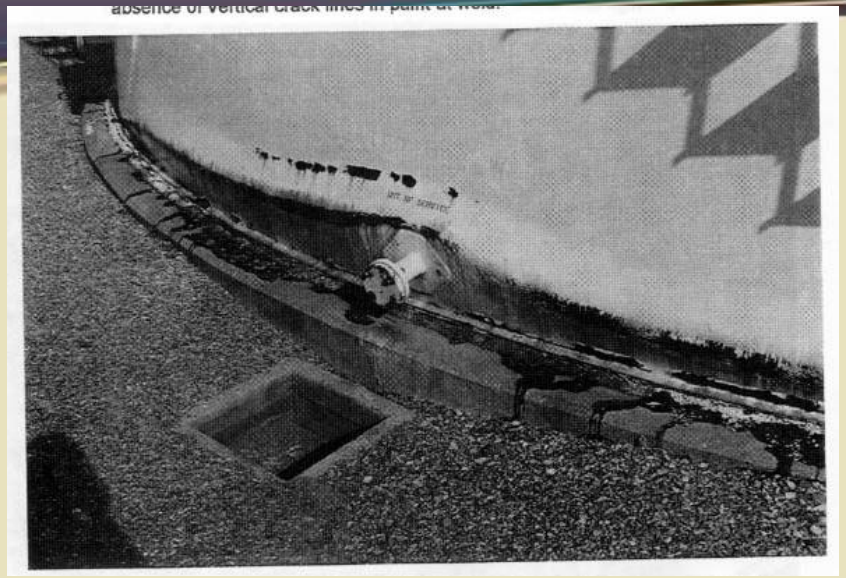
Aluminum Domes

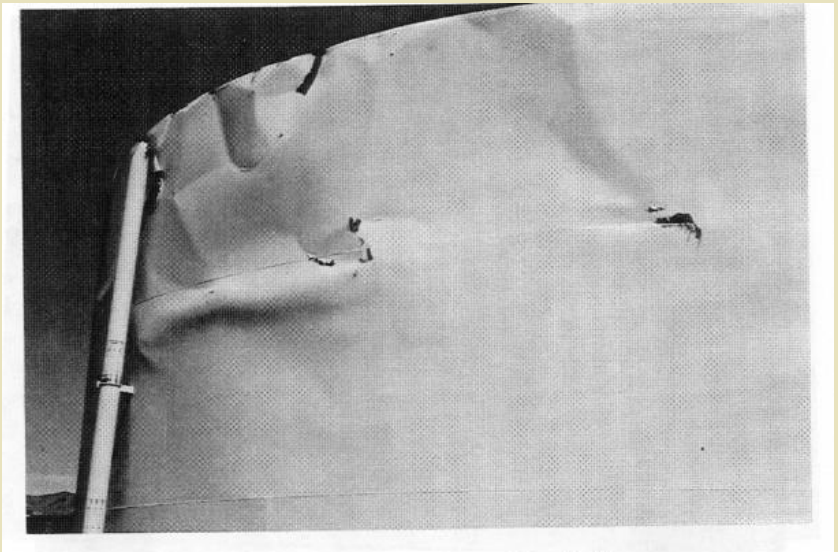
- With integral tension ring
  - Dome resists all forces
  - Supports slide radial direction
- Without tension ring
  - Tank resists all forces
  - Dome is fixed to the tank

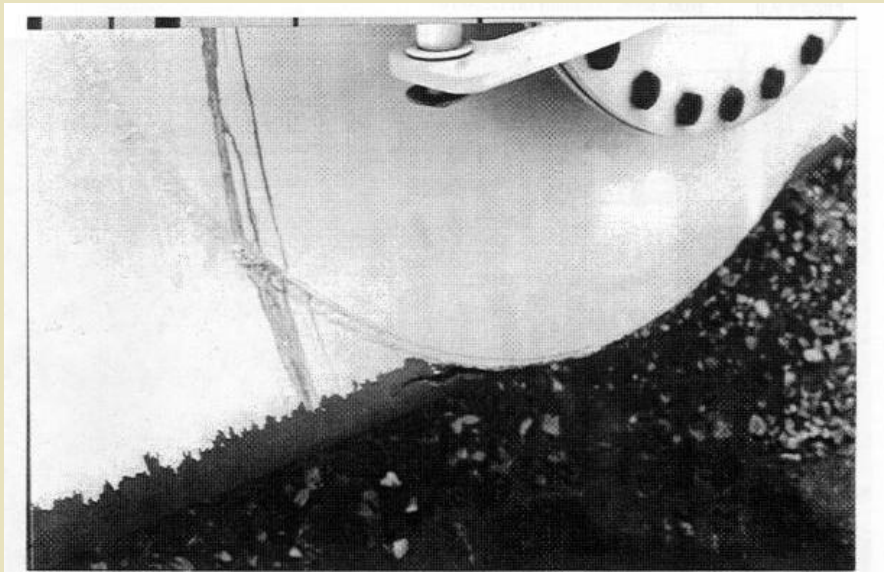




Seismic Design







Appendices

Requirements for Tanks Operating at Elevated Temperatures 260˚C (500˚F)

Appendices

- **Design for external pressure**
  - **Applicable to pressures up to 6.9 KPa (1.0 PSI)**

Appendices

- **Design for Internal Pressures**
  - **Covers from Atmospheric up to 18 KPa (2.5 PSI)**

Thank You