API 653

Tank Inspection, Repair, Alteration, and Reconstruction

Energy Expertise Academy

Training & Competency Solutions Providers

Unit 1: Suitability for Service

- Tank roof evaluation:
  - Fixed Roof
  - Floating Roof
  - Change in Service:
- Tank shell evaluation:
  - Actual thickness determination
  - Minimum shell thickness calculations for welded tanks
  - minimum shell thickness calculations for riveted tanks
  - Shell distortion
  - Shell flaws
  - Wind girders and stiffeners
  - Shell welds
  - Shell penetrations
  - Operating at elevated temperature

Unit 1: Suitability for Service

- Tank bottom evaluation
  - Causes for bottom failure
  - Tank Bottom Release Prevention Systems (RPSs)
  - Bottom Plate Thickness Measurements
  - Minimum Thickness for Tank Bottom Plate
  - Minimum Thickness for Annular Plate Ring
- Tank foundation evaluation
  - Foundation Repair or Replacement
  - Anchor Bolts

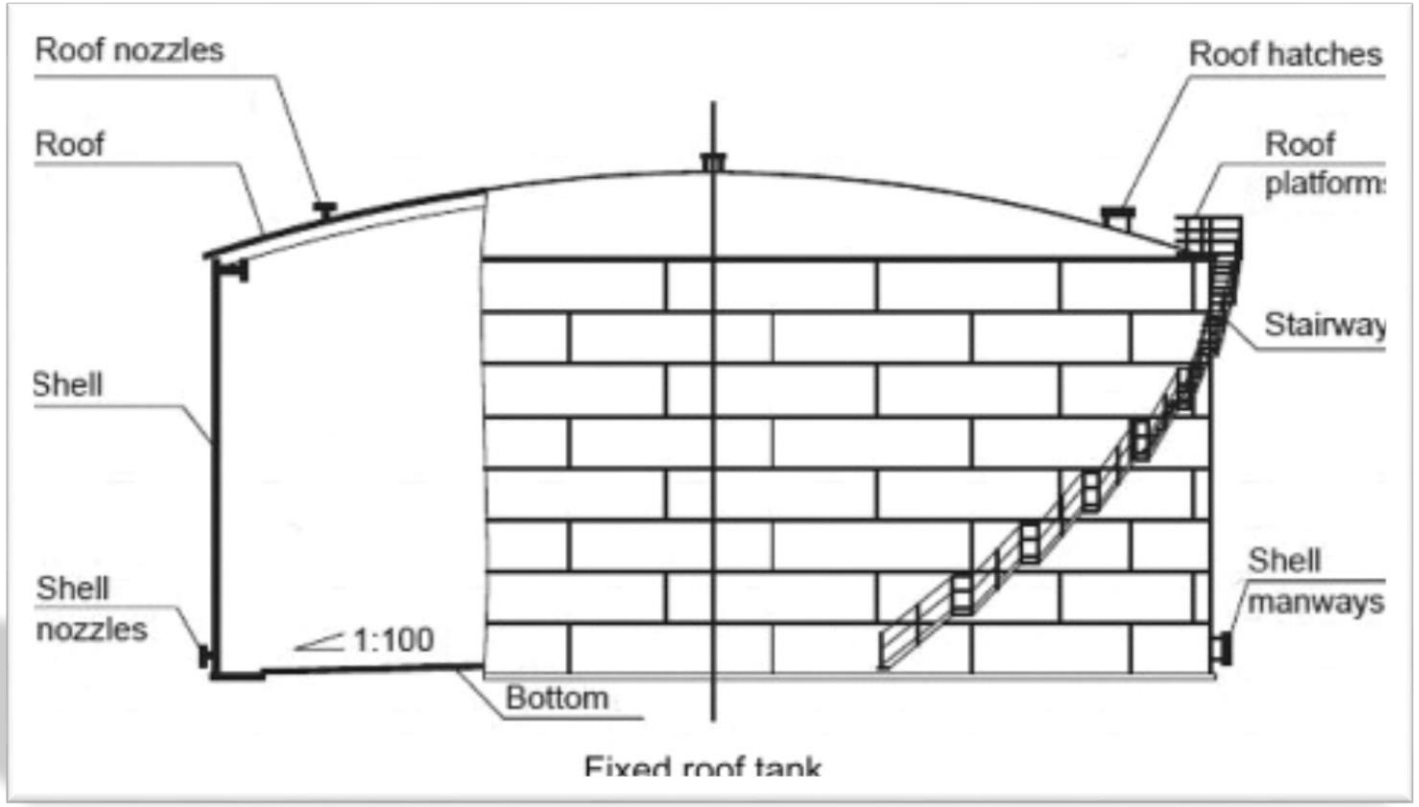
Unit 2 Brittle Fracture

- Brittle fracture
  - Basic Consideration
  - Assessment procedure

Unit 3 Inspection Frequency

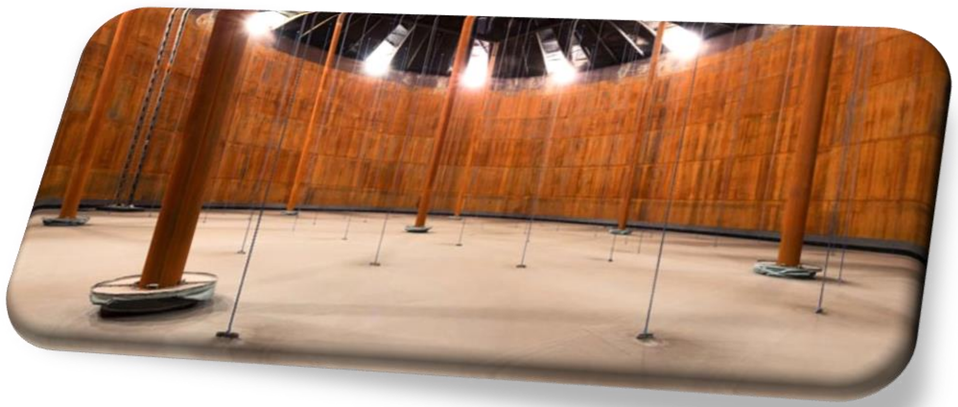
- Inspection
  - Inspection Frequency Considerations
  - Inspection from outside the tank
    - Routine in-service inspection
    - External Inspection
    - Ultrasonic Thickness Inspection
  - Internal Inspection
- Alternative to Internal Inspection to Determine Bottom Thickness
- Preparatory Work for Internal Inspection
- Inspection Checklists
- Records
- Reports

- Material
  - New Materials
  - Original Materials for Reconstructed Tanks
  - Welding Consumables
- Design Considerations for Reconstructed Tanks
  - New Weld Joints
  - Existing Weld Joints
  - Shell Design
  - Shell penetrations
  - Wind girders and Shell Stability
  - Roofs
  - Seismic Design



Unit 5 Tank Repair & Alteration

- Tank repair and alteration
- Removal and Replacement of Shell Plate Material
- Shell Repairs Using Lap-welded Patch Plates
- Repair of Defects in Shell Plate Material
- Alteration of Tank Shells to Change Shell Height
- Repair of Defective Welds
- Repair of Shell Penetrations
- Addition or Replacement of Shell Penetrations
- Alteration of Existing Shell Penetrations
- Repair of Tank Bottoms
- Repair of Fixed Roofs
- Repair of Floating Roofs
- Repair or Replacement of Floating Roof Perimeter Seals
- Hot Taps



Unit 6 Dismantling/Reconstruction & Welding

Energy Expertise Academy
Training & Competency Solutions Providers

- Dismantling and Reconstruction

  Cleaning and Gas Freeing
  - Dismantling Methods
  - Reconstruction
  - Dimensional Tolerances

- Welding
  - Welding Qualifications
  - Identification and Records
  - Preheat or Controlled Deposition Welding Methods as Alternatives to Post-weld Heat Treatment (PWHT)
  - Welding Safety

Unit 7 Examination and Marking

- Examination and Testing
  - NDE
  - Radiographs
  - Hydrostatic Testing
  - Leak Tests
  - Settlement Survey During Hydrostatic Testing
- Marking and Recordkeeping
  - Nameplates
  - Recordkeeping
  - Certification

MODULE 1
SUITABILITY FOR SERVICE

Suitability for Service

4.1.3 Important factors for consideration when suitability for service of tanks:

a) Internal corrosion due to the product stored or water bottoms;

b) External corrosion due to environmental exposure;

c) Stress levels and allowable stress levels;

d) Properties of the stored product such as S.G, temperature, and corrosively

e) Metal design temperatures at the service location of the tank;

f) External roof live load, wind, and seismic loadings;

g) Tank foundation, soil, and settlement conditions;

h) Chemical analysis and mechanical properties of the materials of construction;

i) Distortions of the existing tank;

j) Operating Conditions such as filling/emptying rates and frequency.

4.2 Tank Roof Evaluation

4.2.1.2 Roof plates:

- ❑ Corroded to an average thickness of less than 0.09 in. in any 100 in^2 area
- ❑ Roof plates with any holes through the roof plate shall be repaired or replaced.

4.2.2 Fixed Roofs

4.2.2.1 The Inspection includes:

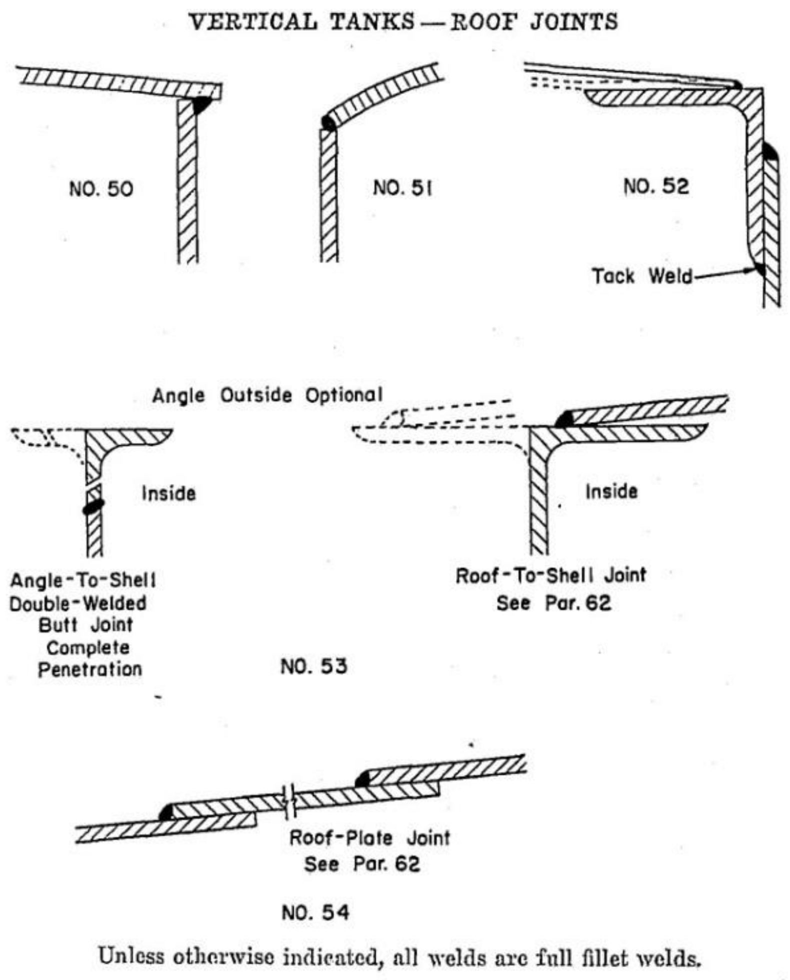
- Roof support members (rafters, girders, columns, and bases)
- Distorted (such as out-of-plumb columns), corroded, and damaged members
- Particular attention must be given to the possibility of severe internal corrosion of pipe columns

4.2 Tank Roof Evaluation

4.2.2.2 Evaluate for items impacting compliance with requirements under API 650.

Examples of some items to evaluate include:

- Tank bottom-to-shell joint corrosion
- Tank roof-to-shell joint modification (such as reinforcement of the joint, attachment of handrail, or other frangible joint area change).



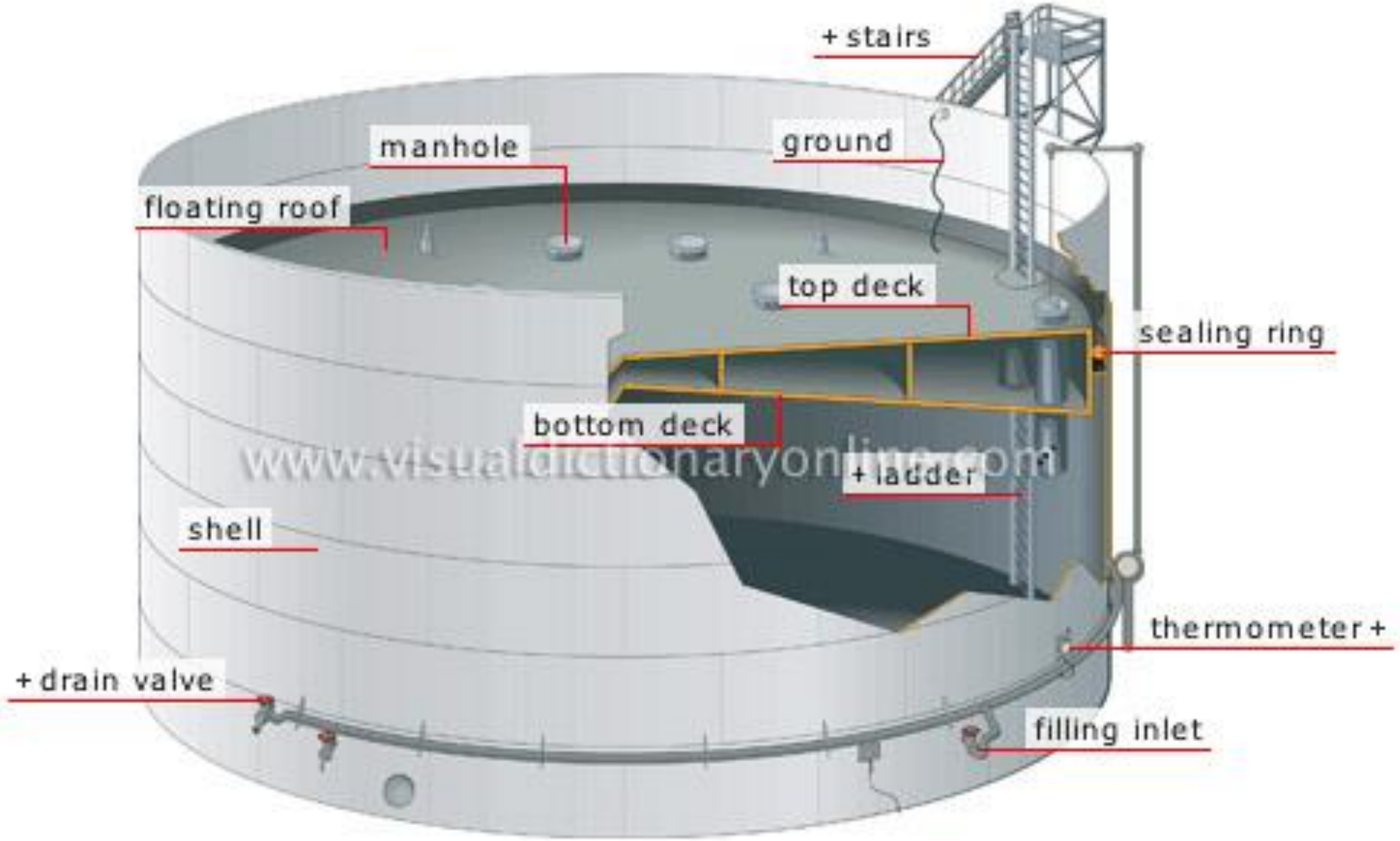
4.2 Tank Roof Evaluation

4.2.3.1 Areas of roof **plates and pontoons** exhibiting **cracks or punctures** shall be repaired or the affected sections replaced. Holes through roof plates shall be repaired or replaced.

4.2.3.2 Areas that are pitted shall be evaluated to determine the likelihood of **through-pitting** occurring prior to the next scheduled internal inspection. If so, the affected areas shall be repaired or replaced.

4.2.3.3 Roof **support systems**, **perimeter seal systems**, **appurtenances** such as a roof **rolling ladder**, **anti-rotation devices**, **water drain systems**, and **venting systems** shall be evaluated for needed repairs or replacements.

4.2.3.4 Guidance for the evaluation of existing floating roofs shall be based on the criteria of API 650, Annex C, for external floating roofs, and Annex H for internal floating roofs. However, upgrading to meet this standard is not mandatory.



floating-roof tank

4.2.4 Change of Service

4.2.4.1 Internal Pressure

All requirements of the **current applicable standard (e.g. API 650, Annex F)** shall be considered in the evaluation and subsequent alterations to the tank roof and roof-to-shell junction.

4.2.4.2 External Pressure

As applicable, the roof support structure (if any), and the roof-to-shell junction shall be evaluated for the effects of a ***design partial vacuum***.

The criteria outlined in API 650, Annex V shall be used.

4.2.4 Change of Service

4.2.4.3 Operation at Elevated Temperature

All requirements of API 650, Annex M, shall be considered **before changing the service of a tank to operation at temperatures above 200 °F.**

4.2.4.4 Operation at Lower Temperature Than Original Design

If the operating temperature is changed to a lower temperature than the original design, the requirements of the **current applicable standard** for the lower temperature shall be met.

4.2.4 Change of Service

4.2.4.5 Normal and Emergency Venting

4.2.4.5.1 Effects of change in **operating conditions (including product service and pumping rates) on normal and emergency venting shall be considered**.

4.2.4.5.2 **Vents shall be inspected** for proper operation and screens shall be verified to be clear of obstruction.

4.3 Tank Shell Evaluation

4.3.1 General

4.3.1.2 The evaluation of the existing tank shell shall be conducted by a storage tank engineer and shall include an analysis of the shell for the intended design conditions , based on **existing shell plate thickness and material** . The analysis shall take into consideration:

- ❑ Pressure due to fluid static head
- ❑ Internal and external pressure
- ❑ Wind loads
- ❑ Seismic loads
- ❑ Roof live loads
- ❑ Nozzle loads
- ❑ Settlement, and attachment loads.

4.3 Tank Shell Evaluation

4.3.1.3 Shell corrosion occurs as:

- General and uniform loss of metal over a large surface area or in localized areas .
- Pitting . Not a significant threat unless severe and dense.

4.3.1.5 If the shell thickness requirements cannot be satisfied, the corroded or damaged areas **shall be repaired, or the allowable liquid level of the tank reduced , or the tank retired**.

4.3.2 Actual Thickness Determination

4.3.2.1 when there are **corroded areas of considerable size**, measured thicknesses shall be averaged in accordance with the following procedure:

a) For each area, the authorized inspector shall determine the minimum thickness, $t2$, at any point in the corroded area, excluding widely scattered pits

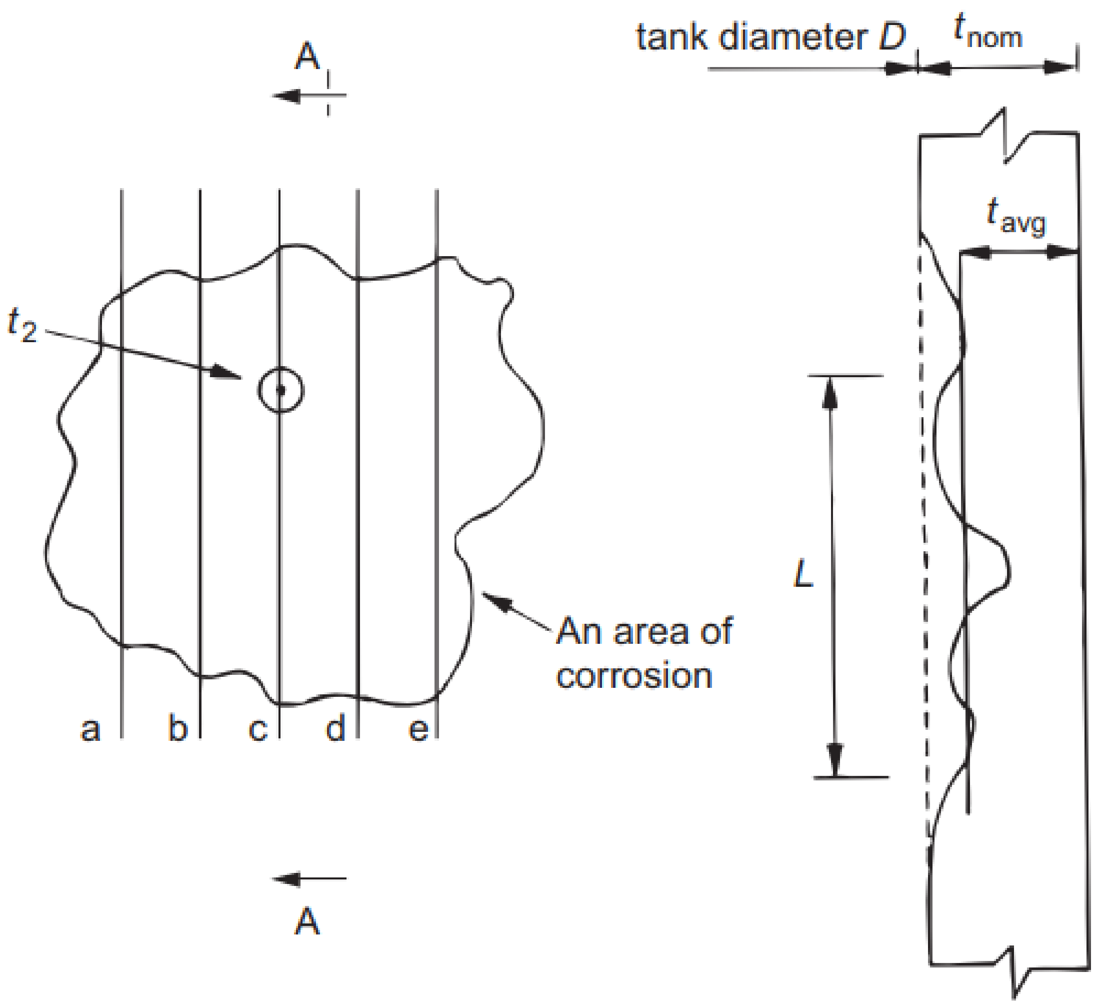
b) Calculate the critical length, L :

$L = 3.7\sqrt{Dt2}$, but **not more than 40 in**.

Energy Expertise Academy
Training & Competency Solutions Providers

4.3.2 Actual Thickness Determination

- ***L*** **is the maximum vertical length, in inches, over which hoop stresses are assumed to "average out" around local discontinuities; The actual vertical length of the corroded**
- **area may exceed *L*.**
- ***D*** **is the tank diameter, in feet;**
- ***t2*** **is the least thickness reading, in inches, in an area of corrosion, exclusive of pits**



Actual Thickness Determination Procedure

- The authorized inspector shall visually or otherwise decide which vertical plane(s) in the area is likely to be the most affected by corrosion.
- Profile (thickness) measurements shall be taken along each vertical plane for a distance, *L*. In the plane(s), determine the lowest average thickness, *t*1, averaged over a length of *L*, using at least five equally spaced measurements over length *L*.

<u>The criteria for continued operation is as follows:</u>

1. the value *t*1 shall be greater than or equal to *t*min:
2. the value *t*2 (least UT reading) shall be greater than or equal to 60 % of *t*min; and
3. any corrosion allowance required for service until the time of the next inspection shall be added to *t*min and 60 % of *t*min

$$t_1 \geq t_{min} \text{ \underline{AND} } t_2 \geq 60\% \; of \; t_{min}$$

Corrosion allowance need to be added to t_{min} or to $60\% \; of \; t_{min}$

4.3.2.2 Widely scattered pits may be ignored provided that :

a) no **pit depth results** in the remaining shell thickness being less than one-half the minimum acceptable tank shell thickness exclusive of the corrosion allowance; and

$$maximum\ pit\ depth \leq \frac{1}{2} t_{min}$$ **(NOT ACCEPTABLE)**

b) the sum of their dimensions along any vertical line does not exceed **2 in. in an 8-in. length (see Figure 4.2).**

$$d1 + d2 + d3 + \cdots . \leq 2. in$$

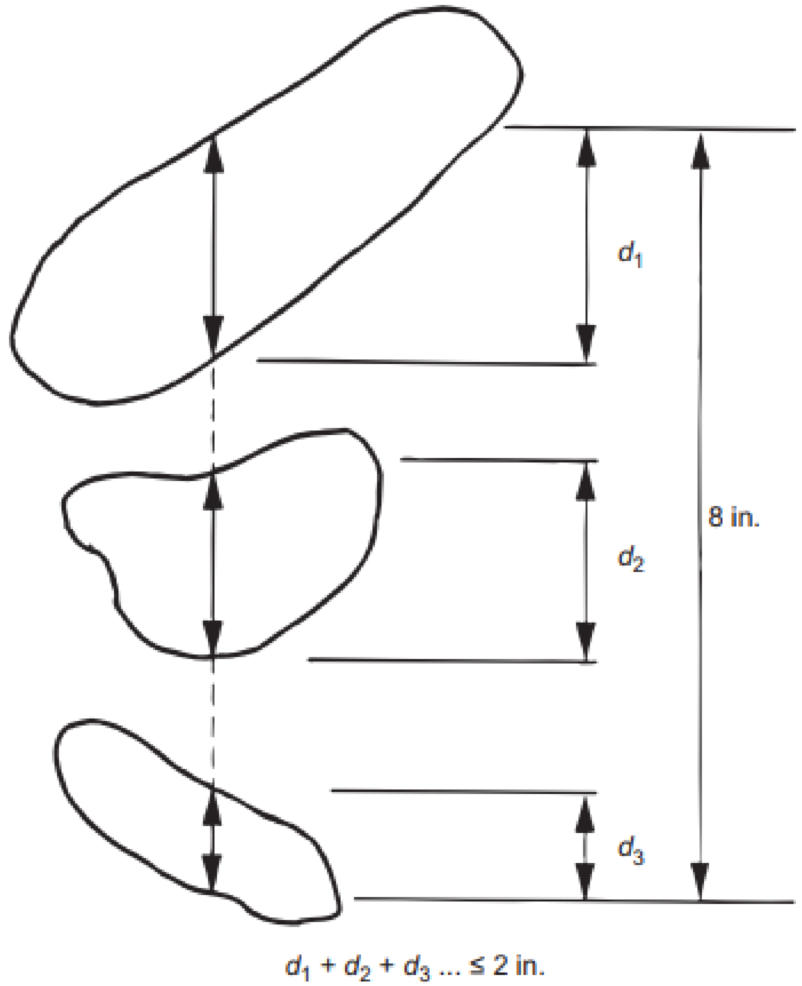


Figure 4.2—Pit Measurement

Minimum Thickness Calculation for Welded Tank Shell

4.3.3.1 The minimum acceptable shell plate thickness for continued service shall be determined by:

a) When determining the minimum acceptable thickness for an **entire shell course**, t min is calculated as follows:

$$t_{min} = 2.6\,\frac{(H-1)DG}{SE}$$

b) When determining the minimum acceptable thickness **for any other portions of a shell course (such as a locally thinned area or any other location of interest),** t min is calculated as follows:

$$t_{min} = 2.6\,\frac{HDG}{SE}$$

Where:

t_{min} The minimum acceptable thickness, in inches for each course as calculated from the above equation; however, t_{min} shall not be less than 0.1 in. for any tank course

D The nominal diameter of tank, in feet (ft). Method valid for D < 200 ft

H:

- The height from the bottom of the shell course under consideration to the maximum liquid level when evaluating an entire shell course, in feet (ft); or
- is the height from the bottom of the length L from the lowest point of the bottom of L of the locally thinned area to the maximum liquid level, in feet (ft); or
- is the height from the lowest point within any location of interest to the maximum liquid level, in feet (ft);

G is the highest specific gravity of the contents

Where:

E The original joint efficiency for the tank. Use Table 4.2 if original *E* is unknown.

E = 1.0 when evaluating the retirement thickness in a corroded plate, when away from welds or joints by at least the greater of 1 in. or twice the plate thickness.

S is the maximum allowable stress in pound force per square inch (lbf/in. 2);

- use the smaller of 0.80 Y or 0.429 T for bottom and second course;
- use the smaller of 0.88 Y or 0.472 T for all other courses.

Table 4.1—Maximum Allowable Shell Stresses (Not for Use for Reconstructed Tanks, See General Note)

Material Specification and Grade	Minimum Specified Yield Stress, Y (lbf/in.^{2})	Minimum Specified Tensile Strength, T (lbf/in.^{2})	Allowable Product Stress, S (lbf/in.^{2}) (Note 6)		Allowable Hydrostatic Test Stress, S_t (lbf/in.^{2}) (Note 6)	
			Lower Two Courses	Upper Courses	Lower Two Courses	Upper Courses
ASTM Specifications						
A 283-C	30,000	55,000	23,600	26,000	26,000	27,000
A285-C	30,000	55,000	23,600	26,000	26,000	27,000
A36	36,000	58,000	24,900	27,400	27,400	30,100
A131-A, B, CS	34,000	58,000	24,900	27,400	27,400	30,100
A131-EH 36	51,000	71,000	30,500	33,500	33,500	36,800
A573-58	32,000	58,000	24,900	27,400	27,400	28,800
A573-65	35,000	65,000	27,900	30,700	30,700	31,500

Energy Expertise Academy
Training & Competency Solutions Providers

Table 4.2—Joint Efficiencies for Welded Joints

Standard	Edition and Year	Type of Joint	Joint Efficiency E	Applicability or Limits
API 650	Seventh and Later (1980 to Present)	Butt	1.00	Basic Standard
		Butt	0.85	Annex A Spot RT
		Butt	0.70	Annex A No RT
	First to Sixth (1961 to 1978)	Butt	0.85	Basic Standard
		Butt	1.00	Annexes D and G
API 12C	14th and 15th (1957 to 1958)	Butt	0.85	
	3rd to 13th (1940 to 1956)	Lap [a]	0.75	3/8 in. max. t
		Butt [c]	0.85	
	First and Second (1936 to 1939)	Lap [a]	0.70	7/16 in. max. t
		Lap [b]	$0.50 + k/5$	1/4 in. max. t
		Butt [c]	0.85	
Unknown		Lap [a]	0.70	7/16 in. max. t
		Lap [b]	$0.50 + k/5$	1/4 in. max. t
		Butt	0.70	
		Lap [d]	0.35	

[a] Full double lap welded.
[b] Full fillet weld with at least 25 % intermittent full fillet opposite side; k = percent of intermittent weld expressed in decimal form.
[c] Single butt-welded joints with a back-up bar were permitted from the years of 1936 to 1940 and 1948 to 1954.
[d] Single lap welded only.

4.3.3.2 Hydrostatic Test High

The tank shall not be filled above the level determined by the lesser value of H_t determined below.

a) After determining the controlling thickness of an entire shell course, H_t calculated as follows:

$$H_t = \frac{S_t\, E\, t_{min}}{2.6\, D} + 1$$

b) For a locally thinned area, or at any other location of interest within a shell course, H_t is calculated as follows:

$$H_t = \frac{S_t\, E\, t_{min}}{2.6\, D}$$

where

H_t The height from the bottom of the shell course under consideration to the hydrostatic test height when evaluating an entire shell course in feet; or

The height from the bottom of the length, L for the most severely thinned area in each shell course to the hydrostatic test height in feet; or

The height from the lowest point within any other location of interest to the hydrostatic test height in feet

S The maximum allowable stress in psi:

- ❑ The smaller of 0.88 Y or 0.472 T for bottom and second course
- ❑ The smaller of 0.90 Y or 0.519 T for all other courses

Other Loads

4.3.3.5 All other loads shall also be evaluated according to the original standard of construction; and engineering judgment shall be used to evaluate different conditions or new information. As applicable, the following loadings shall be taken into account:

a) wind-induced buckling;

b) seismic loads;

c) operation at temperatures over 200 °F;

d) vacuum-induced external pressure;

e) external loads caused by piping, tank-mounted equipment, hold down lugs, etc.;

f) wind-induced overturning;

g) loads due to settlement.

Energy Expertise Academy
Training & Competency Solutions Providers

4.3.5 Shell distortions

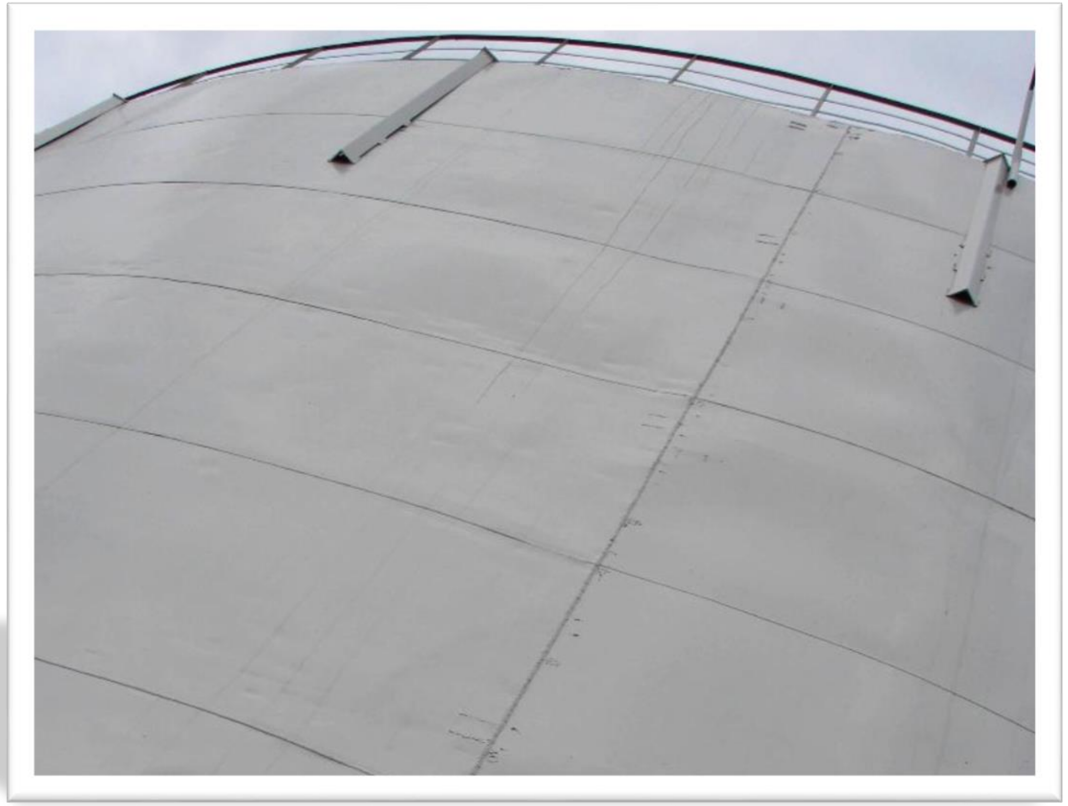
4.3.5.1 Shell distortions include:

- out-of-roundness,
- buckled areas
- flat spots
- Dents
- Peaking and banding at welded joints

4.3.5.2 Shell distortions can be caused by many conditions such as:

- foundation settlement
- over- or under-pressuring
- high wind,
- poor shell fabrication,
- repair techniques

4.3.5.3 **Shell distortions shall be evaluated on an individual basis to determine if specific conditions are considered acceptable for continuing tank service and/or the extent of corrective action**. Review Appendix B



4.3.6 Flaws

Flaws such as cracks or laminations shall be thoroughly examined and evaluated to determine their nature and extent and need for repair.

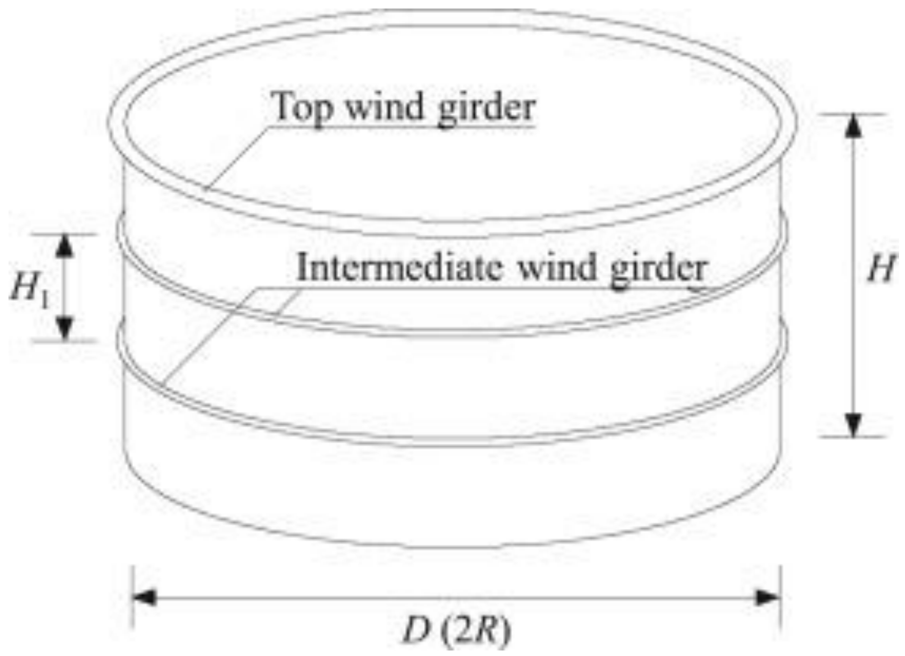
Cracks in the shell-to-bottom weld shall be removed.

-

Energy Expertise Academy
Training & Competency Solutions Providers

4.3.7 Wind Girders and Shell Stiffeners

The evaluation of an existing tank shell for suitability for service must also consider the details and condition of any wind girders or shell stiffeners . Degradation by corrosion of these structural elements or their attachment welds to the shell may render these elements inadequate for the design conditions.



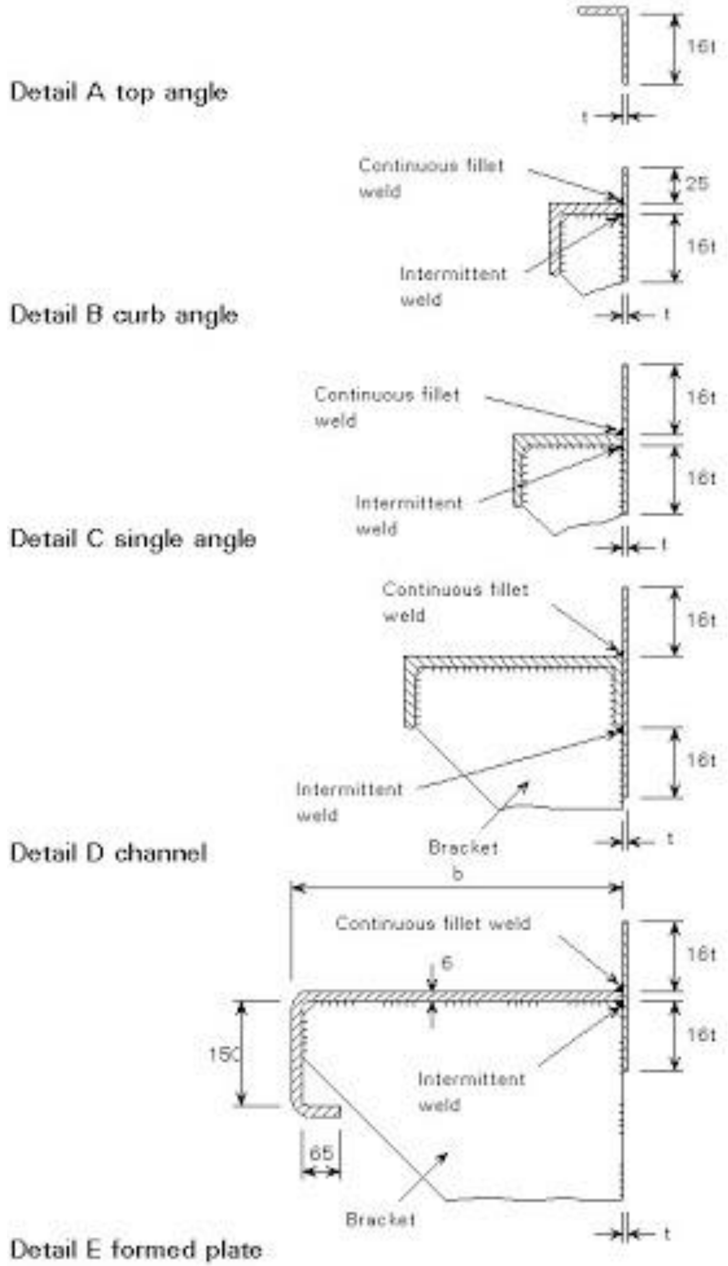
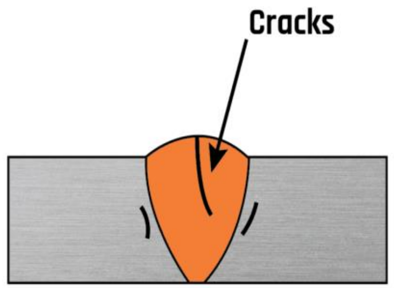
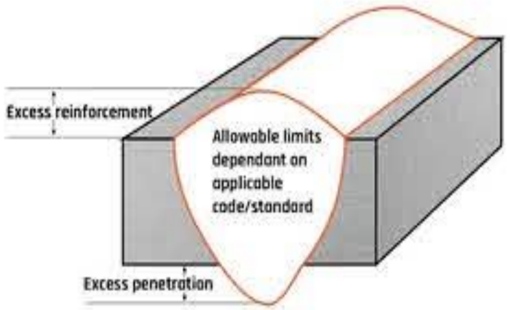
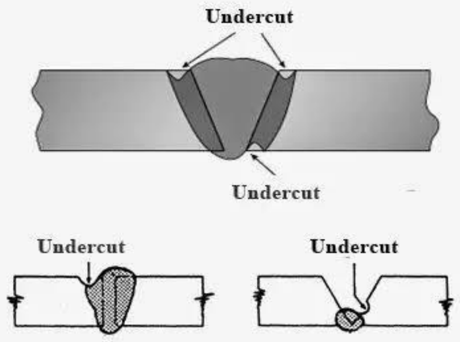


Figure 8 Wind girders

4.3.8 Shell Welds







Cracks

- shall be removed. Removal areas shall be evaluated and repaired if necessary.

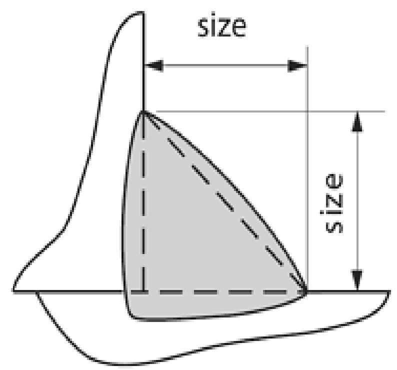
Excessive weld reinforcement

- does not require rework if the tank has a satisfactory history of service. If the reinforcement will interfere with floating roof seal operation, it shall be ground as required.

Undercut of shell butt welds

- shall not require repair if the tank has been hydro-tested or will not undergo a change of service .

4.3.8 Shell Welds



Weld corrosion

- Shall be repaired if the corrosion pit cavity bottom is below the surface of the adjacent shell plate.

Shell-to-bottom weld corrosion

- Shall be repaired if the remaining fillet is less than the required weld size .

Fillet weld size on existing nozzles

- shall be evaluated according to the original standard of construction.

Surface defects

- shall be acceptable if the tank has been hydro tested or will not undergo a change of service.

4.3.9 Shell Penetrations

4.3.9.1 The condition and details of existing shell **penetrations (nozzles, manways, cleanout openings, etc.)** shall be reviewed against compliance with the as-built standard, such as:

- Type and extent of reinforcement
- Weld spacing,
- Thickness of components (reinforcing plate, nozzle neck, bolting flange, and cover plate)

Existing welds on the tank shell that are not to be modified or affected by repairs and are closer than required by API 650 (Seventh Edition or later) are acceptable for continued service if: the welds are examined by the **magnetic particle or ACFM (Alternating Current Field Measurement)** methods and have no rejectable defects or indications.

4.3.9 Shell Penetrations

Grinding to eliminate weld defects is permissible if the resulting profile satisfies base thickness and weld size requirements.

Weld repairs may not be used to accept weld spacings closer than permitted by API 650 (Seventh Edition or later) except as permitted by 9.10.2.7 .

Any other noncompliance, or deterioration due to corrosion, must be assessed and repair procedures established where appropriate or the tank re-rated, as necessary.

-

4.3.10 Operation at Elevated Temperatures

Tanks of welded construction that operate at elevated temperatures **(exceeding 200 ° F, but less than 500 ° F)** shall be evaluated for as per the requirements of this section are based in part on the requirements of **API 650, Annex M**.

- ❖ **Continued Operation at Elevated Temperatures**
- ❖ **Conversion to Operation at Elevated Temperatures**

4.3.10 Operation at Elevated Temperatures

Table M.1b—Yield Strength Reduction Factors (USC)

Temperature (°F)	Minimum Specified Yield Strength (lbf/in.^{2})		
	< 45,000 lbf/in.^{2}	≥ 45,000 to < 55,000 lbf/in.^{2}	≥ 55,000 lbf/in.^{2}
201	0.91	0.88	0.92
300	0.88	0.81	0.87
400	0.85	0.75	0.83
500	0.80	0.70	0.79
NOTE Linear interpolation shall be applied for intermediate values.			

4.3.10.1 Continued Operation at Elevated Temperatures

4.3.10.1.1 Existing tanks that were originally designed and constructed to the requirements of API 650, Table M.1a or M.1b, shall be evaluated for continued service, as follows:

a) The tank shell shall be evaluated in conformance with 4.3.3, except that the allowable stress (S) ***for all shell courses*** shall not exceed 0.80 Y

AND

Y corrected with the yield strength reduction factor in of API 650, Table M.1a/b.

Y is not known, assume value of 30,000 psi

b) If the bottom plate material in the **critical zone** has been reduced in thickness beyond the provisions of the original tank bottom corrosion allowance, **if any, the shell-to-bottom joint shall be evaluated for elevated temperature**, liquid head and thermal cycles. The simplified analysis technique recommended in API 650, Annex M4, may be used

4.3.10.1 Continued Operation at Elevated Temperatures

4.3.10.1.2 Existing elevated temperature service tanks that were not originally designed and constructed to the requirements of API 650, Annex M, but have a successful service history of operation shall be evaluated for continued service as noted in 4.3.10.1.1.

If the tank diameter exceeds 100 ft and the tank was not constructed with a butt-welded annular ring, an analysis of the critical zone is required [see 4.3.10.1.1 b)]. In addition, the maximum operating temperature shall not exceed the temperatures at which the tank has operated successfully in the past.

4.3.10.2 Conversion to Operation at Elevated Temperatures

Existing tanks that were not originally designed and constructed to the requirements of API 650, Annex M shall be evaluated for a change to service to elevated temperatures as follows.

a) The tank shell shall be evaluated in conformance with API 650, Annex M. The allowable shell stresses of this standard (API 653) shall not be used.

b) The need for a butt-welded annular ring shall be determined in conformance with API 650, Annex M and installed if required.

c) The shell-to-bottom joint shall be evaluated for fatigue conditions. In addition, the adequacy of the bottom plate material in the critical zone shall be based upon the requirements of this standard.

4.4 Tank Bottom Evaluation

4.4.2 Causes of Bottom Failure

Causes of tank bottom leakage or failure that shall be considered in the decision to line, repair, or replace a tank bottom:

a) internal pitting and pitting rates in the anticipated service;

b) corrosion of weld joints (weld and heat affected zone);

c) weld joint cracking history;

d) stresses placed on the bottom plates by roof support loads and shell settlement;

e) Underside (soil) corrosion (normally in the form of pitting);

f) inadequate drainage resulting in surface water flowing under the tank bottom;

g) the lack of an annular plate ring when required;

h) uneven settlement that results in high localized stresses in the bottom plates;

j) rock or gravel foundation pads with inadequately filled-in surface voids;

k) nonhomogeneous fill under the tank bottom

l) inadequately supported sumps.

4.4 Tank Bottom Evaluation

4.4.3 Tank Bottom Release Prevention Systems (RPSs)

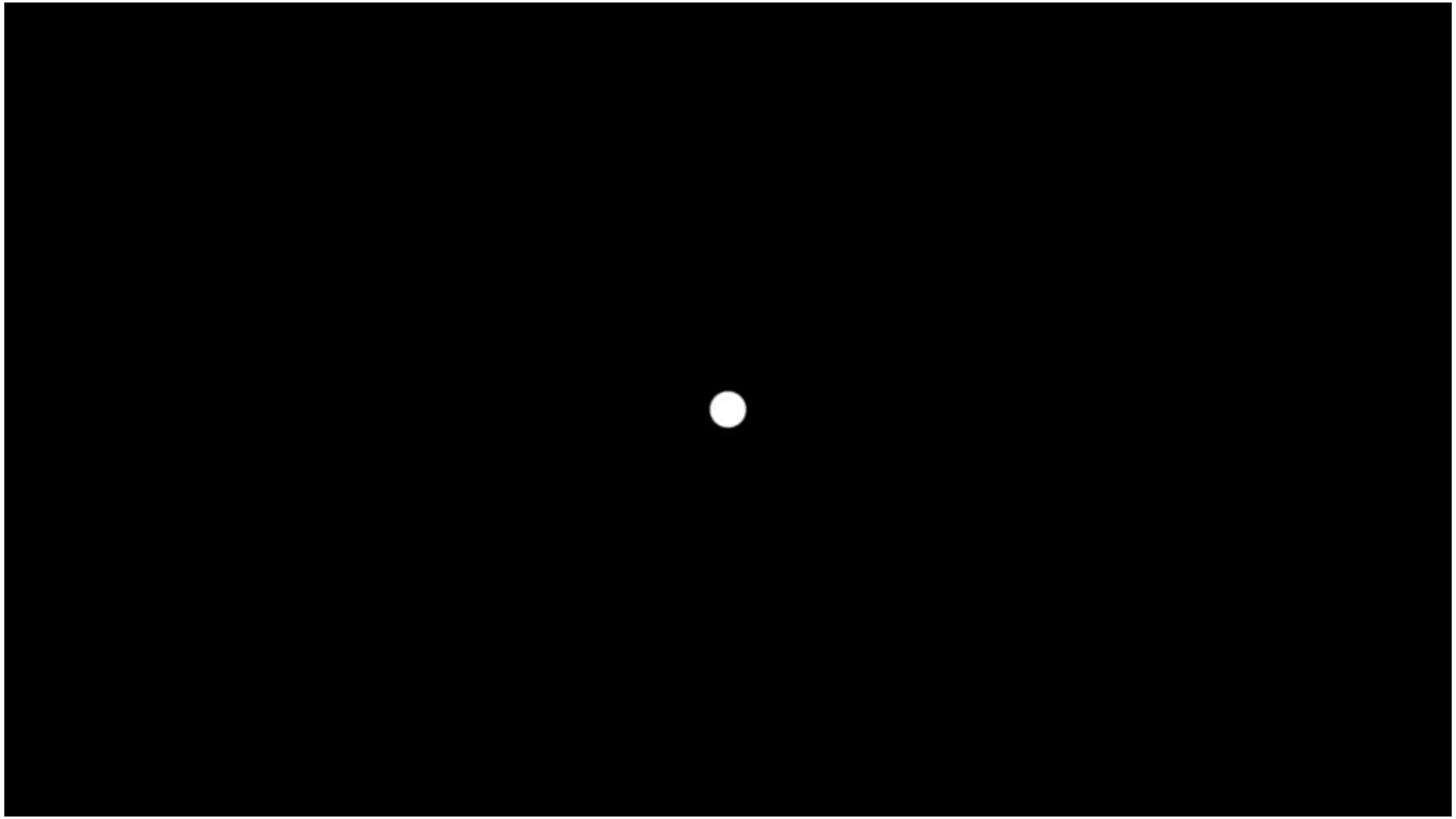
API supports the use of a release prevention system (RPS) to maintain the integrity of tank bottoms.

- ❑The term RPS includes:
  - ❑Internal inspection of the tank bottom;
  - ❑Leak detection systems and leak testing of the tank;
  - ❑Installing cathodic protection for the underside of the tank bottom;
  - ❑lining the bottom of the tank interior;

4.4.3.2 Leak Detection Systems and Leak Testing

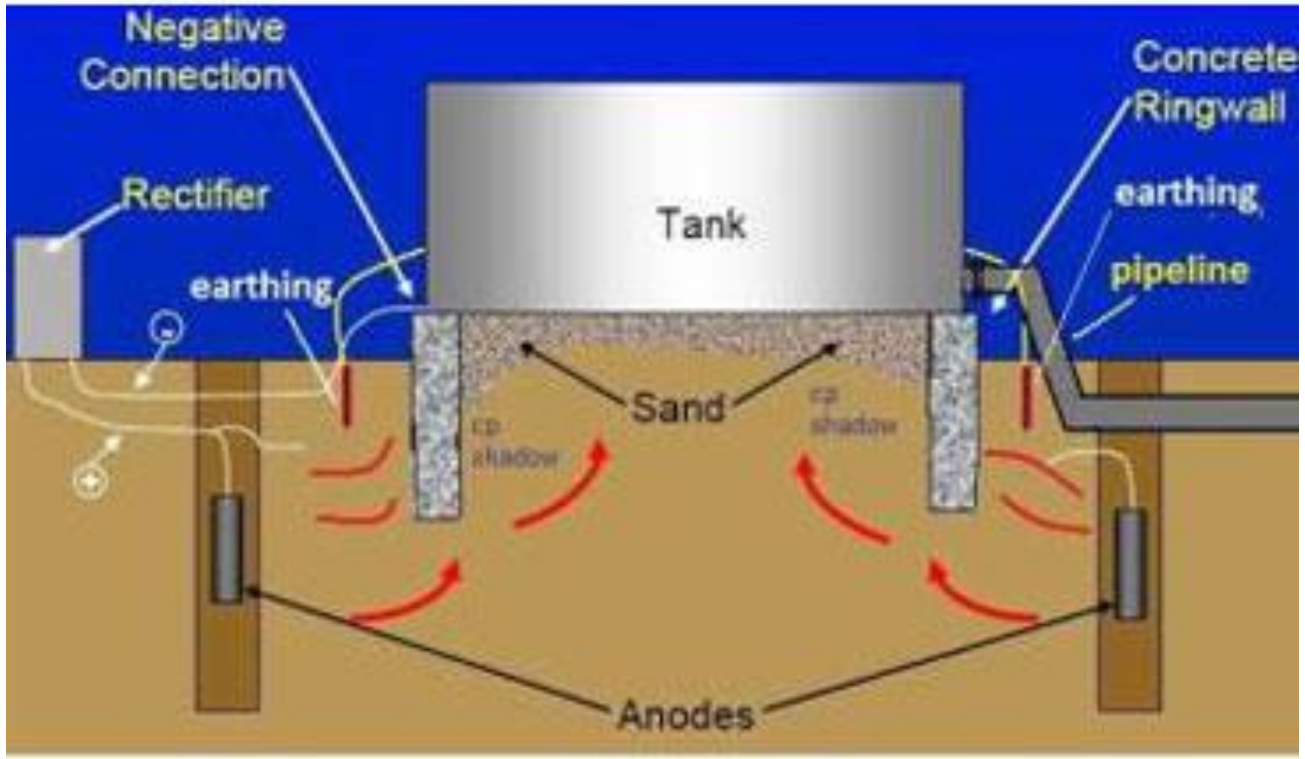
Tank leak detection systems and leak testing are **intended to identify, quantify, and/or locate a tank bottom integrity failure** that is not detectable visually or through inventory reconciliation.

4.4.3.2 Leak Detection Systems and Leak Testing



4.4.3.3 Cathodic Protection

Cathodic protection systems are intended to mitigate corrosion of steel surfaces in contact with soil, such as the underside of tank bottoms. A selection basis for cathodic protection systems is covered **by API 651**.



4.4.3.4 Internal Lining Protection

Internal linings and coatings **for the top side of the tank bottom are intended to mitigate corrosion** by providing a barrier between the tank bottom and corrosion sources.

Applied linings and coatings for internal surfaces of tank bottoms are **covered by API 652** .

4.4.3.5 Release Prevention Barriers (RPBs)

An RPB includes steel bottoms, synthetic materials, clay liners, concrete pads, and all other barriers or combinations of barriers placed in the bottom of or under a tank, which have the function of:

1) preventing the escape of released material, and
2) containing or channeling released material for leak detection.

RPB design is covered in detail in **Annex I of API 650**. Replacement of tank bottoms is covered in 9.10.2.

If a decision is made to replace an existing bottom, API supports the evaluation of installing an RPB or continued use of an RPS. The evaluation should consider the effectiveness of other RPS controls, the product stored, the location of the tank, and environmental sensitivities.

4.4.5 Minimum Thickness for Tank Bottom Plate

Quantifying the minimum remaining thickness of tank bottoms based on the results of measurement can be done by the method outlined in 4.4.5.1.

Other approaches such as the probabilistic method in 4.4.5.2 may be used.

4.4.5.1 An acceptable method for **calculating the minimum acceptable bottom thickness** for the entire bottom or portions thereof is as follows:

$$MRT = RT - Or\ (StPr + UPr)$$

Minimum Future Remaining Thickness (MRT) =
Current Remaining Thickness (MT) – {inspection Interval (years) x (corrosion rate from top side + corrosion rate from soil side)}

Probabilistic Method

- **4.4.5.2** For the probabilistic method, a statistical analysis is made of thickness data from measurements (see 4.4.6) projecting remaining thickness, based on sample scanning of the bottom

Energy Expertise Academy
Training & Competency Solutions Providers

4.4.5 Minimum Thickness for Tank Bottom Plate

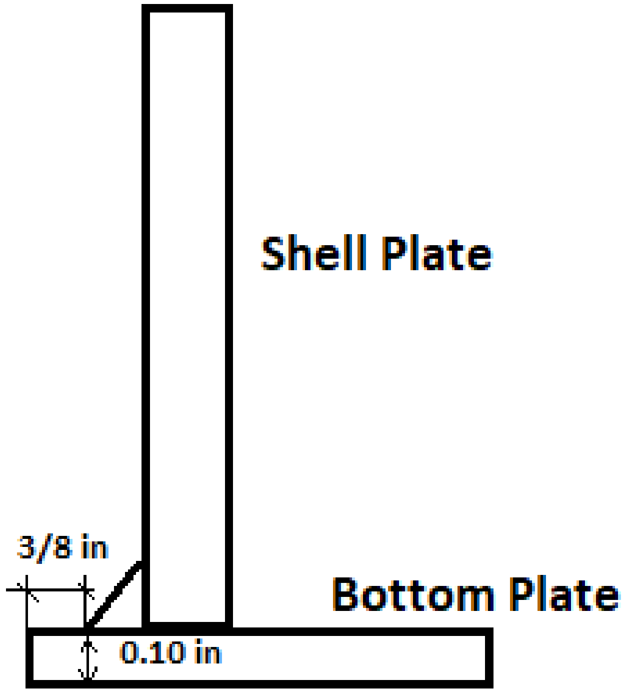
4.4.5.3 If the minimum bottom thicknesses, at the end of the in-service period of operation, **are calculated to be less than the minimum bottom renewal thicknesses given in Table 4.4**, the bottom shall be lined, repaired, replaced, or the interval to the next internal inspection shortened.

Table 4.4—Bottom Plate Minimum Thickness

Minimum Bottom Plate Thickness at Next Inspection (in.)	**Tank Bottom/ Foundation Design**
0.10	Tank bottom/foundation design with no means for detection and containment of a bottom leak.
0.05	Tank bottom/foundation design with means to provide detection and containment of a bottom leak.
0.05	Applied tank bottom reinforced lining, > 0.05 in. thick, in accordance with API 652.

4.4.5 Minimum Thickness for Tank Bottom Plate

4.4.5.7 The thickness of the projection of the bottom plate beyond the shell as measured at the toe of the outside bottom-to-shell fillet weld shall not be less than 0.1 in. The projection of the bottom plate beyond the outside toe of the shell-to-bottom weld shell shall be at least 3/8 in.



4.4.6 Minimum Thickness for Annular Plate Ring

4.4.6.1 the minimum thickness of annular plate ring is usually greater than 0.10 in.

4.4.6.2 **For $G < 1.0$**, which require annular plates for other than seismic loading considerations, the thickness of the annular plates shall be not less than the thicknesses given in Table 4.5, plus any specified corrosion allowance.

4.4.6.3 **For $G \geq 1.0$**, which require annular plates for other than seismic loading considerations, the thickness of the annular plates shall be in accordance with API 650, Table 5.1a or 5.1b, plus any specified corrosion allowance.

4.4.6 Minimum Thickness for Annular Plate Ring

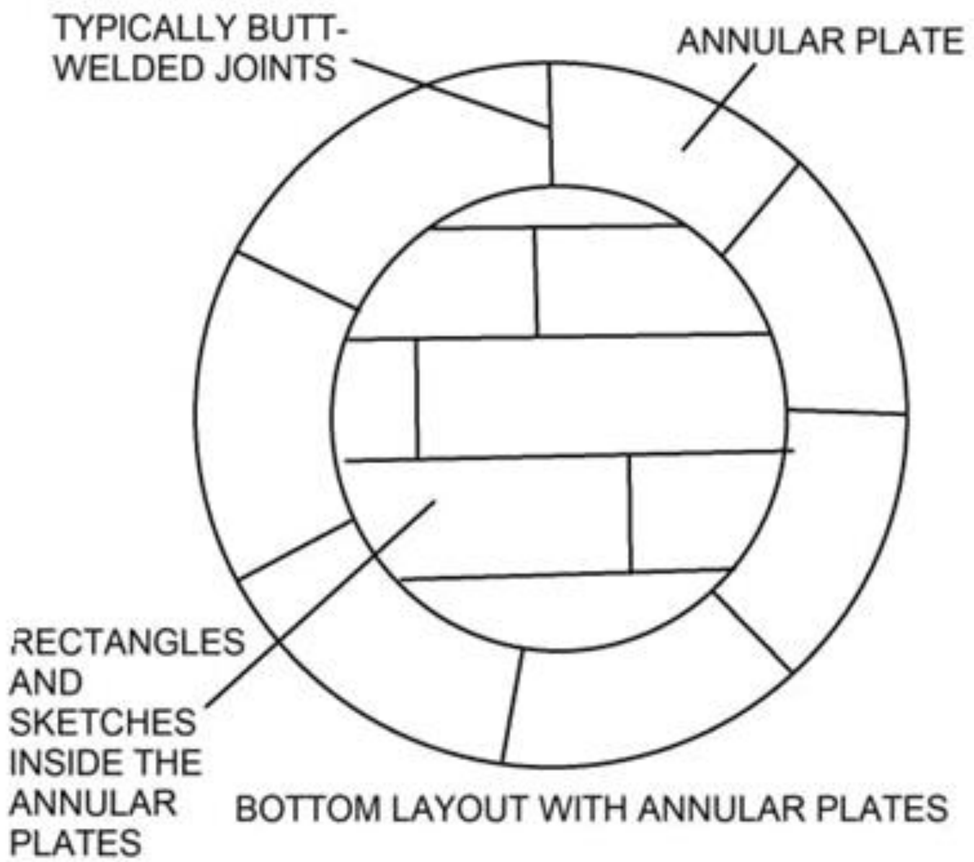


Table 4.5—Annular Bottom Plate Thicknesses (in.) (Product Specific Gravity < 1.0)

Plate Thickness [a] of First Shell Course (in.)	Stress [b] in First Shell Course (lbf/in.^{2})			
	< 24,300	< 27,000	< 29,700	< 32,400
$t \leq 0.75$	0.17	0.20	0.23	0.30
$0.75 < t \leq 1.00$	0.17	0.22	0.31	0.38
$1.00 < t \leq 1.25$	0.17	0.26	0.38	0.48
$1.25 < t \leq 1.50$	0.22	0.34	0.47	0.59
$t > 1.50$	0.27	0.40	0.53	0.68

NOTE The thicknesses specified in the table are based on the foundation providing a uniform support under the full width of the annular plate. Unless the foundation is properly compacted, particularly at the inside of a concrete ringwall, settlement will produce additional stresses in the annular plate.

[a] Plate thickness refers to the tank shell as constructed.

[b] Stresses are calculated from $[2.34D\,(H-1)]/t$.

Table 4.5—Annular Bottom Plate Thicknesses (in.) (Product Specific Gravity < 1.0)

Plate Thickness [a] of First Shell Course (in.)	Stress [b] in First Shell Course ($lbf/in.^2$)			
	< 24,300	< 27,000	< 29,700	< 32,400
$t \leq 0.75$	0.17	0.20	0.23	0.30
$0.75 < t \leq 1.00$	0.17	0.22	0.31	0.38
$1.00 < t \leq 1.25$	0.17	0.26	0.38	0.48
$1.25 < t \leq 1.50$	0.22	0.34	0.47	0.59
$t > 1.50$	0.27	0.40	0.53	0.68

NOTE The thicknesses specified in the table are based on the foundation providing a uniform support under the full width of the annular plate. Unless the foundation is properly compacted, particularly at the inside of a concrete ringwall, settlement will produce additional stresses in the annular plate.

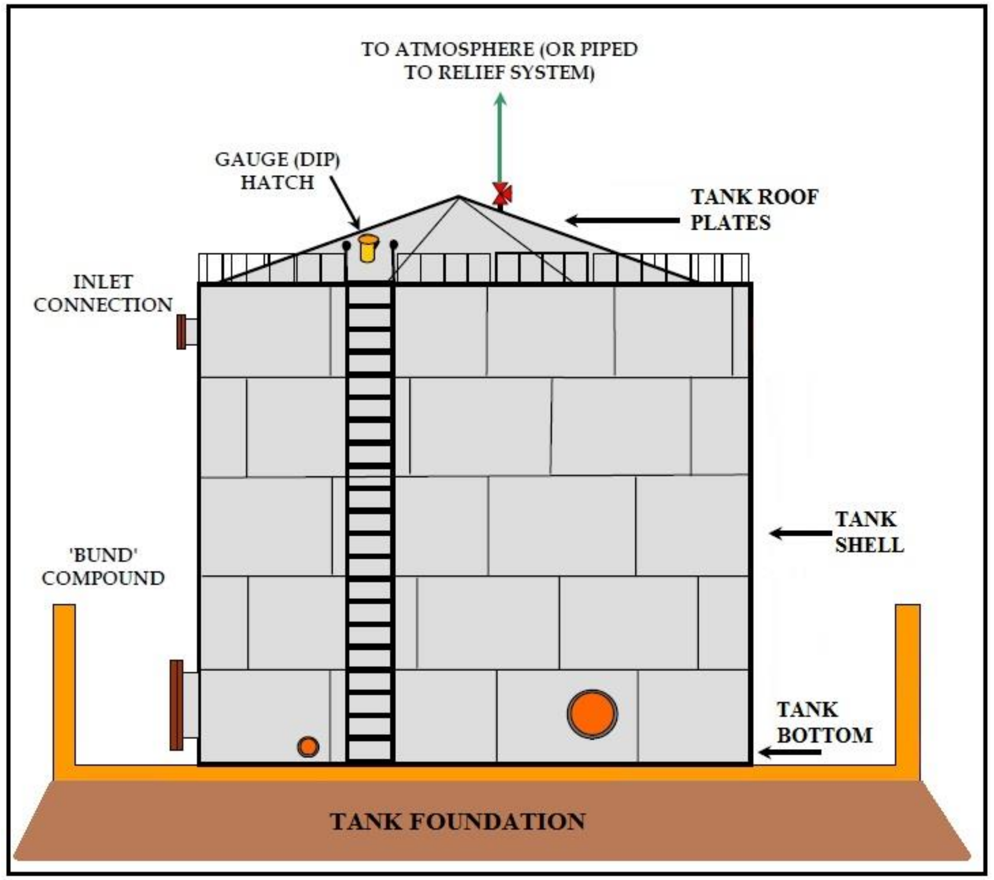
[a] Plate thickness refers to the tank shell as constructed.
[b] Stresses are calculated from $[2.34D (H - 1)]/t$.

4.5 Tank Foundation Evaluation

4.5.1 General

4.5.1.1 The principal causes of foundation deterioration are:

- ✓settlement
- ✓erosion
- ✓cracking
- ✓deterioration of concrete initiated by:
  - ✓calcining,
  - ✓attack by underground water
  - ✓attack by frost
  - ✓attack by alkalies and acids.



QUIZ MODULE 1

1. Tank roof plates which corrode to an average thickness of less than ----------- inches in 100 square in area shall be repaired or replaced.

a) 0.10
b) 0.05
c) 0.09
d) 0.12

2. All requirement of API Standard 650, Appendix M, shall be considered before changing the service of a tank to operation at temperature above:

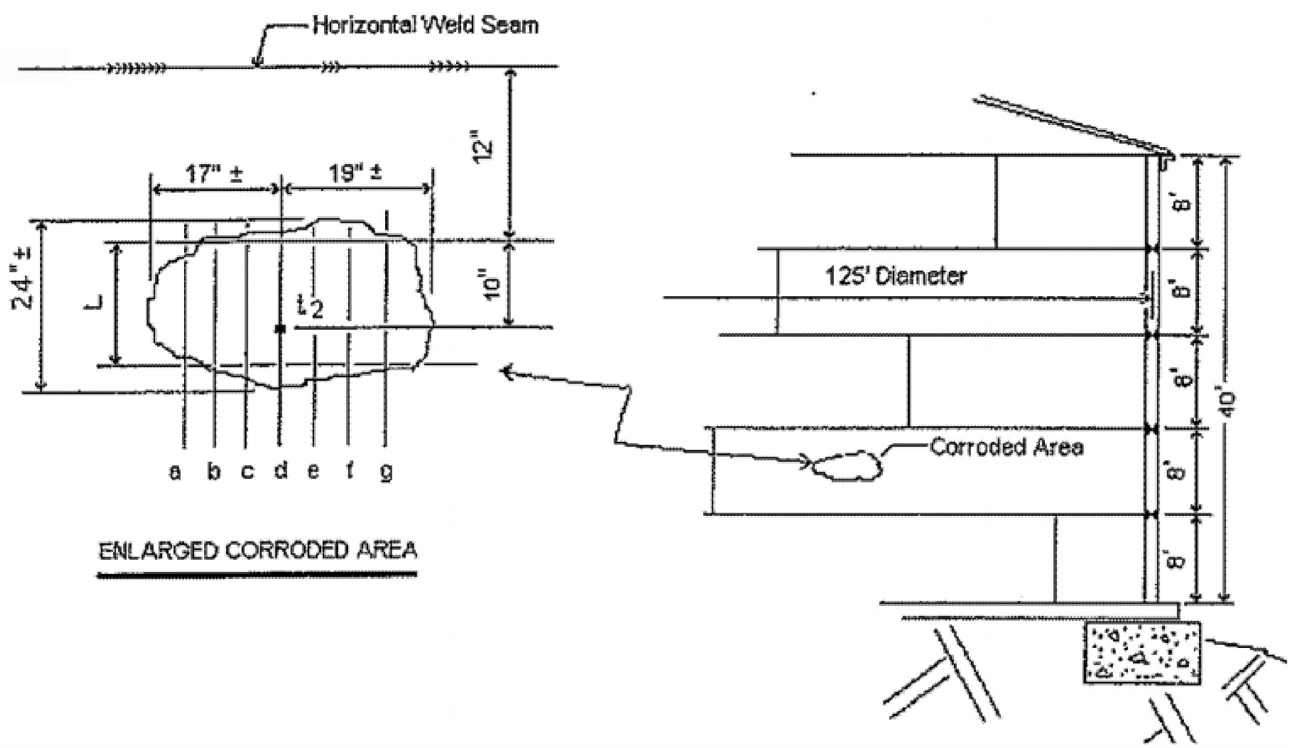
a) 100^o F
b) 150^o F
c) 200^o F
d) 250^o

3. What form of corrosion does not normally represent a significant threat to the overall structure integrity of a tank shell unless it is present in a severe and numerous form?

a) General uniform loss of metal
b) Scattered Pitting
c) Stress corrosion cracking
d) Hydrogen attack

4. A six year old storage tank was inspected. The tank has a diameter of 125 feet and its maximum liquid level height is 40 feet. The tank was constructed of ASTM A-283 Grade C steel. The product stored in the tank has a specific gravity of 0.85. The joint efficiency of the welds is unknown. A corroded area is found as shown by the following sketch and an ultrasonic thickness measurement was conducted and results are summarized as in below table. From the information, determine:

#	a	b	c	d	e	f	g
1	0.530	0.560	0.520	0.510	0.480	0.500	0.550
2	0.540	0.500	0.400	0.350	0.390	0.410	0.490
3	0.500	0.400	0.380	0.310	0.310	0.350	0.380
4	0.390	0.360	0.310	**0.250**	0.280	0.300	0.320
5	0.500	0.460	0.380	0.270	0.390	0.400	0.440
6	0.550	0.480	0.350	0.280	0.400	0.440	0.500
7	0.560	0.510	0.410	0.380	0.460	0.470	0.520
8	0.560	0.540	0.530	0.550	0.500	0.500	0.560
avg	0.516	0.476	0.410	**0.363**	0.401	0.421	0.470



From the information, determine:

a) The least thickness (t_2)?
b) The critical Length L?
c) The minimum t_{avg} and at which vertical section occuring?
d) Minimum acceptable thickness t(min)
e) The hydrostatic fluid high
f) Does this corroded area need repair or replacement? Explain why?

5. An AST operating at 250ºF is evaluated for continuing service. The inspector checks the tank records and finds that the tank was originally built of AST A516 Grade 60. What allowable stress should the inspector use in evaluating the minimum thickness of the tank's shell:

a) 28,160 psi
b) 25,600 psi
c) 22,912 psi
d) 32,000 psi

6. A tank built in in November 2010 was removed from service and internally inspected in November 2020. the bottom course of the tank showed the most general corrosion (no isolated corrosion was found). The original thickness of the bottom course of the tank was 1”. The measured thickness of the bottom course at the inspection was 0.93. The tank has no means for foundation/bottom leaks.

Calculate :

a) The corrosion rate
b) The future projected thickness after 10 years
c) What is the bottom plate acceptable minimum thickness
d) What is the remaining life for the bottom plate?

7. Determine the minimum annular bottom plate thickness for a tank holding product with a specific gravity of 0.85, stress in the first shell course is less than 27,000 psi and the first shell course thickness is 0.9375”

8. Which of the below conditions can cause shell distortion of an AST:

a) Foundation settlement
b) Bottom coating
c) Isolated pitting
d) Lack of cathodic protection

9. Unless a stress analysis is performed, the minimum bottom plate thickness in the critical zone of the tank bottom shall be the smaller of ------the original bottom plate thickness (not including the original corrosion allowance) or --------- percent of t_{min} of the lower shell course but not less than 0.1 inch

a) ½, 50
b) 1/3, 60
c) 3/8, 40
d) ¼, 30

10. The thickness of the projection of the bottom plate beyond the shell as measured at the toe of the outside bottom-to-shell fillet weld shall not be less than ----------- inch

a) 0.125
b) 0.10
c) 0.195
d) 0.001